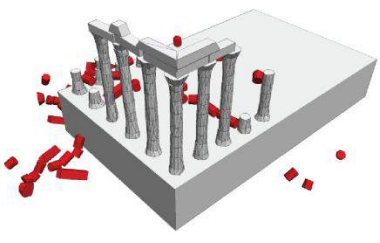
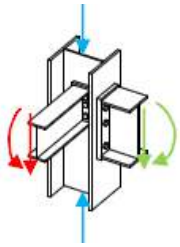
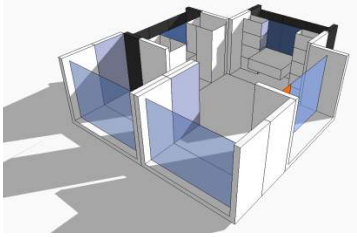
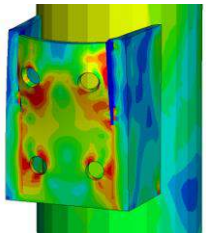
Institute for Sustainability and Innovation in Structural Engineering

Technical & scientific activities report

2012
2014

at: (www.isise.net)

UNIÃO EUROPEIA
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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

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COMPETE

FCTUC FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE DE COIMBRA

Universidade do Minho
Escola de Engenharia







ISISE – Institute for sustainability and innovation in structural engineering


Paulo Lourenço


Luís Simões da Silva

ISISE is a Research, Development and Innovation (RD&I) Unit created in 2007 that involves researchers with different expertise mostly from the Departments of Civil Engineering from the universities of Coimbra and Minho. ISISE currently comprises about 160 researchers, including a large number of PhD students.

There are many exciting news for the reporting period 2012-2014:

- ISISE was externally evaluated by the Portuguese Science and Technology Foundation, receiving the label of "Excellent" (attributed to the top 20% RD&I units in Portugal).
- The number of PhD members increased by 50%, which is a direct consequence of the increasing number of postdoctoral collaborators on contracts and new faculty members.
- The scope of the Institute was consolidated to allow a holistic approach towards the construction industry, by including geotechnical engineering and additional expertise in the functional requirements in construction.
- The usage of electronic communication platforms was extended from the biannual newsletters and triennial report to a Facebook page with over 13,000 friends (www.facebook.com/isise.net).

ISISE possesses full expertise to address the six essential requirements needed to bring building products to the market (Mechanical resistance and stability; Safety in the case of fire; Hygiene, health and the environment; Safety in use; Protection against noise; Energy economy and heat retention). It is well known that assessment of the environmental performance of building products can only be provided considering the building concept and use. ISISE can contribute to this vision by high-level research and development, which fosters innovation, in aspects such as the planning and design of the built environment, the structural and technical concept, and the quality achieved with the construction works.

The Institute continues to be involved in several Advanced Educational Programs, including two Erasmus Mundus International Masters, funded by the European Commission, and three nationally funded PhD programs, funded by the Portuguese Science and Technology Foundation. In the period 2012-2014, ISISE secured important funding (about 10 M€) for the construction and equipment of additional laboratory facilities in its two major campuses (Coimbra and Minho). New facilities will be completed in 2015 and include a state-of-the-art Fire Safety Experimental Laboratory, in Coimbra, and the Institute for Bio-Sustainability, in Minho, joining engineering and biological sciences to address integrative and complex problems in the natural and built environment. These investments will more than double the current experimental capabilities.

The scientific results and outputs are illustrated throughout the report. A global ratio of 2.0 papers in peer-reviewed journals listed in SCI per PhD member per year constitutes an excellent result in the field of Civil Engineering. Cooperation with industry is another strong point of ISISE. Innovation with potential economic value is illustrated by the number of patents being registered and the fact that most RD&I projects involve the industry.

ISISE faces many challenges for its future, including the integration of the recent new members. The funding from the Portuguese Science Foundation for the next period will allow addressing new strategic fields, such as Geotechnics, BioEngineering and Off-Shore Construction. The core of the Institute will remain based on building materials such as concrete, composites, masonry, steel or timber, and aspects related to experimental characterization, advanced simulation, on site testing and life cycle analysis, with a modern perspective of building and structural engineering. The completion of the many projects and PhD theses shown in this report, and the attraction of new students and new financed projects, will allow continuing our quest for excellence, with real impact in science, technology and the economy. The Directors are privileged to lead such an enthusiastic staff of researchers and technicians. We will be very happy to further extend our cooperation to all interested international and national colleagues.

Members

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António Gomes Correia


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Rui Pedreira Marques


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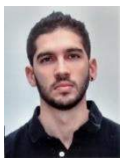
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João Costa

João Fernandes

João Laranjeira

João Nuno Ribeiro

Jocelyn Reyes

Jorge Costa

José Carlos Lino

José Granja

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Mário Freitas Coelho

Marisa Mota Pinheiro

Mateus Nogueira Oliveira

Matteo Breveglieri

Miguel Serra

Mohammad Hoseini

Mohammad Mastali

Mohammad Rezazadeh

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Nelson Soares

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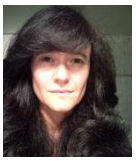
Lúcio Pereira Lourenço


Luís Borges


Luís Bragança


Maria Dulce Rodrigues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Paula Teixeira

Rui Ferreira

Sónia Esteves

Advisory board

Gian Michele Calvi

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Reidar Bjorhovde

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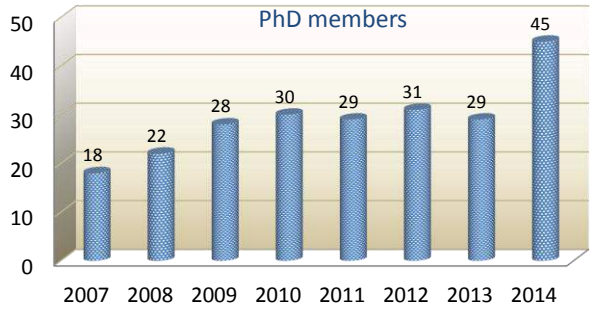
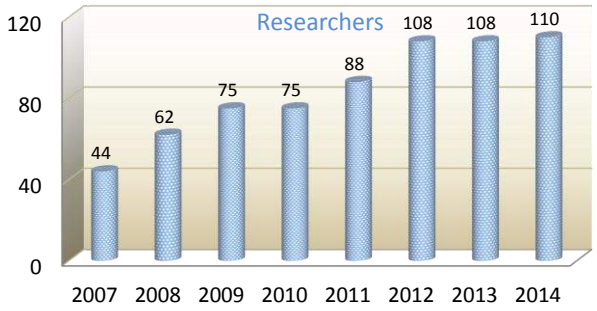
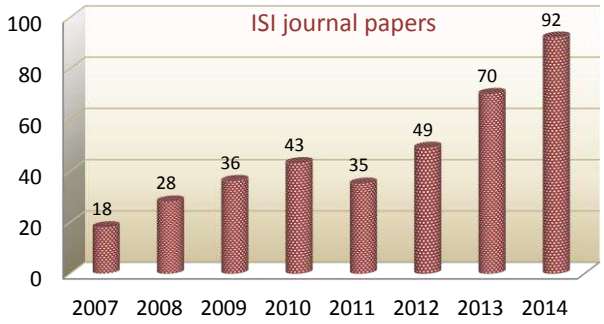
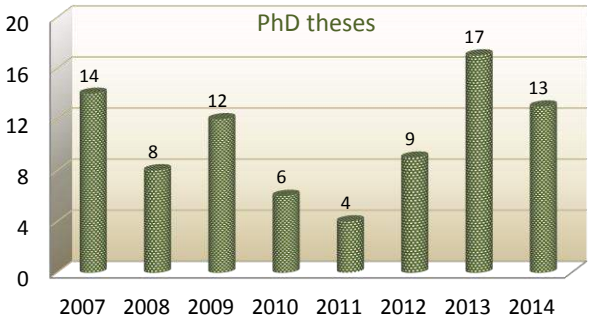
ISISE today

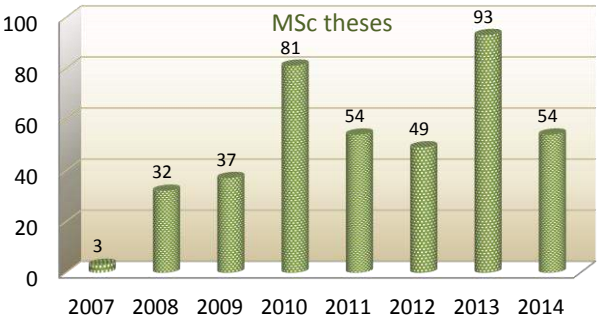
ISISE in numbers

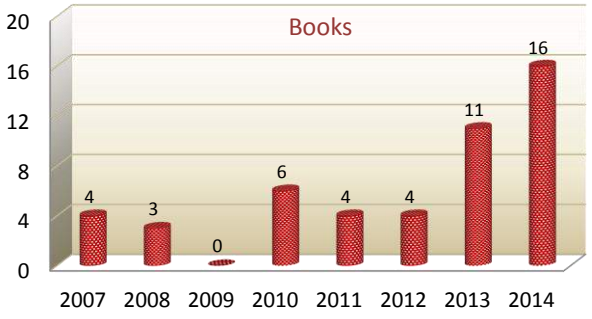


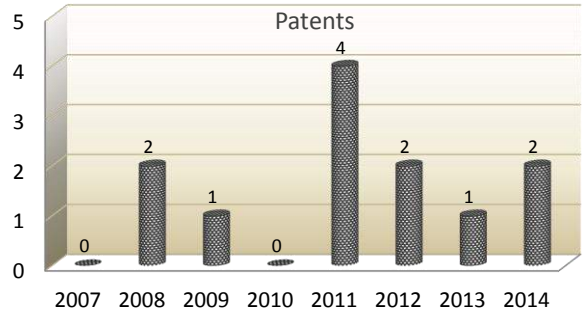






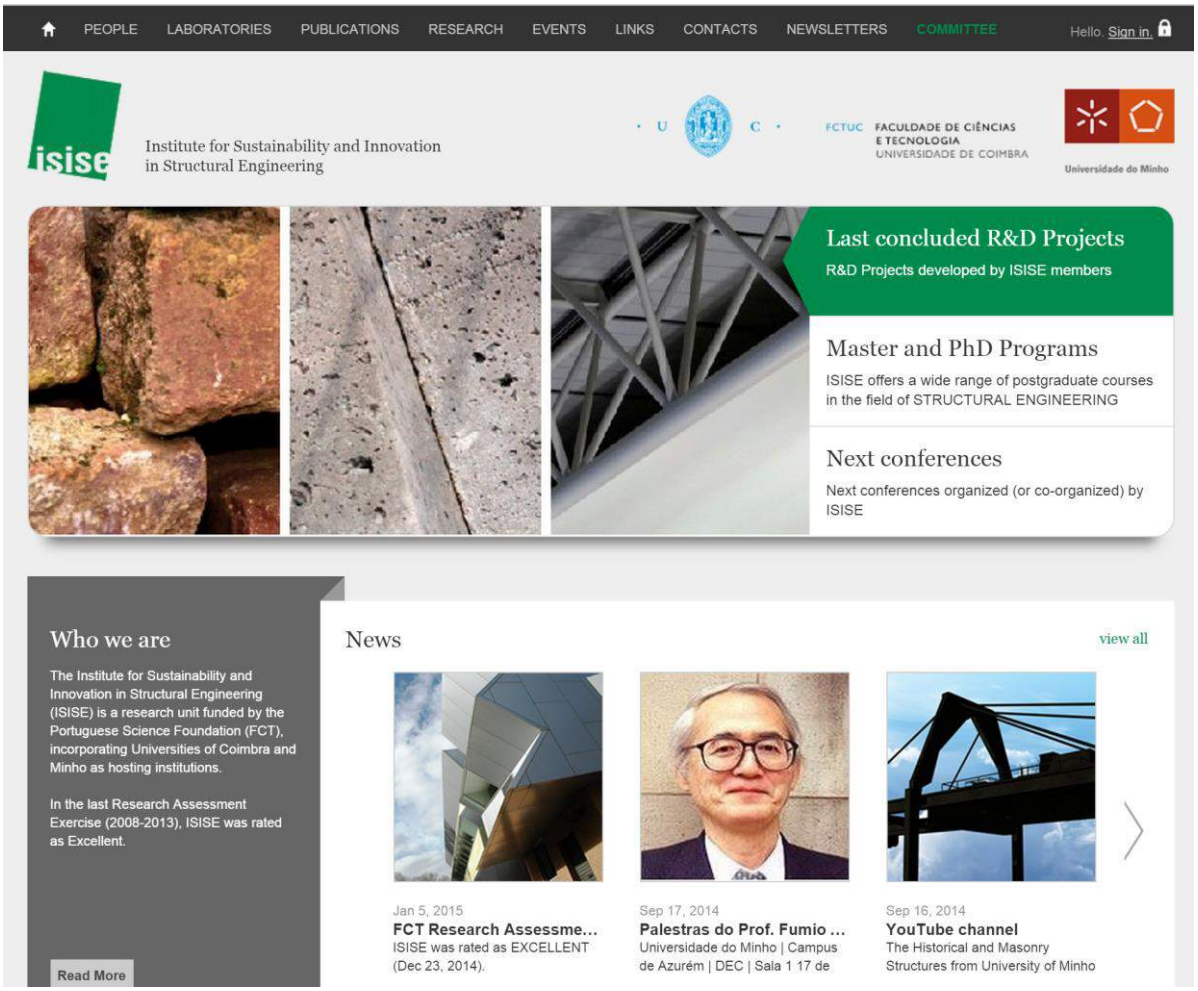






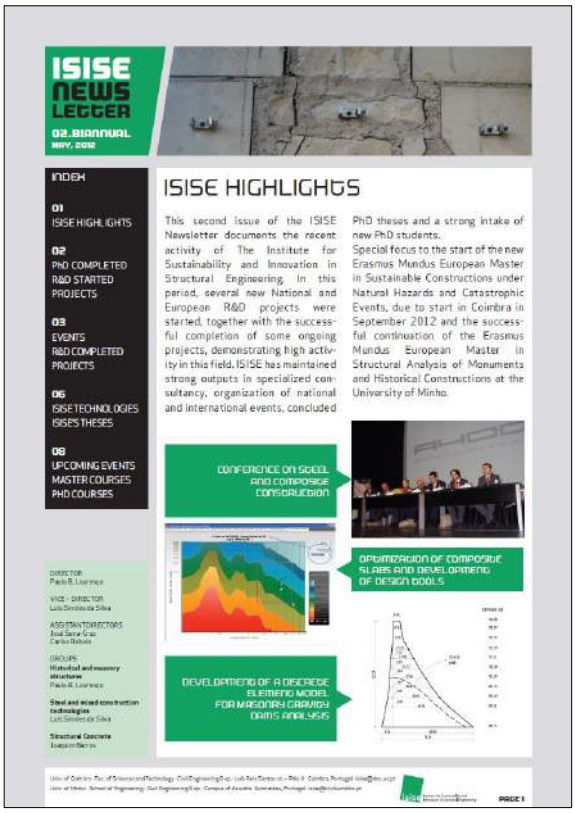
ISISE on line

www.isise.net



www.facebook.com/isise.net

ISISE Newsletters



2012/01 – Issue no. 2

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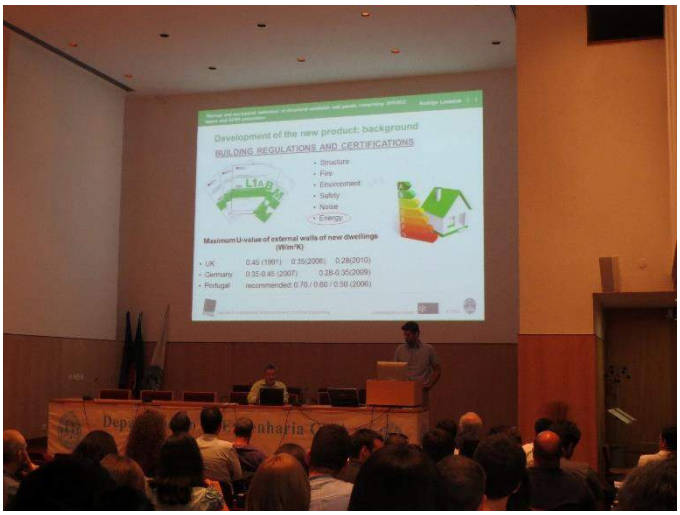
ISISE day out - 2013



Projects and Network Actions

Adjustable partition membrane | AdjustMEMBRANE

Financing Institution(s): FCT

Promoting Institution(s): University of Minho (UMinho)

Coordinator(s): Paulo Mendonça

Researchers and collaborators: Paulo Mendonça, Luís F. Ramos, Raul Fangueiro, Luís Bragança, Ricardo Mateus, Mónica Macieira, João Velosa, Nuno Cruz

Partner Institutions: Territory, Environment and Construction Research Centre (C-TAC), Institute for Sustainability and Innovation in Structural Engineering (ISISE).

Period: May 2010 to October 2013

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho.

Objectives:
The objective of this project is the development of a new material / system, using innovative reinforcement fibers, as 3D or DOS textile structures, with some porosity to guarantee acoustic absorption, thermal insulation, hygroscopic and thermal inertia, eventually complemented with integrated PCMs, but also incorporating several functional agents on the matrix (polymer) in order to guarantee properties such as anti-fungus and self-cleaning. This investigation also expects to contribute on knowledge development at project level, by the definition of a methodology for structural and functional demands integration that explore the limits of optimization, using existing software tools for predicting mechanical, thermal, acoustic and lighting performances. Apart from conventional structural support elements in steel or timber, the use of pneumatic membrane trusses will also be pondered, in order to achieve even more lightweight dividing panels, thus more portable e adaptable to diverse uses and situations. Typological aspects will also be explored, regarding thermal, acoustic and lighting zoning, conducting to the interior housing spaces occupancy in relation to comfort levels (protection, demands) admitted to each use. The influence of the use of furniture for this protection will also be taken into account, and also as partition elements per se, as in some cases they can fulfil this double function. As final objective it is expected to obtain solutions where useful area and gross area are closer, in such a way that partition can be moveable and even portable, as household furniture.

Description:
Architectural membranes are nowadays used with competitive costs for covering big spans, but they can also be suitable for small size constructions, such as housing buildings. The fact of being the lighter constructive solution for facades and coverings used in buildings and nowadays having a life span that exceeds 25 years makes architectural membranes extremely competitive in terms of deconstruction effectiveness, embodied energy, economic cost and durability, even in exterior applications. Membranes have now the advantage of being at the same time translucent, but weighting much less than other solutions, even glass, per square meter. Textile membranes are usually used to cover large spans with complex geometries, using the special properties of the Hypar (Hyperbolic paraboloid). However it is possible to use membranes on small internal division walls, external façades and coverings, with low spans, not only as sandwich panels, but also as a junction of small Hypar modules. Like this the mechanical special properties of this geometry can be well explored, allowing a very small weight and thus a good environmental performance, compared to conventional solutions, on a comparable thickness. Apart from this, the research on membrane materials for thermal regulation, allows to extend its possibilities in order to fulfill contemporary demands of comfort.

The growing necessity to save material and energy resources, together with a growing concern over the environmental issues, are impelling to solutions that present a minimal expression of the materials and products used. This is particularly relevant to the interior partition walls that have a high contribution to the environmental impact of buildings, although these elements are easily reducible. Another aspect is that a great portion of housing designs are not flexible in use and therefore they are not suitably adjustable to the permanent updating of life-styles and variations on the composition of the households. Although there are some lightweight building technologies, in most cases the construction practice in Portugal makes use of heavyweight and static partition walls. This problem reveals to be of particularly importance in the refurbishment phase of existing buildings, but also when it is necessary the rethink of the interior spaces in the operation phase.

A lightweight interior partition walls is certainly a wiser option in many situations as it can be more flexible and even portable, in some cases, as well as having a lower environmental impact in a Life-cycle Assessment. The lower quantity of materials used in lightweight solutions allow a lower specific embodied energy and other more favourable environmental impact indicators. The reduction of material inputs to the minimum is a way to achieve higher eco-efficiency in a building and thus open the road to more efficient interior partition systems.

This project intends to prove that it is possible to use lightweight membranes on interior partition walls and on external façades, even in housing buildings at temperate climate regions, if their properties are well explored. The few material used, even less than conventional lightweight solutions - the most common is plasterboard with light steel frame structure - allow a lower specific embodied energy and other more favourable environmental impact indicators. Compared to conventional heavyweight solutions, such as hollow brick walls, lightweight membranes allow easier deconstruction/ reuse. In the outer skin, architectural membranes can be used as passive or active systems,

for heating (promoting greenhouse effect) and cooling (shading or even evaporative cooling). Lightweight materials are more viable to be used on invariably hot or cold climates, than on temperate climates, as in this context they present problems related with its low thermal storage capacity. However, the research of new architectural membrane materials, with passive and active behavior for thermal regulation, allows extending its possibilities to interior dividing partitions in order to fulfill contemporary demands of comfort. Active and/or passive systems can be used to regulate thermal gains – for example by radiant panels and/or evaporative cooling, but also to achieve thermal inertia. In pavements, thermal storage lightweight elements, using natural Phase Change Materials, were already studied and reported on previous studies from the first author. Examples of how these systems can also be applied to lightweight membrane dividing walls are presented in this paper, and some experimental research is now under course on test cell facilities existing in University of Minho, Guimarães.

Publications:

Papers:

Mendonça, P.; Macieira, M., Lightweight Dividing Walls: Adaptation to Temperate Climates, The International Journal of Environmental, Cultural, Economic and Social Sustainability, Volume 7, Number 2 (2011)

Conference proceedings:

Fangueiro, Raúl; Velosa, J. C.; Macieira, Mónica; Mendonça, Paulo, Lightweight membranes with fibre materials in interior dividing walls, MATERIALS 2011 – VI Internatinal Materials Symposium, 18-20 April, Guimarães, Portugal (2011)

Fangueiro, Raúl; Velosa, J. C.; Mendonça, Paulo, Estudo das propriedades térmicas de materiais aplicados em paredes divisórias leves, International Conference on Engineering UBI2011 - 28-30 Nov, University of Beira Interior, Covilhã, Portugal (2011)

Santos, T.; Velosa, J.; Ramos, L.F.; Fangueiro, R.; Mendonça, P., Characterization of Polyester with Fiberglass Materials as reinforcement in Interior Dividing Walls, 41st Textile Research Symposium, September, 12-14, Guimarães, Portugal (2012)

Velosa, J.; Santos, T., Fangueiro, R.; Ramos, L.F.; Mendonça, P., Potential of Polyester Fibrous Materials in Interior Dividing Walls, 41st Textile Research Symposium, September, 12-14, Guimarães, Portugal (2012)

Mateus, Ricardo, Macieira, Mónica, Mendonça, Paulo, Bragança, L., Life-cycle assessment of different building technologies for partion walls : contribution to future developments on interior partition concepts,

Fangueiro, Raúl, Velosa, J. C., Macieira, Mónica, Mendonça, Paulo, Characterization of porous acoustic materials applied to lightweight partition walls, SB11 Helsinki World Sustainable Building Conference, (2011)

Neiva, Sara Daniela Oliveira; Mateus, Ricardo, Macieira, Mónica; Mendonça, Paulo; Bragança, L.; Life-cycle assessment of lightweight textile membrane partition walls, TRS2012 (2012)

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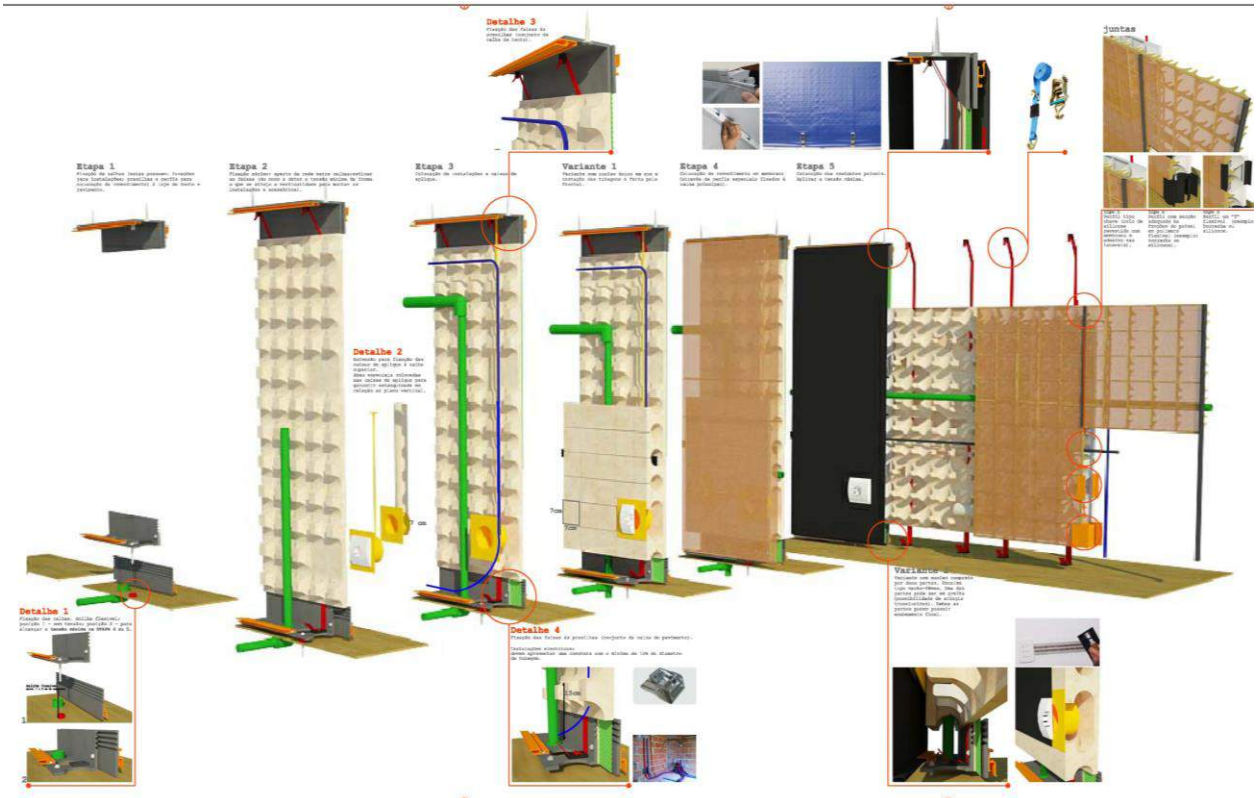

Fig. 1 Panel prototype for membrane division wall.

Behaviour characterization and rehabilitation of earthen construction | BE+EARTH

Financing Institution: FCT

Promoting Institution: University of Aveiro (UAveiro)

Local Coordinator: Daniel Oliveira (UMinho)

Researchers and collaborators: Daniel Oliveira, Paulo Lourenço, Rui Silva and Eduarda Luso (only UMinho researchers listed)

Partner Institutions: University of Aveiro, University of Minho, Technical University of Lisbon

Period: June 2013 to May 2015

Relevant facilities: Laboratory facilities: strong floors and reaction walls; several universal hydraulic tension-compression load frames, closed-loop servo-controlled actuators and data acquisition and control equipment; climatic chambers; diverse day-to-day laboratory equipment / Computational facilities: advanced FE numerical tools.

Objectives:

The main objectives of BE+EARTH are to analyse the behaviour of adobe and rammed earth constructions and contribute to the research on retrofit and performance enhancement solutions of the important adobe and rammed earth built heritage existing in Portugal.

Description:

Earth has been used as a building material since ancient times until the present days due to its advantages such as simple construction methods or interior comfort. Currently, one third of the world population lives in earthen houses, as a result of cultural, climatic and economic reasons. Large percentage of these buildings is currently associated to rural populations with low economic resources. There is a vast architectural heritage stock, mainly in developing countries, which needs to be preserved. Until recently, earth has been a common construction material in Portugal. Adobe and rammed earth were used through years in almost all types of buildings. This utilization progressively declined since the middle of the 20th century, due to the development of the cement industry.

At the present moment, Portugal still presents a vast number of earthen buildings, many of which are in use. There are numerous examples of buildings with cultural, historical and architectonic recognized value. In spite of this, there has been a general loss of traditional knowledge. On the other hand, little attention has been given to the study and conservation of this built heritage. As a consequence, many of the existing earthen buildings present various structural and non-structural anomalies and deficiencies.

When under horizontal actions, such as earthquakes, earth constructions structures can suffer severe structural damage and sometimes total collapse. The seismic behaviour of earthen structures is typically characterized by fragile failures. Besides seismic events, earthen constructions are also particularly vulnerable to other agents, like water and wind. But earth, as a building material, presents very attractive characteristics. It is low cost, locally available and recyclable. In addition, it possesses excellent thermal and acoustic properties, and is associated to quite simple construction methods that require small consumes of energy. These qualities are triggering an increasing interest, all around the world, among the community concerned with sustainable building.

In spite of the increased interest, the existing knowledge concerning earthen construction is still mainly empirical. Few countries have codes for the rehabilitation and building with earth, and the existent codes are frequently incomplete. On the other hand, the study of earthen structures has been mainly oriented towards the architectural and historical aspects, while the material and structural characterization has been systematically relegated to a second plan. This lack of knowledge, together with a certain prejudice against earthen materials have been contributing to the disappearing of the earthen building stock, namely in many recent rehabilitation interventions has been practice to replace these materials by materials called modern. The fact that many times the earthen constructions have been built or repaired by staff without adequate training, contribute further more to this reality.

The project BE+EARTH intends to provide a strong technical scientific based contribution, not disregarding the architectonic point of view. The main general objectives of this project are the behaviour analysis of adobe and rammed earth constructions along with the research of retrofit and performance enhancement solutions, considering the important patrimony existing in Portugal. The consolidation of this knowledge will have a fundamental role on the preservation of the earthen built heritage. In addition it will contribute to the development of earth construction as building solution following current structural demands, which will allow giving response to the increasing interest on this building solution.

The contribution of ISISE/UMinho to fulfil the proposed objectives includes the following integrated steps: a) experimental characterization of the structural behaviour of rammed earth; b) Assessment of the repair efficiency of the injection of mud grouts in the repair of rammed earth walls; c) Assessment of the strengthening of rammed earth walls by means of geo-mesh reinforcing coatings; d) development of compressed earth blocks (CEBs) building system based on alkaline activation of fly ash; e) FEM modelling of the structural behaviour of rammed earth.

Publications:

PhD theses:

Silva, R. (2013) Repair of earth constructions by means of grout injection, PhD Thesis, University of Minho, hdl.handle.net/1822/28793

Msc theses:

Machado, J. (2013) Reparação estrutural de construções em terra através de injeção de caldas compatíveis, Msc Thesis, University of Minho, hdl.handle.net/1822/30797

ISI papers:

Miccoli L., Oliveira D.V., Silva R.A., Müller U., Schueremans L. (2014) Static behaviour of rammed earth: experimental testing and finite element modelling, Materials and Structures, 10.1617/s11527-014-0411-7

Silva R.A., Soares E., Oliveira D.V., Miranda T., Cristelo N., Leitão D. (2015) Mechanical characterization of dry-stack masonry made of CEBs stabilised with alkaline activation, Construction and Building materials, 75, pp. 349-358, 10.1016/j.conbuildmat.2014.11.038

Conference proceedings

Silva R.A., Oliveira D.V., Miranda T., Soares E., Cristelo N., Lourenço P.B. (2014) Characterization of the shear behaviour of dry-stack masonry made with compressed earth blocks. CNME2014 - 9º Congresso Nacional de Mecânica Experimental, 15-17 October, Aveiro.

Silva R.A., Oliveira D.V., Miccoli L., Schueremans L. (2014) Modelling of rammed earth under shear loading, Peña, F., Chávez, M. (eds), 9th International Conference on Structural Analysis of Historical Constructions, Mexico City, 14-17 October 2014. ISBN 04-2014-102011495500-102.

Silva R.A., Oliveira D.V., Schueremans L., Miranda T., Machado J. (2014) Modelling of the Structural Behaviour of Rammed Earth Components, Lourenço, Topping, B.H.V., Iványi, P. (eds), 12th International Conference on Computational Structures Technology, Naples, 2-5 September 2014.

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Silva R.A., Oliveira, D.V., Schueremans, L., Lourenço, P.B., Miranda, T. (2014) Repair of rammed earth by injection of mud grouts: a case study from Portugal, Mazzolani F.M., Altay G. (eds), 2nd International Conference on Protection of Historical Constructions, Antalya, 7-9 May, p. 107-113, ISBN 978-978-518-361-9.

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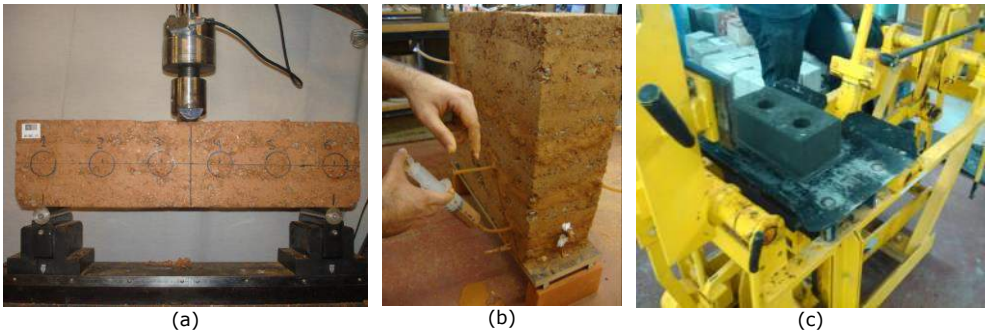
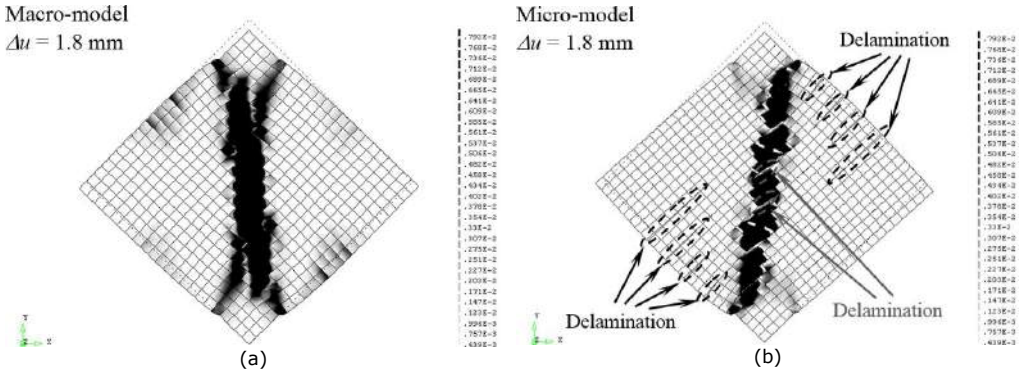


(a) (b) (c)

Fig. 1 Experimental program: (a) testing of a rammed earth beam (b) injection of a rammed earth wallet; (c) manufacturing of CEBs.



(a) (b)

Fig. 2 FEM modelling of rammed earth: (a) macro-model; (b) micro-model.

Design of composite joints for improved fire robustness | COMPFIRE

(RFSR-CT-2009-00021)

Financing Institution(s): Supported under the European Community within the framework of the Research Fund for Coal and Steel (RFCS)

Promoting Institution(s): University of Coimbra

Coordinator(s): Luís Simões da Silva and Aldina Santiago

Researchers and collaborators: Rui Simões; João Paulo Rodrigues; Milan Veljkovic; František Wald; Buick Davison; Ian Burgess;Shan-Shan Huang; Yong Wang; Parthasarathi Mandal; Martin Skorepa; Petr Velda; Andrew Orton; George Koutlas; Trevor Mustard; and 8 PhD students *(Fernanda Lopes-UC; Tim Heistermann-LTU; Naveed Iqbal-LTU; Gang Dong-US; Mostafa Jafarian-UM; Sherif Elsawaf-UM; Kamila Horová-CTU; Tomas Jana-CTU)*

Partner Institutions: Luleå University of Technology (SE), Czech Technical University in Prague (CZ), University of Sheffield (UK), University of Manchester (UK), DESMO A.S. (CZ), TATA Steel (UK).

Period: July 2009 to June 2012

Relevant facilities: Hydraulic Jacks up to 3000kN; Restraining frames; Ceramic pad heating electrical elements; Bundle of transducers and actuators; Universal tension-compression load testing machines; Diverse day-to-day laboratory equipment; Modular electrical furnace for columns and beams; Additional data acquisition and control equipment.

Objectives:

The aim of this project is to provide an integrated approach for the practical application of performance-based fire engineering design of steel and composite structures by focusing on the critical issue of the performance and robustness of joints under natural fire conditions, taking into account the structural behaviour during the cooling phase. The joints to be investigated in this project will be those to composite columns, including concrete-filled tubular (CFT) columns and partially encased profiled columns. These composite columns are often assumed to possess inherently high fire resistance, yet there is very little knowledge on their joint behaviour in fire. By developing methodologies to evaluate the full 3D behaviour of joints between composite floor systems and composite columns, including an assessment of their ductility limits, and incorporating the joint models into global frame analysis, innovative solutions can be achieved which ensure cost-effective design against fire attack and a realistic estimation of real safety levels, and which avoid premature collapse of a composite structure in fire.

Description:

The main goal of the research framework is to allow prediction of the behaviour of a joint throughout any fire event in a manner consistent with the ambient-temperature design of joints, which is currently impossible. It is proposed the detailed study of the behaviour of composite steel-concrete joints under natural fire conditions, especially during the cooling phase. Fire testing is included on composite joint components, isolated composite joints, composite structural subassemblies and demonstration structures. Numerical analyses of temperature development in protected and unprotected composite joint components in natural fires and coupled thermo-structural analyses will foster development of the integrated component-based model, consistent with Eurocode procedures, for composite steel-concrete joints.

Innovative results and solutions will be garnered from this whole investigation project, namely:

1. Models for temperature development in connection components under natural fire conditions. Current recommendations in the Eurocodes are based on very limited study, and are for end plate connections to open-section steel columns only. They have been shown to be grossly inaccurate, especially for natural fire conditions. Without an accurate method of predicting connection temperature distributions under arbitrary fire conditions, performance-based fire engineering design of joints is not possible. This project will make major contributions to the field.
2. Application of the Component Method to the prediction of the behaviour of joints under fire loading, including the cooling phase. This is currently only applicable to joints to profiled steel columns at ambient temperature. This will generate significant progress beyond the current state-of-the-art.
3. Integration of coupled thermo-mechanical modelling of 3D steel joints within global structural analysis, leading to identification of interactions between members and joints, including characterization of the time-varying forces induced in the joints as a fire develops. This will lead to a significant improvement of existing knowledge.
4. Development of detailing rules for joint robustness to achieve improved structural resistance to progressive collapse under fire attack. The objective is to make a significant improvement to the competitiveness of steel/composite buildings by allowing more economical design solutions using less fire protection.
5. Development of innovative testing schemes for subassemblies under defined fire conditions, including the performance of fire tests of joints and structural subassemblies with variable joint forces, filling important gaps in existing knowledge.
6. Demonstration of the robustness of composite frames with improved joint design under realistic fire conditions.

Examples of outcome of the project are represented in Figs 1 to 5.

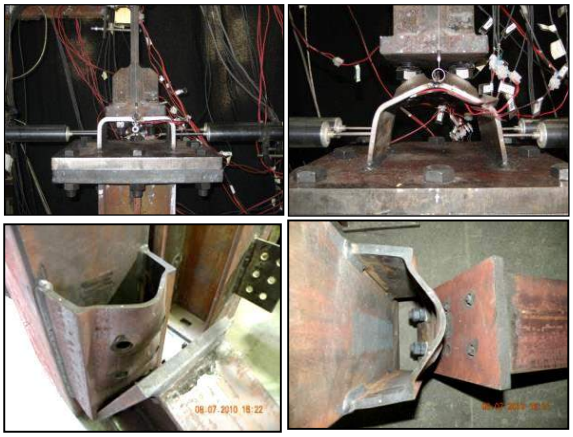


Fig. 1 Experimental tests to establish temperature distribution within the joint and behaviour of the joint components at ambient temperature and under fire conditions.

Fig. 2 Testing schemes proposed to experimental fire testing of structural subassemblies (small- and full-scale tests).

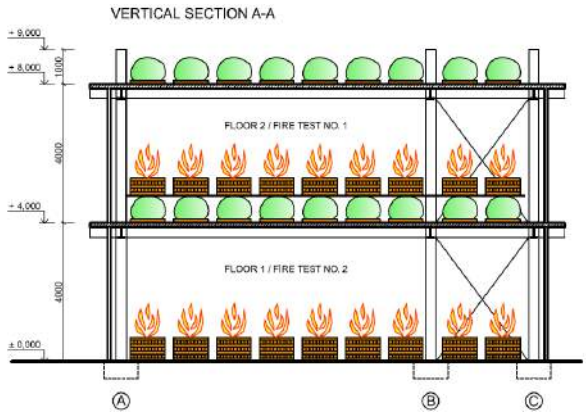


Fig. 3 Structural scheme to demonstration fire test on complete composite building.

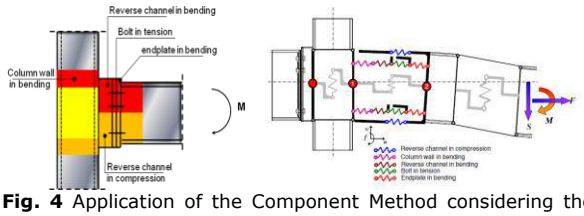


Fig. 4 Application of the Component Method considering the fire loading.

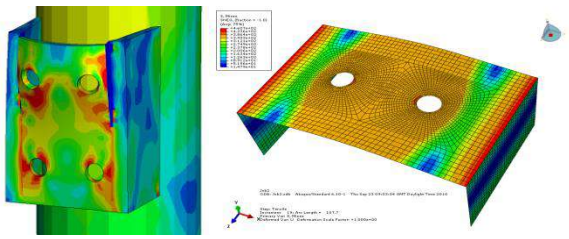


Fig.5 FE modelling for validation with test results and parametric study (heat transfer and structural analyses).

Publications:

Reports:

Simões da Silva, L., Santiago, A., Lopes, F., Veljkovic, M., Heistermann, T., Iqbal, N., Wald, F., Tomáš, J., Davison, B., Burgess, I., Huang, S-S., Dong, G., Wang, Y., Mandal, P., Hu, Y., Jafarian, M., Koutlas, G. 2011. COMPFIRE: Design of composite joints for improved fire robustness, Final report, Research Fund for Coal and Steel, Grant agreement n° RFSR-CT-2009-00021, European Commission, Brussels.

International journal papers:

Huang, S.S., Burgess, I.W. and Davison, J.B., 'A Structural Fire Engineering Prediction for the Veseli Fire Tests, 2011', Journal of Structural Fire Engineering, 4 (1), (2013), pp 1-8.

Huang, S.S., Davison, J.B. and Burgess, I.W., 'High-Temperature Tests on Joints to Steel and Partially-Encased H-Section Columns', Journal of Constructional Steel Research, 80 (2013) pp 243-251.

Huang, S.S., Davison, J.B. and Burgess, I.W., 'Experiments on Reverse-Channel Connections at Elevated Temperatures', Engineering Structures. 49 (2013) pp 973-982.

Elsawaf, S., Wang. Y.C., Mandal, P., "Numerical modelling of restrained structural subassemblies of steel beam and CFT columns connected using reverse channels in fire", Engineering Structures 33 (2011) 1217–1231.

Elsawaf, S., Wang. Y.C., "Methods of improving the survival temperature in fire of steel beam connected to CFT column using reverse channel connection", Engineering Structures 34 (2012) 132–146.

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Lopes F.C., Santiago A., Simões da Silva L., Heistermann T., Veljkovic M. e da Silva J.G.S., "Experimental behaviour of the reverse channel joint component at elevated and ambient temperatures". *International Journal of Steel Structures* 13 (3), pp. 459-472, 2013 (DOI: 10.1007/s13296-013-3006-1). Nº citações: **0** (scopus).

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Developing Innovative Solutions for Seismic Retrofitting of Masonry Infill Walls | RetroInf

Financing Institution(s): FCT

Promoting Institution(s): University of Minho (UMinho)

Coordinator(s): Graça Vasconcelos

Researchers and collaborators: Graça Vasconcelos, Paulo Lourenço, Farhad Ackoundi, Luis Ramos, Raul Fangueiro, Fernando Cunha

Partner Institutions: Faculty of Engineering of University of Porto

Period: April 2012 to July 2015

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho

Objectives:

The quality of the built heritage play a central role on the quality of daily human lives as they interact continuously with the built spaces, either in the work, social events and at home. In particular, the safety of the built spaces is indeed a demand of modern societies and remains a huge concern in prone seismic regions. It is known that seismic vulnerability is not exclusive of ancient masonry structures but affects also the built heritage from XX century, composed in a majority of reinforced concrete (RC) buildings, both in structural and non-structural elements. In this constructive typology, brick masonry walls represent the most traditional enclosure system and have demonstrated reasonable performance with respect to healthy indoor environment, temperature, noise, moisture, fire and durability, even if there has been some trend for improvement serviceability by purposing newly solutions. Therefore, the main goals of the research project are; (1) to develop of innovative materials and solutions for retrofitting masonry infill walls; (2) to derive sound concepts for the analysis of masonry infill walls; (3) to derive design guidelines for retrofitting masonry infills.

The major innovation in relation to past recent studies is the development of structural textile based materials that can be used both on the surface of masonry infills to improve simultaneously the in-plane and out-of-plane performance. Additionally, due to the lack of detailing on existing buildings about the connections between masonry infills and RC frames, which is a major source of vulnerability as concern the out-of-plane resistance, anchor systems to RC frames will be developed. The out-of-plane vulnerability of cavity masonry infills due the lacking of connection between the leaves should be solved by designing adequate fasteners linking the leaves. An interesting property that fibre textile based materials should have introduced is its sensing ability, enabling to record the damage extent during seismic event.

Description:

In the scope of the research project RetroInf, an innovative strengthening technique was developed based on meshes composed of braided composite rods (BCR) in which two distinct reinforcing fibres were considered, namely carbon and glass fibres. The idea is that these meshes are added to the rendering mortar working similarly to the reinforced textile mortar (TRM). The production technology considered to manufacture the reinforcing meshes was based on the braiding technique of three distinct materials, each one with different functions. This technology consists in the combination of yarns that make up the base of the braid, involving a central core responsible for the mechanical resistance (carbon or glass fibres) (Fig. 1).

The validation of the mechanical performance of the meshes to work as a retrofitting technique was based on flexural tests on small specimen of brick masonry.

Samples of masonry walls are composed of units of brick units most used in construction of masonry infill walls in Portugal. Masonry specimens with dimensions of 300mm x 200mm x 150mm (length x height x thickness) were considered. Besides the developed mashes, commercial meshes using the same type of reinforcing fibres were also considered. Ir was concluded that the developed meshes are very similar in terms of flexural resistance but present a remarkable enhanced behavior in terms on capacity of nonlinear deformation. With the developed meshes, it is possible to reach very important flexural deflections; particularly in case of meshes of braided rods have glass fibres in the reinforcing f nucleous.

The developed meshes will be also applied in reinforced concrete (RC) with masonry infilled frames, designed to represent RC frames from the eighties.

In-plane and out-of-plane tests were designed on reduced scale RC frames, being the tests under development. For the in-plane testing, an existing testing setup was updated and for the out-of-plane testing, a novel out-of-plane testing setup was designed based on airbags to better represent the out-of-plane forced induced by earthquakes. The out-of-plane testing procedure is automatic for which a software was developed (Fig. 2 and Fig. 3a). Additionally, combined tests aiming at assessing the influence of the in-plane damage on the out-of-plane performance of the masonry infill walls (resistance and deformation) are under preparation.

The nonlinear numerical analysis encompasses the definition of a numerical model, its calibration based on the experimental results and a parametric study aiming at assessing the influence of selected parameters in the in-plane and out-of-plane of RC masonry infilled frames. The non-linear behavior of the concrete and masonry was represented by a Total Strain Crack Model based on a fixed stress-strain law concept available in the commercial. It describes the tensile and compressive behavior of the material with one stress-strain relationship in the local coordinate system that is fixed upon crack initiation. Exponential and parabolic constitutive laws were used to describe the tensile and compressive behavior of concrete and

masonry infill respectively. An example of the stress distribution of the masonry infill is shown in Fig. 3b.

Publications:

Papers

Martins A., Vasconcelos G., Fangueiro R., Cunha F. Experimental assessment of an innovative seismic strengthening material for brick masonry infills, Composites Part B: Engineering, January 2015 (Under revision).

Ackoundi F., Lourenço P.B., Vasconcelos G., Numerically Based Proposals for the Stiffness and Strength of Masonry Infills with Openings in Reinforced Concrete Frame, Earthquake Engineering and Structural Dynamics, October 2014. (Under revision).

Conference proceedings

Vasconcelos, G., Mora, J., Fangueiro, R., Cunha, F., Martins, A. Flexural behaviour of brick masonry retrofitted with braided textile meshes, IRF2013 - 4th International Conference on Reliability and Failure of Mechanical Systems, Funchal, 23-27 June, 12pp., 2013.

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Akhoundi F., Lourenço, P.B., Vasconcelos, G., Numerical modelling of masonry-infilled reinforced concrete frames: model calibration and parametric study, 07-09 July, University of Minho, 2014. (In CdRom).

Martins, A., Vasconcelos, G., Fangueiro, R., Cunha, F. Caracterização experimental do comportamento de aderência de varões compósitos têxteis, 9º Congresso Nacional de Mecânica Experimental, 15-17 Out., Universidade de Aveiro, Portugal, 2014.

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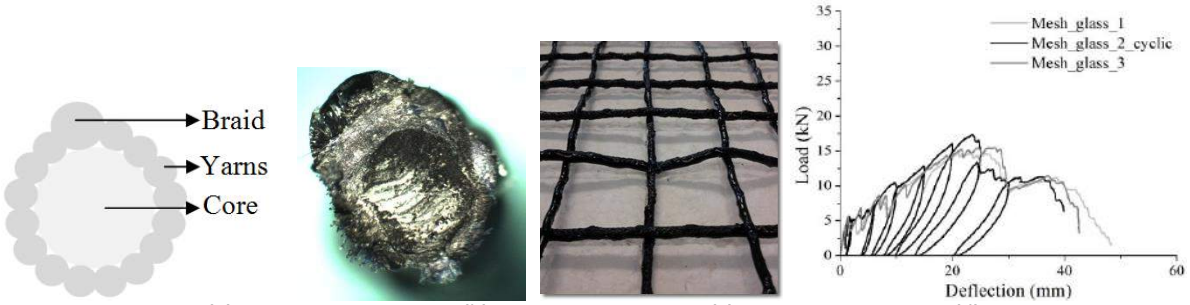

Fig. 1 (a) Representation of the cross section of the a BCR; (b) cross section of the BCR with glass fibres; (c) developed mesh; (d) force-displacement diagram for cyclic flexural tests.

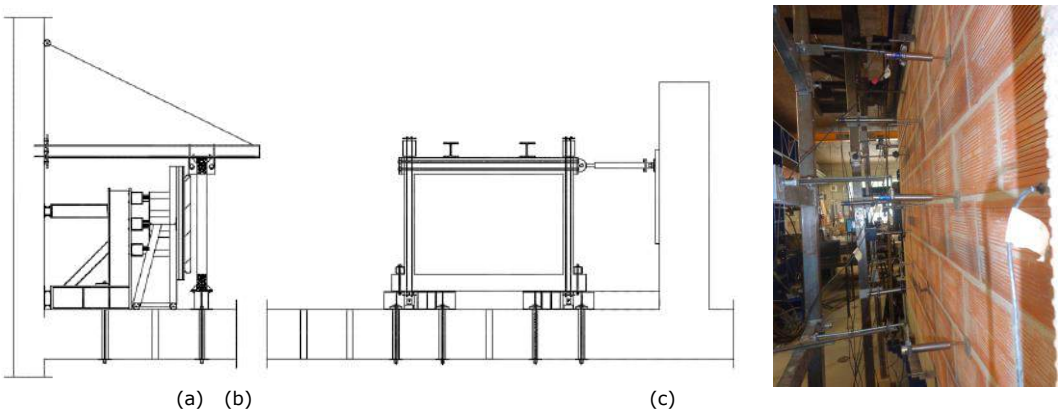

Fig. 2 Tests setups for cyclic tests; (a) out-of-plane testing with airbags; (b) in-plane test setup; (c) instrumentation for measuring out-of-plane deformation of the brick masonry infill wall.

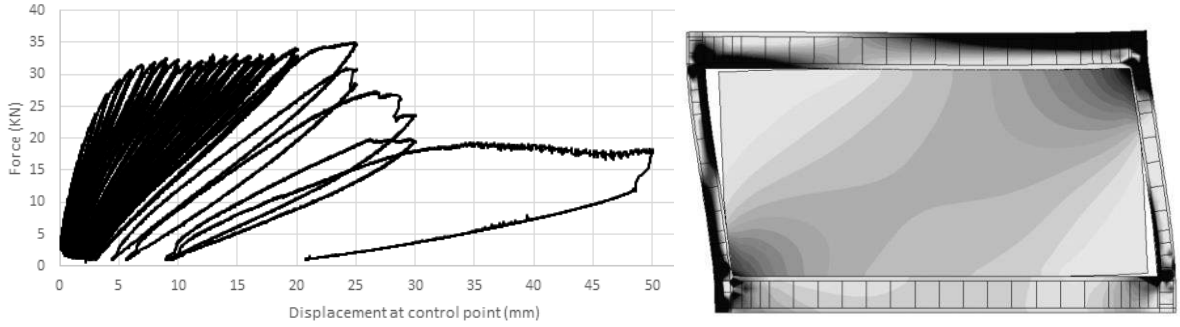

Fig. 3 Out-of-plane force-displacement diagrams (OOP test) on masonry infill walls.

Development of a prefabricated emergency house prototype made of composite materials | CLICKHOUSE

Financing Institution: Adi

Promoting Institution: ALTO – Perfis Pultrudidos, Lda.

Coordinator: José Sena Cruz (Local coordinator)

Researchers and collaborators: UM - José Sena-Cruz, Joaquim Barros, Isabel Valente, Julio Garzón-Roca, Hassan Abdolpour, Gonçalo Escusa

Partner Institutions: ALTO, IST, UM

Period: March 2014 to June 2015

Relevant facilities: Laboratory equipment and facilities from the structural lab of UMinho (LEST).

Objectives:
The main objective of the CLICKHOUSE project is to develop a prefabricated housing prototype with advanced composite materials for being used as an emergency house or temporary building in disaster areas. As an accommodation for the surviving communities of a natural disaster, the CLICKHOUSE dwelling will be fully functional, incorporating water networks, sewage and electricity. The use of a prefabricated system and composite materials give rise to a series of advantages, such as the ease of transporting to the disaster area, the speed and ease of assembly/disassembly the house, a good resistance to aggressive agents, a total compatibility with regularity requirements of structure safety and thermal performance according to the latest recommendations and standards, as well as good stiffness/weight and strength/weight ratios.

Description:
After a natural disaster, survived communities have to be accommodated in temporary dwellings. Normally people inhabit in these temporary houses for long period of time, making necessary providing people with a relative high quality standard of living, as well as basic facilities like water, electricity and sewage. Different types of temporary houses are currently available, most of which made of steel, wood and plastic, but in many cases, these temporary dwellings do not offer a basic level of security and protection for its occupants, and/or result in very complex and expensive solutions.

In the field of temporary houses designing, the main aspect is using materials with high functional properties with aspect to the low prices. Building industrialization by prefabrication manufacturing lead to reduce the cost of building and improve the quality of manufacturing. Likewise, after a natural disaster, accessibility to the roads is limited; hence, transporting prefabricated dwellings which are compromised of various segments of low weight is very convenient. As an alternative to the classical temporary housing solutions and materials, the use of composite sandwich panels for configuring the enclosure surfaces, and glass fibre reinforced polymer (GFRP) pultruted profiles for forming the substructure, fit very well into this trend. In this context, the project "CLICKHOUSE – Development of a prefabricated emergency house prototype made of composites materials" aims to develop a prefabricated housing prototype using advanced composite materials for being used as an emergency house in disaster areas or just as a temporary building.

The main structural elements of the house, i.e. the beams and the columns, consists of pultruted composite profiles made of GFRP. This material presents a series of promising advantages such as lightness, low production costs, low maintenance, high durability, corrosion resistance and strength. For floor, roof, and both interior and exterior walls, sandwich panels are utilized. Nowadays, composite sandwich panels provide an efficient structural system for being used in different application areas. In this system, an interior core is enclosed by two skins, having the core and the skins different mechanical functions. Hence, while skins bear the bending loads, the core deals with shear loads and stabilizes the skins against buckling and wrinkling. Bond between skins and core should be of sufficient strength to withstand the shear and tensile stresses introduced between them. In the case of the present project, GFRP was used for the skins and polyurethane foam comprises the core. It interesting to mention that the existence of a foam between both skins also provide the house with the required level of thermic and acoustical isolation.

In a first step, a floor module prototype of the CLICKHOUSE has been selected to be studied, as well as to serve as a reference to design all the other elements of the project. The selected prototype have consisted of four columns, four beams, and two sandwich panels as floor slabs. Columns have been materialized by tubular GFRP pultruded short elements with a cross section of 120×120 mm^2 and wall thickness of 8 mm. For the sake of decreasing segments variation in the manufacturing process, the same profile has been used for the perimetral beams. The composite panels have presented an overall height of 70 mm, a width of 1000 mm and a length of 3000 mm. GFRP skins have had a thickness of 5 mm and have been produced by the hand-layup technique, using dry fibres impregnated with an isopthalic polyester resin; multiple plies of GFRP fabrics and mats has been used in the process of composition. The core material have consisted of polyurethane foam blocks of 60 mm of thickness and a nominal density of 48 kg/m^3.

Connecting the different elements forming the prototype is a very important aspect. Connections must be resistant and stiff, but at the same time they must permit an easy and fast assemblage/ disassemblage of the prototype. In total, three types of connections exist in the system: beam-column, beam-panel and panel-panel. In the case of the beam-column connections, a bolted connection by means of

a steel tubular profile of 120×120 mm^2 has been utilized to transfer the loads from the beams to the columns. For the beam-panel and panel-panel connection, a U-shaped GFRP pultruded profile has been adhesively bonded on each outer faces of panels; this profile has been then connected to a smaller GFRP square tabular profile, which, in the case of the panel-beam connection, is adhesively bonded to the beam elements. As can be seen, for decoupling functionality reasons, chemical connection such as adhesive has not been used for connecting the different elements.

For assessing the performance of the prototype designed as a residential floor structure, an experimental program has been conducted. In this program, the prototype has been subjected to uniform distributed characteristics live load of 1.6 kN/m^2 to analyse its performance to deal with serviceability vertical loads; a characterization of the mechanical properties of the sandwich panel constituent materials has been carried out too. Moreover, an ambient vibration test has been conducted to study the capacity of the prototype to absorb the pedestrian vibrations. Additionally, the two sandwich panels forming the floor slab have been independently tested by four-point bending and three-point bending tests up to failure in order to evaluate the flexural response of the panels and the failure mechanism.

A numerical model using the finite element method is now in developing process. This model will allow a better understanding of the prototype analysed and will lead to make important improvements in the future development of the project. Besides, further experimental work is expected, including testing new sandwich panels to be used as wall and roof, as well as studying the creep behaviour and the aging performance of the sandwich panels.

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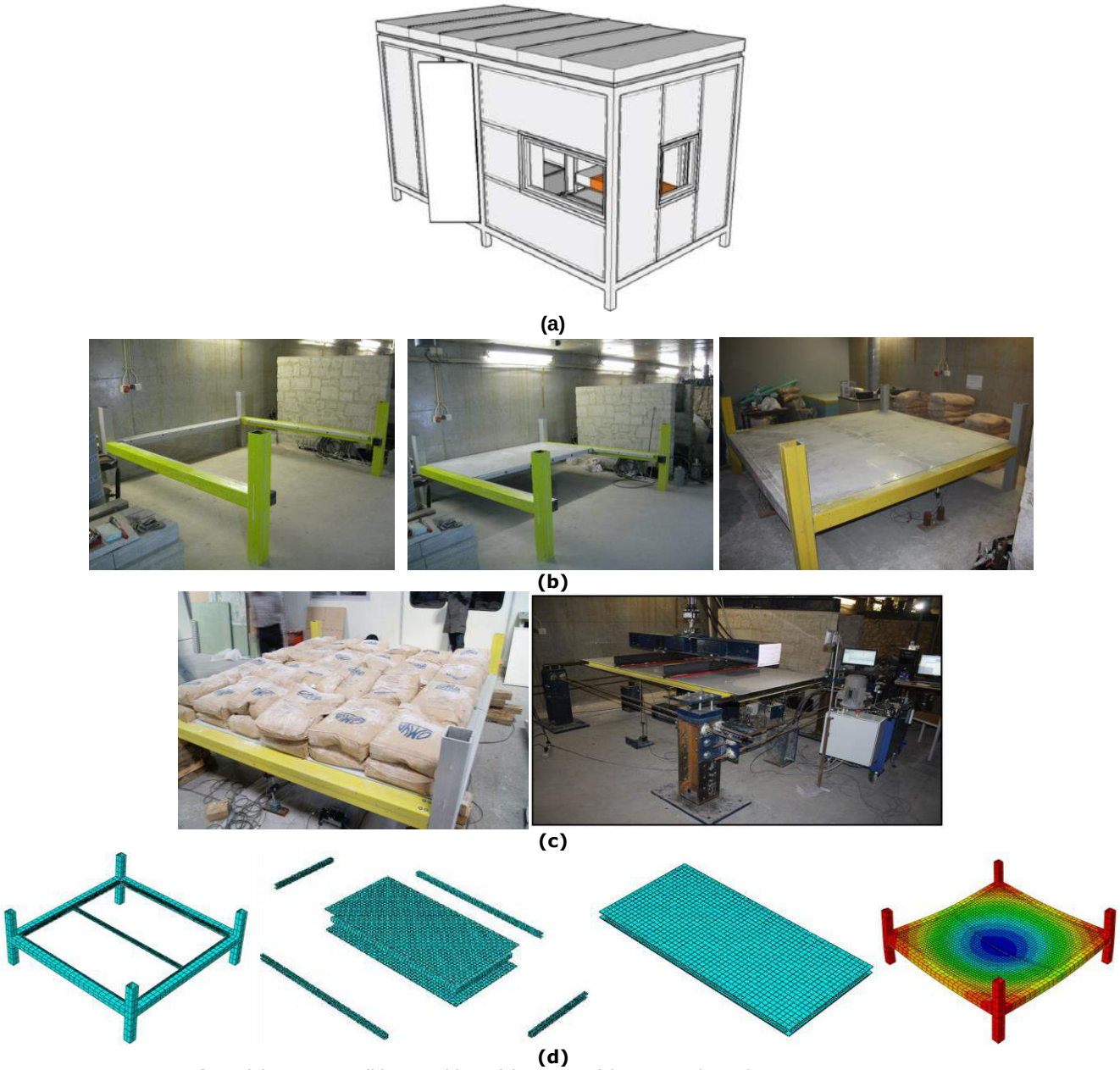

Fig. 1 (a) Prototype; (b) Assembling; (c) Testing; (c) Numerical simulations.

Development of a prototype of a pedestrian bridge in GFRP-SFRSCC | PONTALUMIS

Financing Institution(s): ADI

Promoting Institution(s): ALTO

Coordinator(s): Mátio Tomé (ALTO), Joaquim A. O. Barros (UMinho), Fernando Branco (IST)

Researchers and collaborators: Joaquim A. O. Barros, José Sena Cruz, Salvador Dias, Rui Miguel Ferreira, Aires Camões, António Matos, Marco Jorge, Hamidreza Salehian, Pedro Mendes, Ajaya Kumar Jena, Mahsa Taheri, Florian Thiery, Ziaaddin Zamanzadeh, Pedro fernandes

Partner Institutions: ALTO, University of Minho (ISISE), University of Lisbon/IST (CEris).

Period: 01/12/2008 – 30/04/2013

Relevant facilities: Laboratory equipment and facilities of UM and IST.

Objectives:

The objective of this project is to deep investigate the phenomena subjacent to a new concept of pedestrian bridge. The conceived bridge deck presents a hybrid cross-section constituted by glass fibre reinforced polymer (GFRP) pultruded profiles connected, at the level of the top flange, to a compressive layer of steel fibre reinforced self-compacting concrete (SFRSCC). The connection between the SFRSCC layer and the profiles is assured by a layer of epoxy adhesive and steel bolts. To avoid shear failure of the GFRP profile at the support zones, an innovative process is applied combining the strength and fluidity characteristics of SFRSCC. This structural system can retrieve all the high potentialities of the involved materials. The SFRSCC layer significantly increases the stiffness of the structural system, since it is constituted by a material of high strength, ductility and energy absorption capacity. The built and tested pedestrian bridge is lightweight, of quick erection, with electromagnetic insulation properties, high durability and low maintenance requirements during the service life.

Description:

In the Pontalumis project research activities were carried out that conducted to the construction and testing a 11 m long hybrid footbridge, with a total dead-weight of about 3 tonf. The structure comprises two longitudinal I-section GFRP main girders (200 × 400 (× 15) mm2), connected to a 2000 mm wide and 37.5 mm thick SFRSCC deck with a 2 mm thick layer of epoxy adhesive and M10 stainless steel anchors. The SFRSCC was designed to limit the crack width to 0.2 mm for all the design conditions for this type of application, and has presented a post-cracking residual strength at 0.5 mm and 2.5 mm of about 10 MPa, with a cost of about 120 €/m3, which is more competitive than using conventional RC.

Structural concept

The built and tested footbridge comprises two I-shaped (400×200(×15) mm^2) GFRP profiles acting as main girders and a thin 37.5 mm thick SFRSCC deck with a width of 2000 mm positioned on top of the GFRP profiles (Fig. 1). The structure presents a total length of 11000 mm and was tested in a 10500 mm simply supported span (L), as shown in Fig. 2.

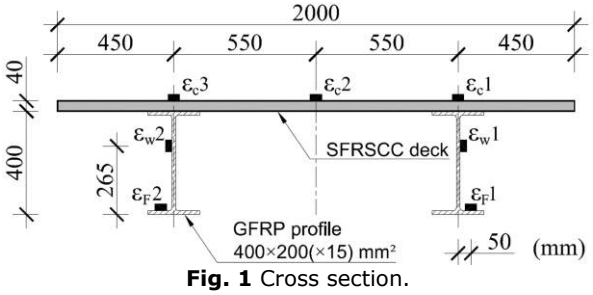

Fig. 1 Cross section.

Construction process

The construction of the footbridge prototype involved the following steps: manufacturing of the GFRP main and secondary girders (Fig. 3a), and the assembly of the main and secondary girders; transportation of the assembled girders to the construction site (Fig. 3b); manufacture the SFRSCC thin deck (Fig. 3c); drill holes in the deck to accommodate the stainless steel anchors that were bonded to the deck with an epoxy resin (Fig.3d); roughening the bonding area of the deck to enhance the adhesive bonding and application of a 2 mm thick epoxy adhesive layer (Fig. 3e); assembling the SFRSCC deck and the GFRP girders; the prototype was kept in position for a period of 9 days to guarantee a proper curing of the epoxy adhesive (Fig. 3f); the footbridge prototype was rotated 180º, with an auxiliary system especially designed for that purpose (Figs. 3g and 3h), and placed in its final position.

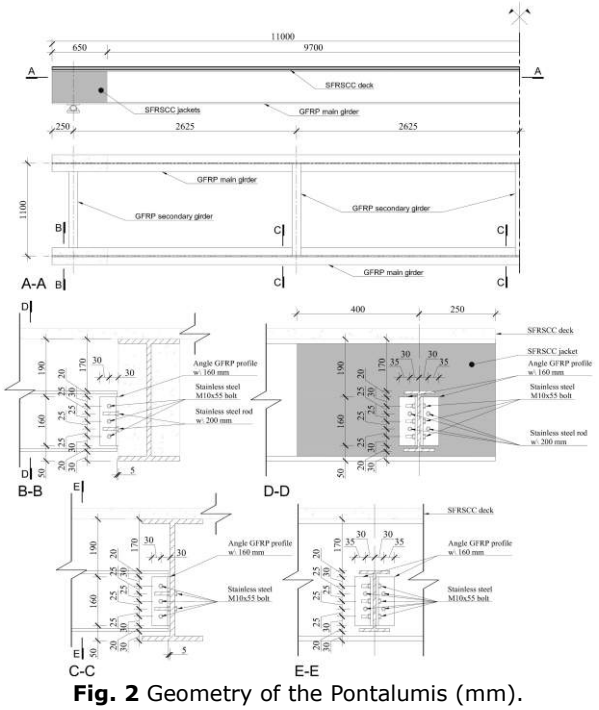

Fig. 2 Geometry of the Pontalumis (mm).

Fig. 3 Construction process of the Pontalumis.

Static behaviour

The static tests performed for several loading configurations (Fig. 4) attested the adequate structural response of the hybrid footbridge, showing that it fulfils the deflection requirements for serviceability limit states. The experimental responses were accurately predicted using FEM-based models considering elastic behaviour for the constituent materials (Fig. 5).

Fig. 4 Static tests.

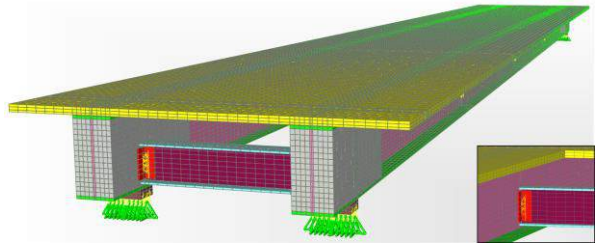

Fig. 5 Numerical simulations

Dynamic behaviour

The modal identification tests, complemented with the EFDD method, allowed determining the modal parameters, including the global damping ratio, which was estimated between 0.95% and 1.05%. The numerical model developed was able to predict the most relevant vibration mode shapes and frequencies (Fig. 6). The dynamics tests under pedestrian loads (Fig. 7) showed that there is very low probability of pedestrian discomfort due to the structural vibrations, except for an exposure period over 16 hours, which naturally is not expected in an 11 m long footbridge.

Creep behaviour

In the flexural creep test the instantaneous deflection increased by approximately 40% after 5 months (Fig. 8). An analytical model was proposed to predict the long-term deflections of this type of hybrid structures, which considers the flexural and shear stiffness of the structural system, including the environmental temperature-dependent long-term moduli of the materials involved (Fig. 9).

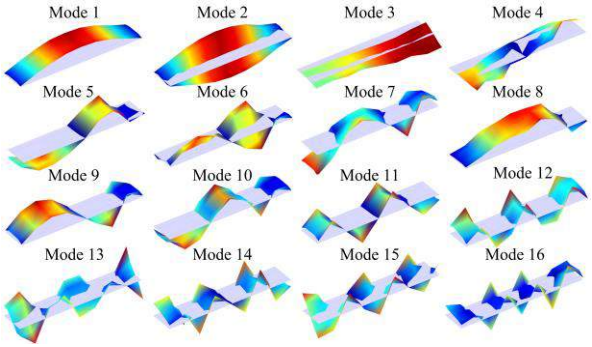

Fig. 6 Modal identification test: results of the first 16 mode shapes with ambient excitation.

Fig. 7 Pedestrian response tests: undergoing tests with several pedestrians.

Fig. 8 Structure loaded for the creep test.

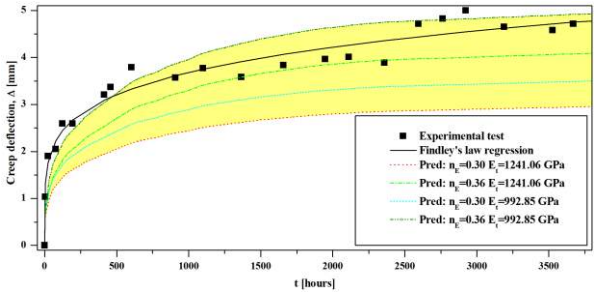

Fig. 9 Creep deflections.

Publications

Nº of papers in ISI international journals: 7
Nº of papers in non ISI international journals: -
Nº of papers in national journals: 1
Nº of papers in international conferences: 6
Nº of papers in National conferences: 2
Nº of technical/scientific reports: 6
Books Chapters: 3

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Development of a Sustainable Self-Construction System for Developing Countries | HiLoTec

Financing Institution(s): Mota-Engil S.A.

Promoting Institution(s): University of Minho – Mota-Engil S.A.

Coordinator(s): Luís F. Ramos

Researchers and collaborators: Luís F. Ramos, Paulo Mendonça, Aires Camões, Thomas Sturm, Rute Eires, João Sousa, Pedro Reis, Said Jalali, Graça Vasconcelos, Paulo B. Lourenço

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE), Territory, Environment and Construction Research Centre (C-TAC), Mota-Engil Malawi, Technical University of Malawi (Blantyre), Habitat for Humanity Malawi.

Period: January 2010 to October 2012

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho, and shaking table of the National Civil Engineering Laboratory in Lisbon.

Objectives:

The main goal of the HiLoTec project was to improve the strength and durability of houses in rural areas of Malawi. The use of CEBs could improve not only the strength of earth houses when compared to the existing ones, but also contribute to the deceleration of the deforestation. Furthermore, ICEBs present the possibility of constructing without mortar (i.e. dry-stack), which allows a fast and easy construction process suitable for self-construction.

Description:

Earth is still used as a building material to construct houses in Africa. One of the most common techniques is the masonry of sun dried or kiln fired mud bricks with earth mortar. Although this technique is cheap and allows the self-construction, the bricks vary largely in shape, strength and durability. This leads to weak houses which suffer important damage during floods and seismic events. A solution which has been proposed in the last decades is the use of dry-stack masonry with stabilized interlocking compressed earth blocks (ICEB). These blocks are manufactured by compacting cement stabilized earth in a manual or hydraulic press into a mould and then air cured for 28 days. The resulting blocks present uniform shapes, higher values of strength and durability and lower embodied energy than the traditional bricks. The material properties of ICEBs has been researched extensively, but little has been concluded with respect to the structural behaviour of these masonry dry-stack systems.

In the context of the HiLoTec project, a prototype for a social house was developed. The idea was to design a house that improves some of the problems current housings in Malawi face today, such as strength and durability, but also daily life issues such as thermal performance, plan distribution, noise pollution, amongst others. To create a prototype that is consistent with the needs and sensibilities of the local population (i.e. aesthetics, traditions, daily life), first the existing housing stock of Malawi had to be studied. This would permit assessing the local houses, from the architectural and engineering point of view, and allow to detect the weaknesses of the existing stock.

To attain this objective, the existing housing stock was studied in the visit to Malawi. The dwellings studied were located in or near the cities of Lilongwe, Blantyre, Salima and Ntcheu. The work was mainly focused on the study of ICEBs to be used in dry-stack masonry of one storey houses in regions with moderate seismicity. The mechanical characterization of the masonry was made by first studying the material properties of the blocks. Parameters such as compression and flexural strength, the Young's modulus and compressive and tensile fracture energy have been determined through laboratory tests. In a second phase, masonry specimens were tested to determine the compressive strength, shear behaviour of the dry joints and shear behaviour of full scale walls. To study the behaviour of a real structure under seismic action, a small masonry mock-up of a house was tested on a shaking table. Finally, the knowledge gained in the project was used to produce a construction manual of ICEB houses. In this manual, each construction step, from the soil selection to the roof, has been covered. The manual uses graphical mediums and minimalistic text content to make it understandable for self-construction.

The results of the Project showed that it is possible to produce ICEBs of sandy soils with sufficient strength. The tests of shear walls revealed that the shear strength of this masonry is low, but comparable to that of other earthen walls. The walls also showed high values of ductility and behaviour factor. The shaking table test showed that the mock-up resisted without significant damage peak ground accelerations (PGA) of 0.2 g, which are equivalent to those expected for frequent earthquakes in Malawi. It also showed that moderate damage can be expected for rare earthquakes with PGAs of 0.3 g and that near collapse would occur at almost twice that value. The behaviour factor was of 1.5, which is the maximum permitted by the Eurocode 8 for unreinforced masonry.

Examples of outcome of the project are represented in Figs 1 to 5.

Publications:

PhD Thesis

Thomas Sturm Moreira, Experimental characterization of dry-stack interlocking compressed earth block masonry, PhD in Civil Engineering, University of Minho, 2015

MSc Thesis

Diogo Gomes, Sustainable Construction with Compressed Earth Blocks (in Portuguese), Master thesis in Civil Engineering, University of Minho, 2012

Jounal Papers

Sturm, T.; Ramos, L.F.; Lourenço, P.B., Characterization of Dry-Stack Interlocking Compressed Earth Blocks, Materials and Structures, DOI: 10.1617/s11527-014-0379-3, Published on-line July 2014

Conference papers:

Sturm, T.; Ramos, L.F.; Lourenço, P.B., Campos-Costa, A. Mechanical characterization of dry-stack interlocking compressed earth masonry 9th International Masonry Conference July 7-9 Guimarães, Portugal no 1466, 12 p. 2014

Ramos, L.F.; Sturm, T.; Lourenço, P.; Campos-Costa, A., Poderão os blocos de terra compactada com estabilização fazer parte de um sistema sismo-resistente?, 5as Jornadas Portuguesas de Engenharia de Estruturas, Novembro, 26-28 Lisboa, Portugal, no 238, 2014

Eires, R.; Moreira, T.S.; Camões, A.; Ramos, L.F., Study of a New Interlocking Stabilised Compressed Earth Masonry Block, TERRA 2012, April 22-27, Lima, Peru, 2012

Mendonça, P.; Sousa, J.; Reis, A.P.; Ramos, L.F., Low-Cost Housing in Underdeveloped Countries – Simple Strategies for a More Sustainable Construction, TerraAsia - 2011, International Conference on Earthen Architecture in Asia, October 11th – 14th, Mokpo, Republic of Korea, pp. 269-277, 2011

Ramos, L.F.; Mendonça, P.; Camões, A.; Sturm, T.; Eires, R.; Reis, P.; Sousa, J.; Vasconcelos, G., As paredes Divisórias num Sistema Integrado de Alvenaria Estrutural em BTC, Seminário Paredes Divisórias: Passado Presente e Futuro, Junho, 22 Porto, Portugal, pp.163-176, 2011

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Fig. 1 Prototype design and development.

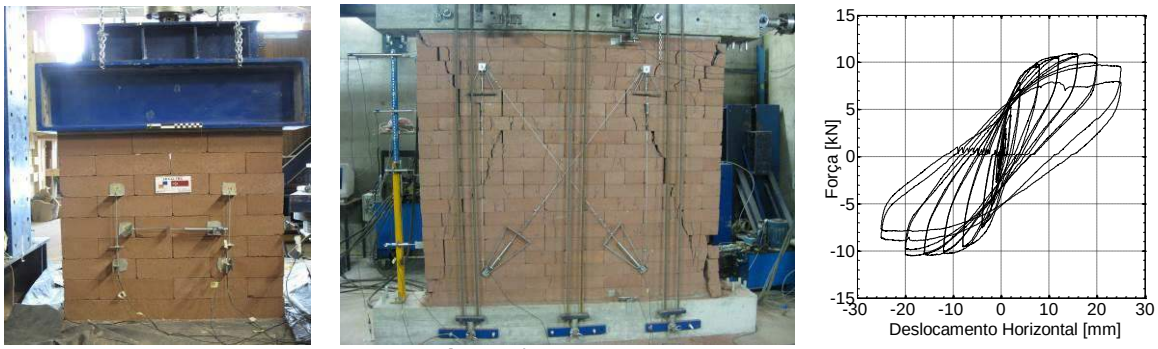

Fig. 2 Laboratory tests on masonry specimens.

Fig. 3 Shaking table test on a mock-up.

Development of an integrated strengthening system for historical constructions | REPAR

Financing Institution(s): IAPMEI, Augusto Ferreira Oliveira, L.da.

Promoting Institution(s): Augusto Ferreira Oliveira, L.da

Coordinator(s): Luís F. Ramos

Researchers and collaborators: Luís F. Ramos, Jorge Branco, Paulo B. Lourenço

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE).

Period: July 2012 to June 2013

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho.

Objectives:
The promoter intends to increase its skills to the strengthening of historical buildings with heritage value through the development of an alternative integrated and innovative solution to increase the out-of-plane flexural strength of masonry walls and improve the connections of timber beams in the same walls, enabling the use of adequate techniques for the difficult challenges to strength historic buildings and ruins, especially in seismic regions. The solution will be developed based on modern principles of intervention in heritage, such as respect for the original buildings fabric and the principles of minimum intervention and reversibility of structural interventions.

Description:
Historic ruins – vacant buildings without floors and roofs; parts of ancient walls; partially destroyed castle walls or archaeological sites – representing high heritage value are unlike the current masonry buildings. These buildings are often only supported in their foundations, cantilevering with no connection to any other construction element that would function as bracing. Other types are left without horizontal support between the roof structures and their foundations, acting as thin supported wall beams. These structures are extremely vulnerable to seismic and wind effects, as they can have very low resistance against out-of-plane actions. It is difficult to find a technique, which is especially developed for the structural consolidation of these types of constructions and at the same time does not adversely affect their authenticity

The main objective of the project is to develop an integrated solution for reinforcing structural (unreinforced) masonry walls, based on the application of a flexible embedded reinforcement in mortar joints, associated with the development of local reinforcement of deliveries of wooden beams in masonry walls stone. As reinforcement techniques, local joist of wooden beams in masonry walls were studied three possible techniques: a) reconstruction of damaged delivery using epoxy mortars, b) use of wooden prostheses linked to existing wood (sound) through plates, threaded rods and rod GFPR c) Splicings use of wood screwed to the existing wood (sound).

Following the main idea of Borri ("reticulatus") a research was aiming at (1) starting a test campaign that investigates the full structural capacity of stone walls reinforced with this technique, and (2) develop special constituents and equipment to increase the workability of the technique.

The research aims to decrease labour time by implementing a helical shaped bar and developing a special head creating the Heli-needles as anchors (see Figure 1). The head allows the passage of cords and does not allow them to fall out of the joints. The special heli-needle allows an easy application with a simple tool that was especially developed for this purpose (see Figure 1). The helical bar penetrates the joint with a rotation while it is inserted. The special hammer-head is able to (a) rotate with the bar, and (b) enter the joint with the heli-needle for full insertion, allowing the connectors to be hidden in the joints.

The system includes the following steps in application:
1) Removal of the mortar from the joints in a depth of 2 to 3 cm, to be able to embed the reinforcing grid
2) Introduction of helical stainless steel needles in masonry cross joints (where horizontal and vertical joints meet). Before the application of needles a pre-drill is made with a diameter smaller than the diameter of the heli-needles, in order to make the insertion easier. Subsequently the connectors are inserted by hammering with the device designed for this purpose;
3) The end of the needles close to the wall surface, is equipped with a head which allows the passage of cables or ropes;
4) The cables/ropes together with the special connectors are creating irregular, distributed armour in the joints. The cables have 2 or 4 mm in diameter, in order to be flexible enough to follow the mortar joints and adapt angles of 90°. The cables should be placed to provide the desired orientation for a better resistance against bending stresses;
5) After the application of cables, all joints are repointed with the appropriate mortar, so that the reinforcement system would not be visible.

When the walls reinforced with this system are subjected to out-of-plane bending forces, the cables / ropes will work in tension. The adaption of helical rods for anchoring the cables is expected to improve the efficiency.

The main characteristics of this system are:
- Cables can be applied on both sides of the wall, so the strengthened structure can resist positive as well as negative bending moments;
- As the reinforcement is placed near surface, the useful height of a bending resistant cross section is quasi equivalent to the thickness of the wall;

- The required work is simple, equipment is easy to handle, and does not require skilled labour;
- The invasiveness of the technique is superficial and only affecting joints, similarly to a shallow structural repointing.
- Reinforcement is not visible after repointing;
- The authenticity of historic building is safeguarded;

Examples in Figs 1 to 3.

Publications:

MSc Thesis
Pedro Basto, Reforço Sísmico de Ligações de Construções Históricas, Master Thesis in Civil Engineering, University of Minho, 2013

Barna Csikai, Flexural out-of-plane retrofitting of masonry walls in historical constructions, Master Thesis in Civil Engineering, University of Minho, 2013

Conference papers:
Csikai, B.; Ramos, L.F.; Bastos, P.; Moreira, S.; Lourenço, P.B., Flexural Out-of-Plane Retroftting Technique for Masonry Walls in Historical Constructions, SAHC2014 – 9th International Conference on Structural Analysis of Historical Constructions, October 14-17, Mexico City, Mexico, no 07-059, 11 p., 2014

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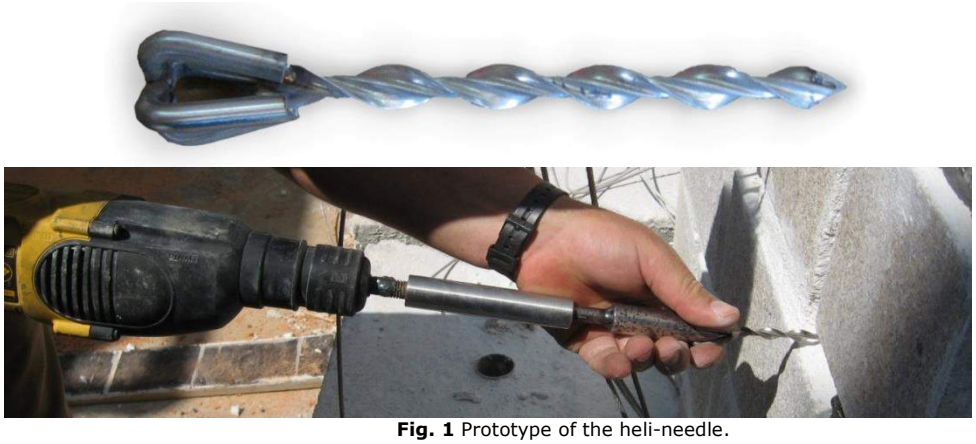

Fig. 1 Prototype of the heli-needle.

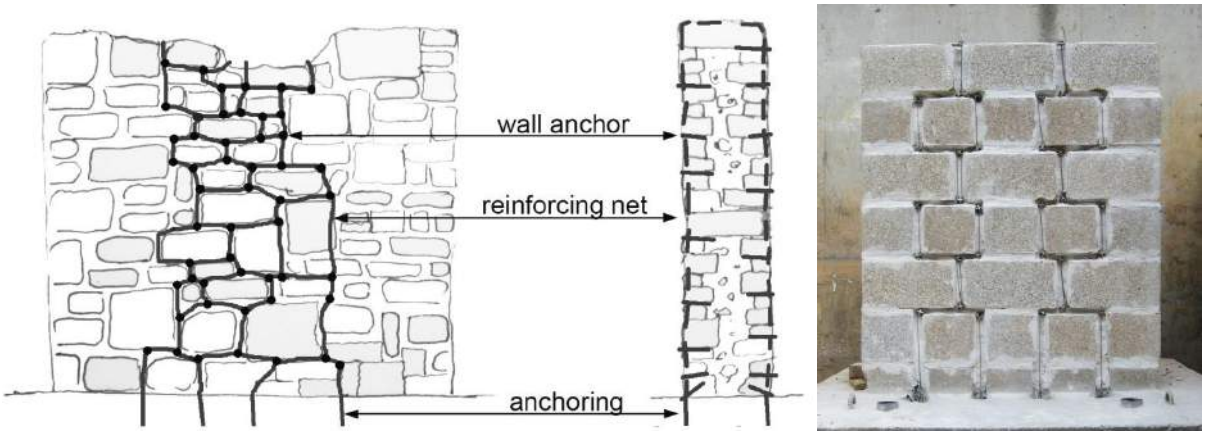

Fig. 2 Application of the improved technique with heli-needles.

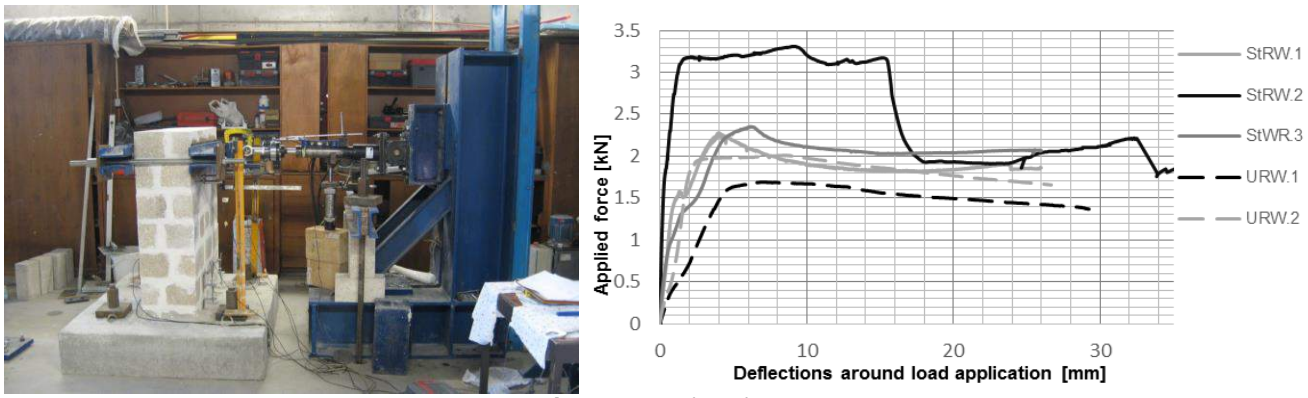

Fig. 3 Tests and results.

Development of cost competitive pre-fabricated modular buildings | LEGOUSE

Financing Institution(s): ADI

Promoting Institution(s): Mota-Engil Engenharia

Coordinator(s): Paulo Lopes (Mota-Engil), Joaquim A. O. Barros (UMinho), Lúcio Lourenço (Civitest)

Researchers and collaborators: Joaquim A. O. Barros, Rodrigo Lameiras, Isabel B. Valente, Miguel Azenha, José Sena Cruz, Aires Camões, Amin Abishambraf, Sandra M. Silva, Umut Yildirim, Manuela Almeida, Salvador Dias, Rui Miguel Ferreira, António Matos, Marco Jorge, Daniel pinheiro, Maria Mercado, Loganathan Balamurugan, Sandro Peixoto, Raphaele Malheiro, Christoph Sousa, Cristina Frazão, Hassan Abdolpour

Partner Institutions: University of Minho (ISISE - Institute for Sustainability and Innovation in Structural Engineering and PIEP - Innovation in Polymer Engineering), CiviTest - Research of new materials for Civil Engineering.

Period: 01/09/2009 to 31/08/2013

Relevant facilities: Laboratory equipment and facilities of Civil Engineering Department of UMinho and PIEP.

Objectives:

The essential aim of Legouse project was the development of a modular construction system for residential buildings, based on a prefabrication technology that was competitive and value-added in technological, economic and environmental terms. To this end, it was necessary to develop and adjust the materials behaviour to its use in the systems to be designed, to optimize structural systems by using advanced calculation tools, to evaluate the performance of the structural systems by testing prototypes and real scale models, to write background documents for design, and to promote and disseminate the obtained results. A prototype was built to validate the solution obtained in a scope as broad as possible: the design of structural elements and their preparation, the steel fibre reinforced concrete, the GFRP connectors, the insulation layer, the moulds and casting procedures, the industrial procedures for fabrication and setup that include hand-intensive manufacturing and assembly, the incorporation of technological networks in prefabricated panels, acoustics and thermal performance solutions, etc.

Description:

An innovative and thermally efficient sandwich panel was proposed for the structural walls of the pre-fabricated modular housing system. Traditionally, sandwich concrete panels consist of reinforced concrete wythes as outer layers, polystyrene foam as core material and steel connectors. However, steel connectors are known to cause thermal bridges on the building envelope, with possible consequent occurrence of condensation and mould problems. Furthermore, the reduction/optimization of the thickness of conventionally reinforced concrete layers is frequently limited by minimum concrete cover requirements for the protection of the reinforcement from corrosion. To overcome these issues, the proposed sandwich panel comprises Glass Fibre Reinforced Polymer (GFRP) connectors and two thin layers of Steel Fibre Reinforced Self-Compacting Concrete (SFRSCC) (Fig. 1).

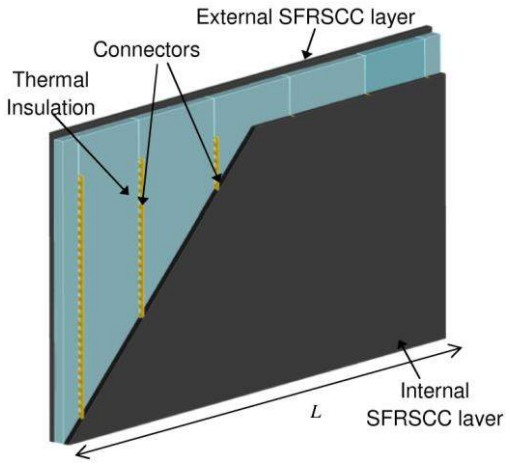

Fig. 1 Proposed building system: components of the devised load-bearing sandwich wall panel.

The material and structural concept of the proposed building system were analyzed. The feasibility of using the proposed connectors and SFRSCC on the outer wythes was experimentally investigated through a series of experimental tests where failure modes and load capacity of the connections were analysed.

Besides the use of unconventional materials, the proposed construction system has other peculiarities that turn it attractive. The walls act as the primary load carrying components of the structure, transferring the loads to the foundation of the structure. The single storey wall panels span vertically between foundations and floor/roof panels without the need for additional intermediate supports. For aesthetic and practicality reasons, the vertical load is applied only in the inner SFRSCC wythe (Fig. 2).

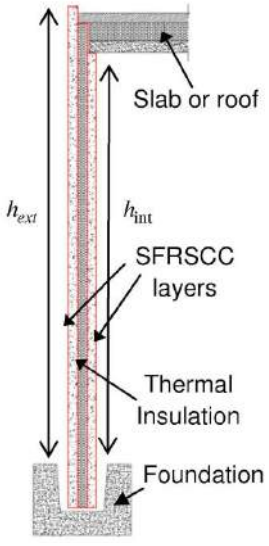

Fig. 2 System cross section.

In this context, the GFRP laminar connectors proposed (Fig. 3) and evaluated experimentally (Fig. 4) play an important role in the structural system to make the two layers of SFRSCC act jointly to withstand the actions to which the structural panels are exposed.

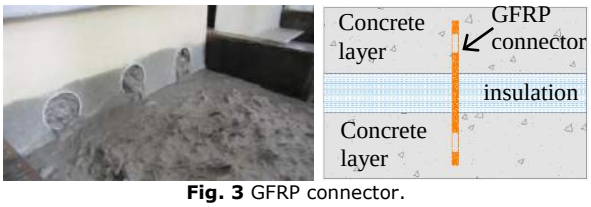

Fig. 3 GFRP connector.

During the project, efforts were made to assess the best solutions for the geometry of the panel components and arrangement of GFRP connectors, through parametric analyses. For a better understanding on how the proposed solution for the structural system performs when subjected to extreme loading conditions such as high winds, a nonlinear design of the sandwich panels was also performed taking into account the degradation (i.e.: cracking) of the SFRSCC layers. Through nonlinear analyses, the ductility of the proposed system under severe conditions was verified, providing the evolution of inelastic phenomena such as crack widths and deflections.

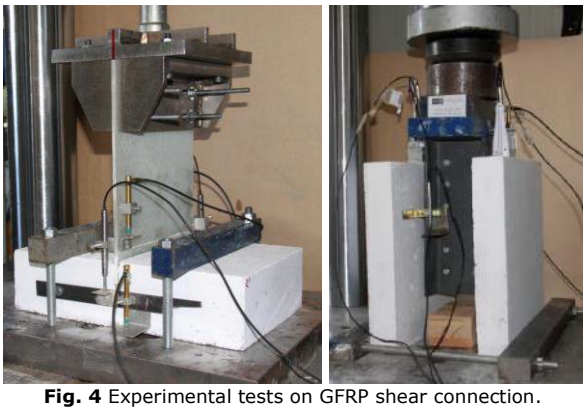

Fig. 4 Experimental tests on GFRP shear connection.

Steel fibre reinforced concrete (SFRC) was developed to remove completely, or in part, conventional reinforcement in concrete structures, with technical and economical advantages. The use of SFRC promotes increased durability, ductility, impact resistance and fire in concrete structures. Composite structures reinforced with glass fibres (GFRP) may also be used in high performance prefabricated structural elements due to their high strength, light weight, good insulation properties and durability in corrosive environments.

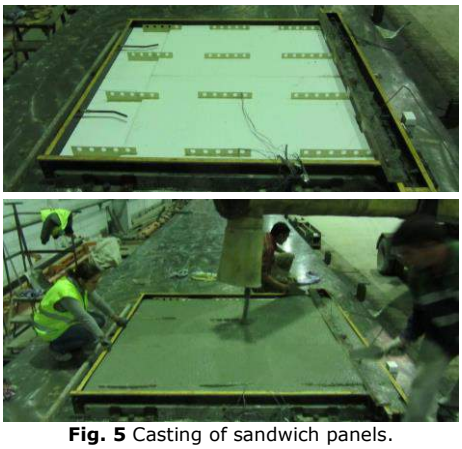

Fig. 5 Casting of sandwich panels.

The project involved development of materials involved in the building systems and characterization of its properties, optimization of structural systems, construction and testing of the modular construction elements, construction and testing of a full scale modular housing, development of technical specifications and design rules and promotion and dissemination of results (Fig. 5). On the other hand, the project trained technicians with advanced training in innovation in materials and structures, which contributed significantly to an increased competitiveness of the companies involved.

A prototype building that possesses of all the representative features of the modular construction system proposed under this project was constructed, monitored and tested. The modular building is running and available to be visited at the manufacturing facilities of Mota-Engil, in Rio Maior. Fig. 6 presents the geometry and a final view of the constructed prototype.

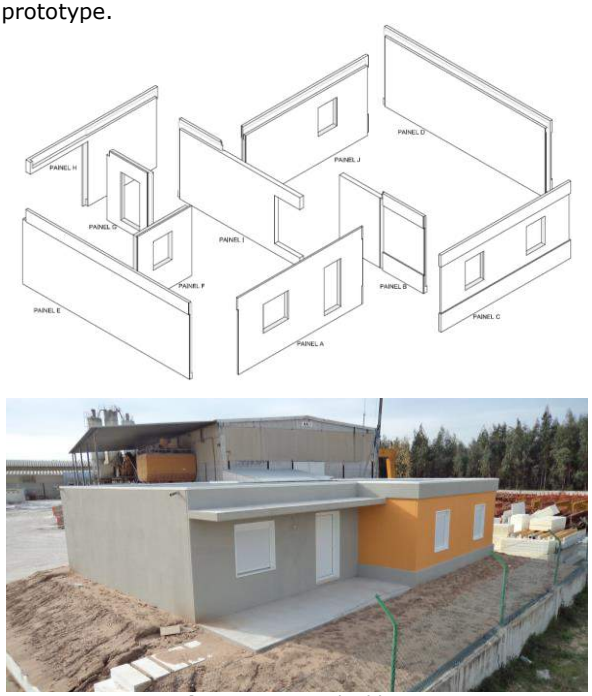

Fig. 6 Prototype building.

The speed of construction and the cost of building elements make this housing solution more competitive than traditional ones. This concept is especially geared towards countries with housing shortage, such as the PALOP, intending to extend its application to other countries of Africa, India and the countries of Latin America, where the lack of adequate housing contributes to the scourge of illegal immigration.

Publications:

Nº of papers in ISI international journals: 7
Nº of papers in non ISI international journals: 1
Nº of papers in international conferences: 9
Nº of papers in national conferences: 6
Nº of technical/scientific reports: 30
Book Chapters: 1
Nº of technical/scientific reports: 2
Nº of PhD thesis: 2
Nº of MSc thesis: 6

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Development of structural solutions for masonry walls | ALVEST

Financing Institution(s): SI Innovation and Technological Development, I&DT Projects enterprises in co-promotion (Funding ADI)

Promoting Institution(s): Costa&Almeida, Lda

Coordinator(s): Paulo Lourenço

Researchers and collaborators: Paulo Lourenço, Graça Vasconcelos, Leonardo Avila, Rui Marques, Pedro Alves

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE), Costa&Almeida, Lda; Abel Luís Nogueiro&Irmãos Lda; Superior Institute of Engineering of Coimbra (ISEC)

Period: October 2009 to March 2014

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho.

Objectives:

This project has as main goal the development of a constructive/structural system in reinforced masonry that is able to be adopted successfully in the Portuguese construction market.

More than the conception of the concrete block, encompassing the selection of the adequate shape and size and the selection of the adequate raw materials, it is essential to define an integrated constructive system with information of constructive details, mechanical and physical characterization as well as with the information about the technical, social and economical sustainability. The construction of real buildings will enable the practical demonstration in field real conditions and the definition of the strategy for the in situ organization of construction.

The mechanical validation focus on the mechanical characterization of masonry materials, masonry as a composite material and the mechanical validation of the constructive system under dynamic loads through shaking table tests on reduced scale prototype buildings. Additionally, characterization of the thermal and acoustic performance of the system will be carried out.

Finally, in order to make the introduction of the new product into the market easy, design and construction guidelines will be provided as a support of structural design to be used by engineers.

Description:

This project addressed the seismic performance of a new masonry structural system developed for residential and public buildings. The use of structural masonry, in particular for the Portuguese construction market, requires a deeper insight on the seismic behavior of masonry buildings, as Portugal is a medium to high seismic hazard country. Additionally, complete background on seismic design of masonry buildings is needed. Notice that a reason that contributes to the absence of structural masonry is the lack of academic training.

The idea is the proposal of an earthquake-resistant new masonry system that ensures good mechanical performance, ensuring that no-collapse and damage limit states are fulfilled, and that provides an economical and simple solution. Studies on the lateral in-plane behavior of concrete block masonry walls have already been done on masonry elements. Those studies provided useful information about the cyclic behavior of masonry walls but validation of the seismic behavior of masonry buildings built with the proposed masonry system solution is still missing. Therefore, in view of this status quo, the main aims of the proposed research project were: (1) experimental validation of the masonry building with the proposed constructive system; (2) assessment of the main parameters defining the seismic performance of the masonry buildings; (3) to obtain a better insight on the numerical modelling approaches for the masonry buildings; (4) provide some design guidelines for the design of new masonry buildings. Based on the complexity of the dynamic behavior of structures and especially of masonry buildings, the accomplishment of a solution to be used in zones with different seismic hazard necessarily involves the experimental dynamic characterization and the numerical nonlinear analysis, being both techniques powerful tools for the understanding of the global behavior of structures subjected to seismic action. Therefore, aiming at obtaining the seismic behavior of a structural solution for concrete block masonry buildings, an extensive experimental testing program based on shaking table tests, complemented with a detailed numerical nonlinear dynamic time history analysis was planned and carried out.

The work methodology followed encompassed the following steps:

1. Design an experimental program for the characterization of the seismic response of structural masonry buildings based on shaking table tests.
2. Shaking table testing of different typologies of masonry buildings to assess (1) the influence of the geometry configuration on the seismic behavior of the concrete block masonry buildings; (2) the influence of the reinforcing system composed of vertical and horizontal truss type reinforcements.
3. Development of a numerical model based on finite elements to describe the seismic behavior of concrete block masonry buildings. Here, the nonlinear dynamic time history analysis is adopted as it is considered the most advanced numerical simulation that better represent the dynamic behavior of masonry structures.
4. Assessment of the seismic design procedures recommended in the codes for masonry buildings. With this respect, an assessment of the behavior factor, q, to be used in the seismic design of the unreinforced masonry was provided based on the results of the seismic response of symmetric buildings.

Publications:

Papers

Lourenço, P.B., Avila, L., Vasconcelos G., Alves, P., Mendes N., Campos Costa A. Experimental investigation on the seismic performance of masonry buildings using shaking table testing, Bulletin of Earthquake Engineering, 11(4), 1157-1190, 2013.

Conference proceedings

Avila L., Vasconcelos, G., Lourenço, P.B., Experimental and numerical analysis of the seismic performance of concrete block masonry buildings, 07-09 July, University of Minho, 2014. (In CdRom).
Avila, L., Lourenço, P.B., Vasconcelos, G., Mendes, N., Modal identification and stiffness degradation of concrete block masonry buildings, Internacional Operacional Modal Analysis Conference, 13-15 May, Paper 156. 2013.
Avila, L., Vasconcelos G., Lourenço, P.B., Seismic response analysis of concrete block masonry buildings: An experimental study using shaking table tests, 15th World Conference on Earthquake Engineering, 24-28 de September, Lisbon, 2012.
Vasconcelos, G., Lourenço, P.B., Marques, R., Gouveia, J., Avila, L., Implementação de uma solução em alvenaria estrutural de blocos de betão, Congresso Construção 2012, Universidade de Coimbra, Coimbra. 2012.

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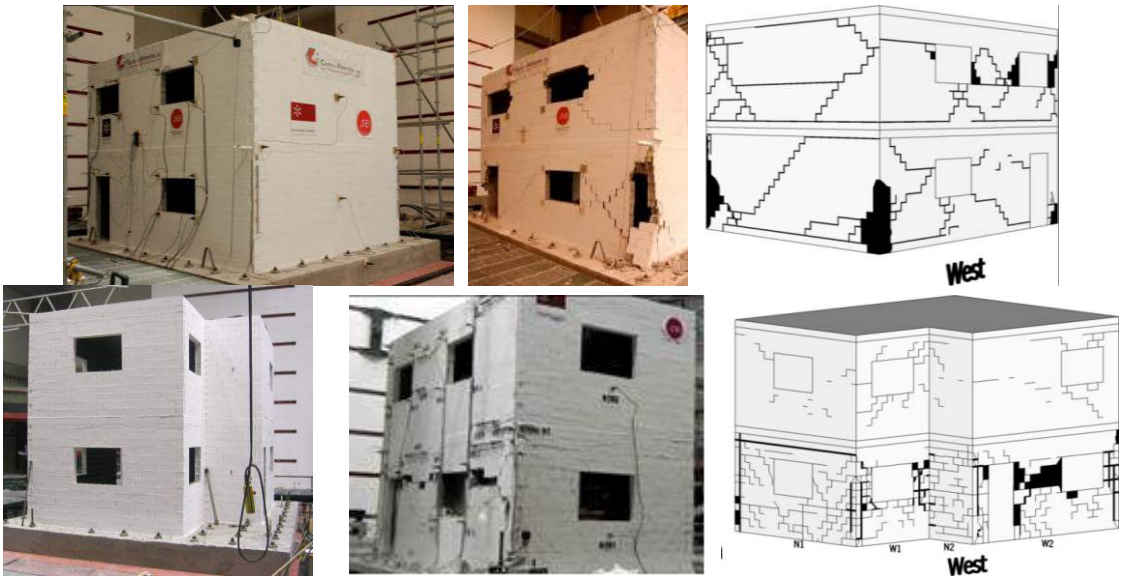

Fig. 1 Shaking table testing on concrete block masonry buildings with distinct layout in plan.

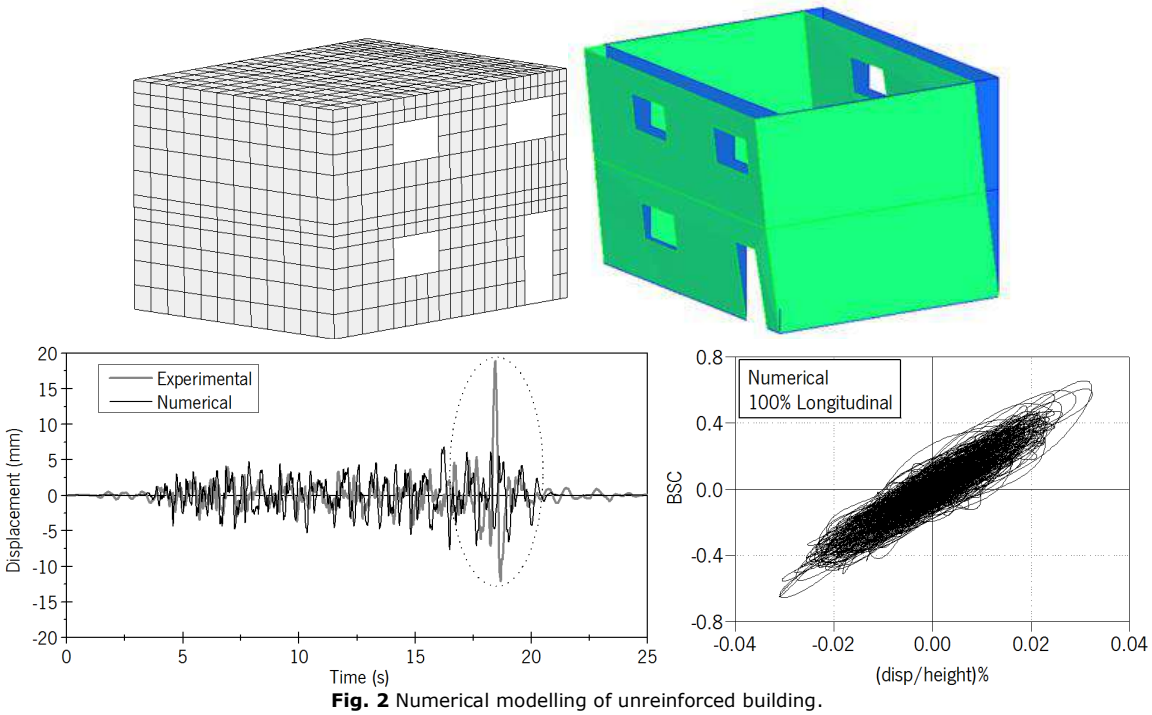

Fig. 2 Numerical modelling of unreinforced building.

Displacement Based Seismic Design of Steel Moment Resisting Frame Structures | DiSTEEL

(RFSR-CT-2010-00029)

Financing Institution(s): Research Fund for Coal and Steel - European Union (EU - RFCS)

Promoting Institution(s): European Centre for Training and Research in Earthquake Engineering Italy; Consorzio Pisa Ricerche Italy; Portuguese Constructional Steelwork Association Portugal; University of Naples "Federico II" Italy; S.C. Britt S.R.L. Romania

Coordinator(s): (CMM/FCTUC, Portugal) Luís Simões da Silva and Carlos Rebelo; (EUCENTRE, Italy) Timothy Sullivan

Researchers and collaborators: (only CMM/FCTUC, Portugal) Luís Simões da Silva, Carlos Rebelo, José Miguel Castro, Hugo Augusto

Partner Institutions: EUCENTRE – European Centre for Training and Research in Earthquake Engineering (Italy), Consorzio Pisa Ricerche (Italy), Portuguese Constructional Steelwork Association, University of Coimbra, University of Napoli, Federico II (Italy), S.C. Britt S.R.L. (Romania).

Period: July 2010 to December 2013

Relevant facilities: Computational equipment of civil departments of FCTUC.

Objectives:

To improve the damage control during earthquakes new seismic design methods are required. DiSTEEL is a research project on the Displacement Based Seismic Design of STEEL Moment Resisting Frame Structures. The main product of the research will be a set of practical performance-based design guidelines for steel moment-resisting frame structures that include performance criteria and a displacement-based design procedure capable of considering different beam-column joint typologies. The research will use existing experimental data and numerous analytical studies to verify the guidelines. The findings will improve confidence in the steel construction industry and increase utilisation of steel in Europe.

Description:

Recent earthquake events have highlighted the need for seismic design approaches that not only ensure life-safety during rare earthquake events but also effectively control the likely damage, or performance, of structures as a function of acceptable levels of seismic risk. These concepts are at the heart of new performance-based design requirements that are emerging internationally in seismic design and need to be employed by the European steel construction industry. Unfortunately, performance-based design cannot be easily or confidently undertaken in Europe as there are several fundamental flaws associated with force-based design methods incorporated within the Eurocode 8 and other international standards.

The problems with force-based design were revealed by Priestley (1993) in a well-known publication on the "Myths and Fallacies" in Earthquake Engineering. The relevant issues identified by Priestley are discussed further within the detailed text of this proposal, but the main message to be taken from the 1993 publication (re-published with more detailed discussion in 2003) is that new seismic design methods are required in order to effectively control the damage expected in earthquake events. In particular, it was pointed out that damage is clearly related to the deformations, or displacements, that a structure undergoes and not the force it is subjected to. This gave birth to the concept of displacement-based design (DBD).

A large amount of work has already been undertaken in the field of displacement-based design since the paper of Priestley in 1993. Priestley, Calvi and Kowalsky published a book on displacement based seismic design of structures in 2007 and more recently Sullivan, Priestley & Calvi released a model code in, 2012. These state-of-the-art documents provide a comprehensive set of DBD guidelines for reinforced-concrete structures but, in contrast, the recommendations for steel moment resisting frame structures are very limited and have not been well verified. The guidelines for steel frame structures included in the model code are applicable only for joints that exhibit Ramberg-Osgood hysteretic behaviour, the design displacement profiles were obtained from the response of concrete frames, and preliminary deformation limits have set with a certain degree of engineering judgment. With this in mind, the DiSTEEL project will deliver a set of practical performance-based design guidelines for steel moment-resisting frame structures that include performance criteria and a displacement-based design procedure capable of considering different beam-column joint typologies.

The consideration of different joint typologies is considered essential given that the joint selection affects the seismic behaviour and the building costs very significantly. The new design guidelines will improve the utilisation of steel in regions of moderate and high seismicity by providing practitioners with the tools and the confidence to control the performance of steel MRF buildings in earthquakes.

In developing the guidelines, the research will also highlight the advantages and disadvantages of different joint details, both from a structural behaviour standpoint and from a practical construction viewpoint so that designers and contractors can identify optimum design solutions. Moreover, the project will considerably improve our ability to control the risk posed by earthquakes, ensuring safer communities and reducing the impact of future earthquakes.

Publications:

Reports:

DiSTEEL –report for the first annual reporting period 2011.

DiSTEEL – Mid-term report 2012.

DiSTEEL –report for the third annual reporting period 2013.

DiSTEEL – Final report 2013.

T.J. Sullivan, G.J. O'Reilly - Characterising the Seismic Behaviour of Steel Beam-Column Joints for Seismic Design - Report EUCENTRE 2014/01

R. Roldan, D.P Welch, C.I. Nievas, T.J. Sullivan, A.A. Correia, G.M. Calvi - Guidelines for the Performance-Based Seismic Design of Steel MRF Structures - Report EUCENTRE 2014/02

Conference proceedings:

DiSTEEL Workshop - Displacement Based Seismic Design of Steel Moment Resisting Frame Structures. Associação Portuguesa de Construção Metálica e Mista (CMM) (Ed.) 2011, Portugal.

H. Augusto, J.M. Castro, C. Rebelo, L. Simões da Silva - Modelling of the Dissipative Behaviour of Partial-Strength Beam-to-Column Steel Connections. *in* 15WCEE, paper 2325, 2012, Lisbon.

H. Augusto, J.M. Castro, C. Rebelo, L. Simões da Silva - Determinação dos parâmetros relevantes para a caracterização de ligações metálicas de resistência parcial Sujeitas a Carregamento Cíclico. in 4th Congresso Construção, 2012, Coimbra.

H. Augusto, J.M. Castro, C. Rebelo, L. Simões da Silva - Numerical Simulation of Partial-Strength Steel Beam-to-Column Connections under Monotonic and Cyclic Loading. *in* Numerical Methods in Engineering, CMN 2013, June 25-28, 2013, Bilbao, Spain, pp. 121-140.

H. Augusto, J.M. Castro, C. Rebelo, L. Simões da Silva - Assessment of Key Parameters for Displacement-Based Seismic Design of Steel Moment Frames with Partial-Strength Connections. In XXIV Le Giornate Italiane della Construzione in Acciaio, CTA, 2013, Turin, Italy, Vol. 1, pp. 613-620.

H. Augusto, J.M. Castro, C. Rebelo, L. Simões da Silva - Calibração de um modelo de elementos finitos de ligação metálica viga-pilar para validação dos modelos de cálculo do Eurocódigo. In Congresso de Construção Metálica e Mista & I Congresso Luso-Brasileiro de Construção Metálica Sustentável, 2013, Porto, Portugal, pp 467-477.

H. Augusto, J.M. Castro, C. Rebelo, L. Simões da Silva - Characterization of the Cyclic Behaviour of End-Plate Beam-to-Column Steel Connections. In II DiSTEEL workshop, Associação Portuguesa de Construção Metálica e Mista (CMM), Recent Developments and Contributions for the Seismic Design Approaches for MRF Steel Structures, 2013, 25 of October, Porto, Portugal, pp. 71-87

H. Augusto, J.M. Castro, C. Rebelo, L. Simões da Silva - Dynamic simulation of beam-to-column partial-strength steel joints for the assessment of ductility-equivalent viscous damping relationships, in IX International Conference on Structural Dynamics, EURODYN2014, 2014, Porto, Portugal.

H. Augusto, J.M. Castro, C. Rebelo, L. Simões da Silva - A contribution to the extension of the component method to beam-to-column connections subjected to cyclic loading, in EUROSTEEL 2014, 2014, Naples Italy.

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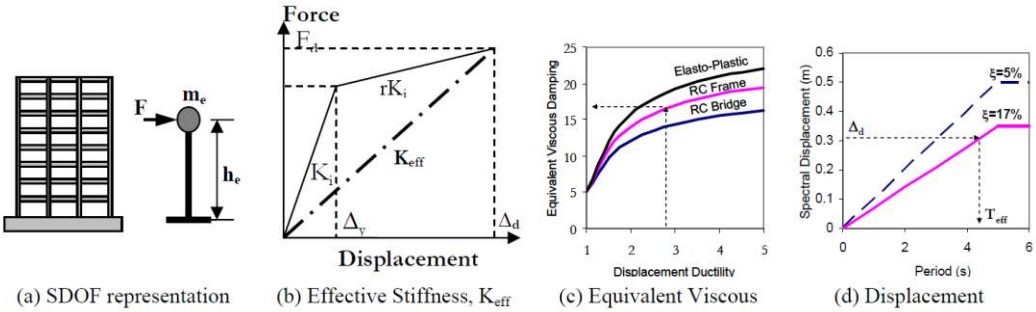

(a) SDOF representation (b) Effective Stiffness, K_{eff} (c) Equivalent Viscous Damping (d) Displacement Spectrum

Fig. 1 Basic formulation of the displacement-based seismic design of MRF structures (DDBD), (adapted from Priestley et al., 2007).

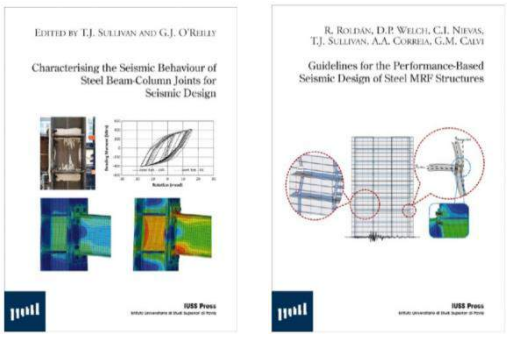

Fig. 2 Publications by the IUSS press disseminating the research result.

Environmentally-friendly solutions for Concrete with Recycled and natural components | EnCoRe

Financing Institution(s): FP7-PEOPLE-2011-IRSES

Promoting Institution(s): Università degli Studi di Salerno (UNISA) - Italy

Coordinator(s): Joaquim Barros (at UMinho)

Researchers and collaborators: Joaquim A.O. Barros, J.M. Sena-Cruz, M.Â.D. Azenha, M. Isabel B. Valente, Mário Coelho, Zia Zamanzadeh, Cristina Frazão

Partner Institutions: University of Minho (UMINHO); Politecnico di Milano (POLIMI); University of Buenos Aires (UBA); University of Tucuman (UNT); Federal University of Rio de Janeiro (UFRJ)

Period: January 2012 to December 2014

Relevant facilities: Laboratory and computational facilities.

Objectives:

The main objective of the present International Cooperation Project dealt with the investigation of the physical, chemical and mechanical performance of concretes made out of recycled and natural components. In particular, UMinho had the responsibility in this project to investigating the physical and mechanical behavior of concrete reinforced with steel fibers obtained from the industry of tyre recycling. To achieve this goal, three main activities were involved: A1) Experimental Work, oriented at building up a shared database of test results, collected from executed experimental tests and scientific works available in the technical literature; A2) Theoretical Modelling, aimed at formulating and calibrating general and accurate theories and models which are able to simulate the mechanical behavior of the recycled steel fiber reinforced concrete (RSFRC); A3) Design Guidelines, aiming to collect and organise the knowledge achieved in the two previous activities to formulate a "model code" for describing production protocols of recycled components and design-oriented rules for employing RSFRC in structural applications.

Description:

The EnCoRe project was conceived to bring together a number of research groups working on the topic of sustainability for the concrete industry. Particularly, it was intended at stimulating the exchange of ideas and experiences on using recycled components (i.e. recycled aggregates and fibers) and naturals ones (i.e. natural fibers and reinforcements) to obtain a greener structural concrete, which represents a new challenge in the field of environmentally-friendly solutions for buildings.

Recycled steel fiber reinforced concrete (RSFRC) appears a promising candidate for both structural and non-structural applications (Fig. 1). The research activities carried out were mainly dedicated to the development of production protocol and design guidelines for the RSFRC.

Fig. 1 Recycled steel fibers extracted from rubber tyres.

The aim of these guidelines was to draw up a document for the design, construction and control of RSFRC structures, representing an aid for all technicians to filter through the large amount of literature currently available. The guidelines developed are composed in three main sections. Section 1 describes the method developed and the materials used in the present work for RSFRC production. Section 2 provides information about material characterization and design approaches for ultimate limit states (ULS). The section 3 addresses the structural design of RSFRC for serviceability limit states (SLS).

Relevant research carried out:

Production protocol of RSFRC

A new methodology was developed for the manufacture of RSFRC.

Three point notched beam tests were carried out in order to characterize the post-cracking flexural tensile behavior of RSFRC (Fig. 2). From these curves the residual flexural tensile strength parameters were determined according to the recommendations of CEB-FIP Model Code 2011 (Table 1). The RSFRC test results are compared with the ones obtained with specimens of concrete reinforced with commercial hooked end steel fibers (ISF) (Fig. 2 and Table 1).

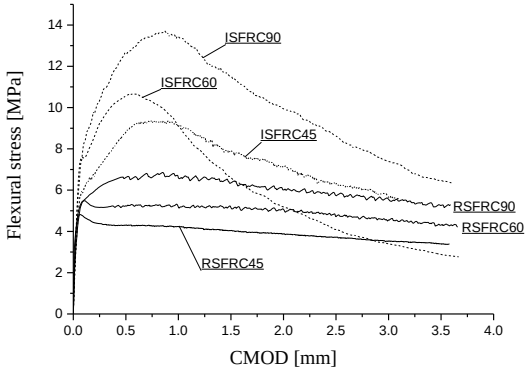

Fig. 2 Flexural behavior of ISFRC and RSFRC (prisms with different content of fibers (45, 60 e 90 kg/m^3).

Based on the obtained $f_{R,j}$, the stress-strain constitutive laws characterizing RSFRC for ULS and for SLS were determined to be used on the design of RSFRC structures. This design was executed by adopting two approaches: analytical model according to CEB-FIP Model Code 2011 recommendations; finite element method (FEM).

	C_f Kg/m^3	$f_{fct,L}$ MPa	$f_{eq,2}$ MPa	$f_{eq,3}$ MPa	$f_{R,1}$ MPa	$f_{R,2}$ MPa	$f_{R,3}$ MPa	$f_{R,4}$ MPa
RSFRC	45	4.74	4.30	3.91	4.16	3.94	3.70	3.43
	60	5.01	5.39	5.09	5.36	5.18	4.87	4.41
	90	4.56	6.78	6.35	6.63	6.57	5.91	5.56
ISFRC	45	5.15	8.66	7.87	8.61	8.37	6.83	5.64
	60	6.62	10.49	7.25	10.43	7.40	4.87	3.40
	90	5.99	12.76	11.31	12.38	12.01	9.71	7.39

Table 1 Post-cracking behavior of RSFRC and ISFRC.

Constitutive laws

Two simplified stress-crack opening constitutive laws were deduced from the bending test results: a plastic rigid behavior or a linear post cracking behavior (hardening or softening) as schematically shown in Fig. 3, where f_{Fts} represents the serviceability residual strength, defined as the post-cracking strength for serviceability crack openings, and f_{Ftu} represents the ultimate residual strength.

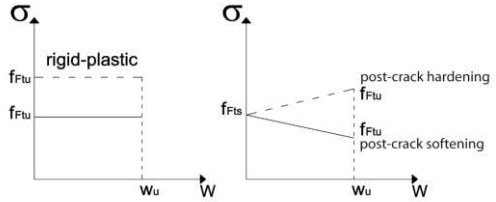

Fig. 3 - Simplified post-cracking constitutive laws: stress-crack opening.

Design approaches

Inverse analysis

Applying the inverse analysis to the Force-CMOD obtained in the three point notched beam bending tests, the stress-crack width will be obtained, which will be used as the fracture mode I crack propagation in FEM-based approaches, simulated by the trilinear softening diagram represented in Fig. 4.

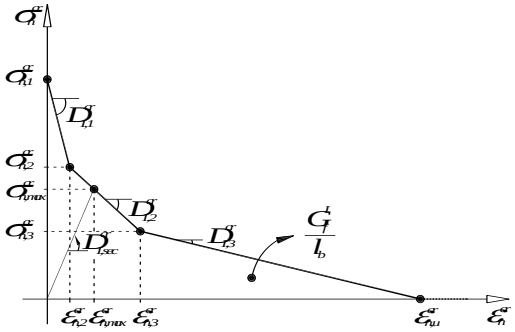

Fig. 4 Trilinear stress-strain diagram to simulate the fracture mode I crack propagation.

Yield line theory

An approach was proposed to evaluate the load carrying capacity of RSFRC slab, based on yield line theory. Two approaches were presented for the evaluation of the resisting plastic bending moment of a RSFRC slab's cross section, one based on a closed form-solution to determine the moment-curvature relationship of a cross section, and the other based on the experimental results derived from round panel tests.

FEM approaches

Under the framework of finite element material nonlinear analysis, smeared crack models have high potential to predict with good accuracy the behavior of RSFRC structures up to their failure capacity.

A shear softening constitutive law implemented in the FEMIX computer program was demonstrated capable of simulating the behavior of concrete elements reinforced with commercial and recycled steel fibers failing in shear.

Fig. 5 shows the finite element mesh that is generally used in the inverse analysis corresponding to the three notched beam bending test.

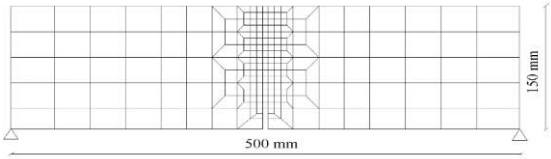

Fig. 5 Finite element mesh adopted in the inverse analysis.

Shear

An experimental program and numerical simulations were carried out in order to estimate the contribution of RSF for the shear resistance of shallow RC beams.
Fig. 6 and 7 present the shear capacity of the tested beams registered experimentally and obtained from numerical simulations.

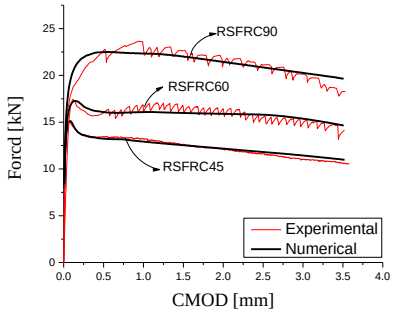

Fig. 6 Average experimental load vs CMOD and numerical load vs CMOD.

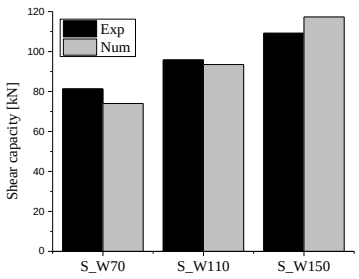

Fig. 7 Comparison of the shear capacity of the RC beams registered experimentally and obtained from numerical simulations.

Publications

Nº of papers in ISI international journals: 1
Nº of papers in international conferences: 4
Nº of technical/scientific reports: 3

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Euro-Latin America partnership in natural risk mitigation and protection of the cultural heritage | ELARCH

Financing Institution(s): The Education, Audiovisual and Culture Executive Agency

Promoting Institution(s): Università degli Studi della Basilicata

Coordinator(s): Michelangelo Laterza

Researchers and collaborators: Paulo Lourenço

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE), University of Minho (UMinho) and 36 other partners from Europe and America

Period: July 2014 to July 2018

Relevant facilities: Not applicable.

Objectives:

Despite the advances of science and technology, natural risks are still resulting in dramatic human and economic consequences in the world's most vulnerable regions for the natural and built environment as well as for the cultural heritage. The capacity to mitigate the impact of risks relies on implementation of research and technology results into policy. Mitigation practices are more effective if incorporated into academic research and higher education curricula in an international and global context, representing an important opportunity for promoting innovation, creation of new jobs, international cooperation and dialogue.

The objective of this project is to establish higher education cooperation between institutions across Europe and Latin America, through academic mobility measures in natural risk reduction and preservation of the cultural heritage. Researchers, future policy makers and practitioners will strengthen their curricula in architecture, engineering, geological sciences, environmental sciences, management and planning, etc. Specific educational and interdisciplinary research activities will focus on innovative practices in: conservation of the cultural heritage, life-cycle analysis and resilient/sustainable design, health monitoring and diagnostics, seismology, experimental studies, social/economic impact evaluation, disaster and asset management, national and international policy. Cooperation will take place between universities and research centres active in protection of the cultural heritage, environmental risk mitigation and training. Mobility will involve 36 Undergrads, 32 Masters, 23 PhDs, 17 Post-Docs, and 11 Staff. Universities, NGOs, Industry and Philanthropy groups, local and International Authorities will develop a human resources infrastructure incorporating credit recognition, joint degrees, UNESCO chair charters, innovative E-learning platforms, field case-study laboratories, cultural policy strategies, social and cultural inclusion.

Description:

Threats are significant in the world's most vulnerable regions for the natural and built environment as well as for the cultural heritage. Successful experiences have shown that a country's capacity to manage and mitigate the impact of natural risks relies on implementation of research and innovation results into policy. In the field of disaster risk management and protection of the cultural heritage, it is well known how international best practices are more effective if strongly linked to professional curricula. This project gives the chance to effectively incorporate successful mitigation practices and approaches based on ICT into academic research and higher education curricula in an international and global context. This can contribute to reduce the gap between advanced and less developed regions and this represents also an important opportunity for promoting innovation and creation of new jobs, as well as international cooperation and dialogue.

The proposal presented by this partnership focuses on the promotion of cooperation and on the enhancing of a mutual recognition between European and Latin American (LA), in particular through a transfer of know-how and good practices in the field of student and academic staff mobility. Science and Technology as a tool for risk prevention, protection of the cultural heritage and ultimately peace negotiation have been chosen as core subject by most of the partners. Therefore a higher share of the scholarships will be assigned to applicants that demonstrate a sound commitment to have an impact in the following fields: Conservation and Protection of the Cultural Heritage, Architecture, Urban Planning, Management Sciences, Earthquake Engineering, Hydrology, Tsunami, Flood and Drought hazard mitigation, and in general risk management, etc. The comprehensive mix of skills and scientific expertise needed to address these issues at a global level, allows the partnership to cover most of the thematic fields, while keeping a desired core focus on science, engineering, architecture, geology, computer science and business/management. This will be done drawing the mobility flows from and towards an interdisciplinary system of established academic programs and excellences at different divisions: undergraduate programmes, masters programmes, doctoral schools, departments and research centres.

Latin America has been undergoing an important transformation for some decades. Education has played a key role in the steady development of the region, and levels of participation in higher education have increased significantly over the past 40 years. Studies and projections indicate that by 2035 the region will have about 60 million enrolments in higher education and that it will have the third most enrolments in the world. A group of countries stands out from the rest in the region as these countries are performing relatively well on a number of indicators, and their higher education national systems are more advanced. Another group of countries is behind the standouts of the region, but these countries are

relatively small in terms of population and economy, or their national systems are still undergoing transformation. However these could be considered over the medium to long term as emerging markets for tertiary education. Most Central American countries are yet to undergo the transformative process that should put them in a competitive position in the region.

This proposal targets all Latin America (LA) and three Countries of Central America, under a particular set of thematic fields and expertise that are relevant to natural risk mitigation, disaster management and preservation of the cultural heritage and landmarks. Under these thematic fields the target groups are treated under the double perspective of contribution to development cooperation ad of promotion of excellence and innovation.

The objective is to develop professional and academic/research curricula in engineering, architecture, business, computer science, geological, natural and social sciences, public policy, etc. The proposal targets EU Undergraduate and Masters programmes that have a strategy of internationalization, and therefore are good platforms for receiving students and allocating incoming teaching academic staff, and will increase the success of the EU-LA mobility. In the doctoral divisions, and under the same thematic fields, the objective is to provide excellence training and innovative knowledge tools for capacity building in risk mitigation, and to establish research cooperation among departments and research centres. The proposal targets different doctoral schools, some with already ongoing dual degree processes. The medium term objective is to establish joint research projects, and to allocate the project mobilities as human resources. Ongoing research cooperation can continue and be strengthened through research postdocs. Academic staff exchange will be incorporated into to training courses, to exchange best practices in teaching and carry a perspective of development cooperation consistent with the needs of the home institutions.

The European Commission point out that "although the Latin American region is extremely rich in natural resources and biodiversity, its environment is under threat from rampant urbanization, deforestation with the attendant harmful consequences and natural hazards, which mainly affect the poorest sections of the population".
The "Latin America and the Caribbean Region is exposed to a wide variety of natural hazards including earthquakes, volcanoes, storms, extreme temperatures, droughts, floods, landslides, etc., many of which are regularly aggravated by the recurrent El Niño/ENSO phenomenon. The global trend toward increasing climate variability is likely to exacerbate many of these hazards. The World Bank Natural Disaster Hotspots study indicates that seven among the world's top 15 countries exposed to three or more hazards are located in Latin America and the Caribbean. Similarly, 15 among the world's top 60 countries exposed to two or more hazards are Latin America and Caribbean countries." (The World Bank, Disaster Risk Management in Latin America and the Caribbean Region: GFDRR Country Notes).

Partner countries also host a large part of the World's population and large portions of their territories are prone to destructive disasters and host significant historical and architectural landmarks. In many areas the recurrence and increasing strength of disasters impairs their economic and social development. Both the Caribbean side and the American portion of the so-called "Pacific Ring of Fire" are exposed to some of the world's highest seismicity, and produced a large number of destructive events from the Pacific Coast of America from southern Chile to Alaska, with the active zones and a high potential to trigger devastating tsunamis and landslides. The inner areas are prone to landslides, and the unregulated urbanization makes large portion of the population exposed to risk. The territory is also home to a vast portion of the World's UNESCO cultural and natural heritage sites. The significant inherent richness and the exposure to degradation and hazard, makes the preservation of the natural and built environment a challenge, but at the same time an opportunity for promoting prevention activities based on innovation and to exploit economy and tourism.

Based on these general premises, the partnership gathered consensus around the idea to create a thematic partnership under a technical field. This stems from an academic policy analysis context, where the job market requires stronger curricula in these disciplines.

Fig. 1 Mobility flow in network.

Fig. 2 Kick-off meeting in Matera, Italy.

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European master on Sustainable Construction under natural Hazards and Catastrophic Events | ERASMUS MUNDUS SUSCOS

(Project EACEA – 520121-1-2011-1- CZ ERA_MUNDUS-EMMC)

Financing Institution(s): European Commission

Promoting Institution(s): University of Coimbra

Coordinator(s): Luis Simões da Silva (UCoimbra)

Researchers and collaborators: Luís Simões da Silva, Aldina Santiago, Carlos Rebelo, Helena Gervásio, Paulo Santos, Sandra Jordão, Rui Simões, Liliana Marques, Luís Borges, Maria Constança rigueiro,Tiago Abecasis (only UCoimbra researchers listed)

Partner Institutions: Czech Technical University (CZ); Technical University of Lulea, Lulea, Sweden; University "Politechnica" Timisoara, Romania; University of Liège, Liège, Belgium; University of Naples "Federico II", Naples, Italy

Period: September 2012 to August 2017

Relevant facilities: Laboratory facilities: strong floors and reaction walls; several universal hydraulic tension-compression load frames, servo-controlled actuators and data acquisition and control equipment; climatic chambers; heating equipments;diverse day-to-day laboratory equipment; Computational facilities: advanced FE numerical tools.

Objectives:

The focus of master course SUSCOS_M is to provide attendees the engineering ability and know-how to design and construct structures in a balanced approach between economic, environmental and social aspects, enhancing the sustainability and competitiveness of the steel industry. The course is organized in three modules covering buildings; bridges and energy-related infra-structures from concrete, steel, timber, and composite structures with a practice oriented approach. The degree awarded is a Master Degree, provided as a multiple diploma.

Description:

SUSCOS is an advanced postgraduate program in Sustainable Steel Construction led by an international consortium of universities. The consortium comprises the 6 following universities: University of Coimbra, Portugal; University of Liège, Belgium; Czech Technical University at Prague, Czech Republic; Technical University of Lulea, Sweden, University "Politehnica" of Timisoara, Romania and University of Naples "Federico II", Italy. The 1st semester ,course component of SUSCOS MSc takes place at the University of Coimbra, The 2nd semester take place at Prague. The MSc thesis can be developed at any of the partner universities. The successful conclusion of the MSc programmmes leads to the award of the following diplomas: Master Degree provided as a multiple diploma.

Education programme:

The MSc has a duration of 18 months (90 ECTS) organized in 3 modules.
The courses are lectured in English by academics from all partner institutions and invited teachers from associated members.

List of Subjects:

First semester
1C1 Design of sustainable constructions
1C2 Conceptual design of buildings
1C3 Conceptual design of bridges
1C4 Local culture and language
1E5 Advanced design of glass structures
1E7 Rehabilitation and maintenance of structures
2E12 Design for renewable energy systems

Second semester
1E6 Advanced design of timber structures
2C8 Advanced design of steel end composite structures
2C9 Design for seismic and climate changes
2C10 Design for fire and robustness
2C11 Business economics and entrepreneurship
2E14 Design of aluminium and stainless steel structures

Third semester
3C12 Theses

Mobility plan: Edition 2012-2014/2013-2015/2014-2016:

First semester Courses, 30 ECTS- University of Coimbra/ University of Liège/ Lulea University of Technology/
Second semester Courses, 30 ECTS - Czech Technical University in Prague/ University of Timisoara/ Univeristy of Naples "Federico II".
Third semester, Thesis, 30 ECTS - Czech Technical University in Prague, University of Coimbra, Lulea University of Technology, University of Liège, "Politehnica" University of Timisoara, Univeristy of Naples "Federico II".

Web site: http://steel.fsv.cvut.cz/suscos

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Fig. 1 Origin of SUSCOS students.

European Masters in Structural Analysis of Monuments and Historical Constructions | SAHC

Financing Institution(s): European Commission

Promoting Institution(s): University of Minho

Coordinator(s): Paulo B. Lourenço (UMinho)

Researchers and collaborators: Paulo B. Lourenço, Daniel V. Oliveira, Graça Vasconcelos, Luís Ramos, Jorge Branco, José Sena, Isabel Valente (only UMinho researchers listed)

Partner Institutions: Czech Technical University (CZ), University of Padova (IT), Technical University of Catalonia (ES), Institute of Theoretical and Applied Mechanics (CZ)

Period: September 2007 to July 2017

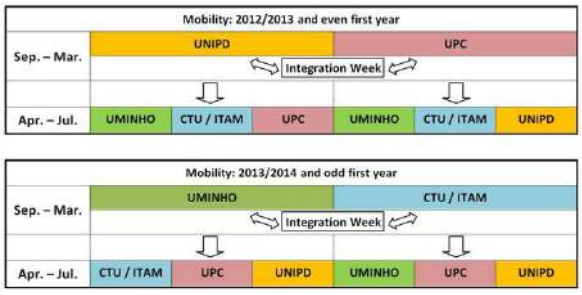
Relevant facilities: Laboratory facilities: strong floors and reaction walls; several universal hydraulic tension-compression load frames, closed-loop servo-controlled actuators and data acquisition and control equipment; climatic chambers; diverse day-to-day laboratory equipment - Computational facilities: advanced FE numerical tools.

Objectives:

The objective of SAHC is to offer an advanced education programme on the engineering of conservation of structures, with a focus on architectural heritage. The Master combines the diversity of expertise at leading European universities in the field, offering education oriented to a multidisciplinary understanding of structural conservation through the involvement of experts from complementary fields (engineers, architects, materials scientists and others). Students face top level structural analysis knowledge in a research oriented environment, with close cooperation with the industry and a focus on problem solving.

Description:

The SAHC programme has duration of one academic year (60 ECTS credits) and is held on a rotating basis among partners. Coursework (September - March) is concentrated in two countries each year and dissertation work (April - July) is divided by all involved institutions. For 2014/2015 and even years, the coursework will be held in Italy and Spain. For 2015/2016 and odd years, the coursework will be held in Portugal and Czech Republic. Dissertation can be performed in any of the involved institutions.



The study programme is composed of eight units, with six sequential units, one unit project-based and one dissertation. The units are as follows:

SA1: History of Construction and of Conservation
SA2: Structural Analysis Techniques
SA3: Seismic Behaviour and Structural Dynamics
SA4: Inspection and Diagnosis
SA5: Repairing and Strengthening Techniques
SA6: Restoration and Conservation of Materials
SA7: Integrated Project
SA8: Dissertation

Units SA1 to SA6 are arranged as a mix of theory and application, in a context of a project-led education. Lectures are held from 9:30h to 12:30h and individual/group work is carried out at University from 14:00h to 19:00h.
The Integrated Project is s truly project-based course, includes a mini group project to solve a real engineering problem, with site visits.
The Dissertation aims at developing research and/or professional competences in the field of conservation and restoration of architectural heritage structures.

Three types of scholarships are made available. Category A scholarships (24,000 Euro) are available to third-country applicants. Category B scholarships (10,000 Euro) are available to students not eligible to the category A scholarship. Category A and category B scholarships are directly sponsored by the European Commission, under the scope of Erasmus+ Programme. Also, a number of Consortium scholarships are planned for students from any geographical origin. These scholarships are financed by the SAHC Consortium

The degree awarded is a Master's degree, provided as a double degree from the institutions involved.

At the end of its 7th edition, the SAHC Masters Course has hosted 194 students from 53 countries, from Africa, America, Asia, Australia and Europe.

Publications:

Relevant international journal papers:

Lourenço, P.B., Trujillo, A., Mendes, N., Ramos, L.F. (2012) Seismic performance of the St. George of the Latins church: Lessons learned from studying masonry ruins, Engineering Structures, 40(7), 501-518.

Häßler, D., Barros, J.A.O. (2012) Exploring the possibilities of steel fibre reinforced self-compacting concrete for the flexural strengthening of masonry structural elements, International Journal of Architectural Heritage Conservation, Analysis, and Restoration, 7(1), 26-53.

Ramos, L.F.; Aguilar, R.; Lourenço, P.B.; Moreira, S. (2013) Dynamic Structural Health Monitoring of Saint Torcato Church, Mechanical Systems and Signal Processing, Vol.35 (1 & 2), 1-15.

Ademović, N., Hrasnica, M., Oliveira, D.V. (2013) Pushover analysis and failure pattern of a typical masonry residential building in Bosnia and Herzegovina, Engineering and Structures, 50, 13-29.

Milani G., Esquivel Y., Lourenço P.B., Riveiro B. Oliveira, D.V. (2013) Characterization of the response of quasi-periodic masonry: Geometrical investigation, homogenization and application to the Guimarães castle, Portugal, Engineering Structures, 56, 621-641.

Razavizadeh, A., Ghiassi, B., Oliveira, D.V. (2014) Bond behavior of SRG-strengthened masonry units: testing and numerical modelling, Construction and Building Materials, 64, 387–397.

Relevant international conference papers:

Lourenço, P.B., Filippoupolitis, M., Corallo, C., Mendes, N., Safety assessment of the South oculus, Canterbury cathedral, Proc. 8th Int. Conf. on Structural Analysis of Historical Constructions, DWE, Wroclaw, Poland, October, 15-17, p. 302-310, 2012.

Moreira, S.; Oliveira, D.V.; Ramos, L.F.; Lourenço, P.B.; Fernandes, R.P.; Guerreiro, J., Experimental study on the seismic behavior of masonry wall-to-floor connections, 15th World Conference on Earthquake Engineering, September 24-28, Lisbon, Portugal, 2012.

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Fig. 1 Origin countries of SAHC students.

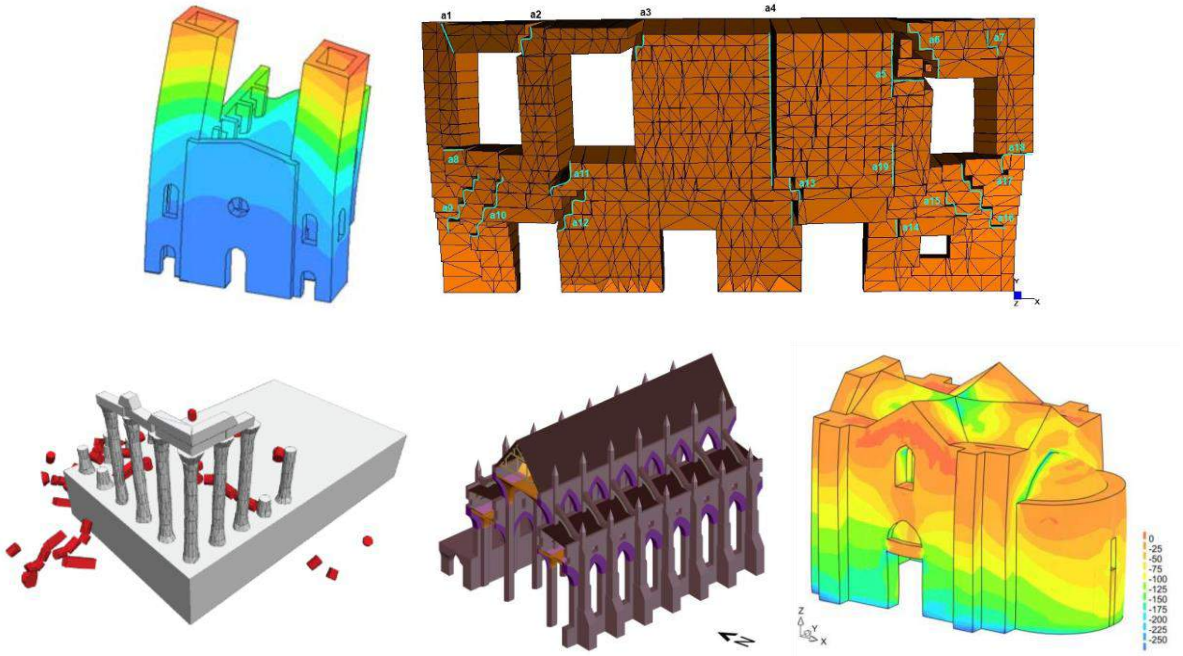

Fig. 2 Some examples of structures studied within the UMinho SAHC theses.

European pre-QUALified steel JOINTS | EQUALJOINTS

Financing Institution(s): Research Fund for Coal and Steel - European Union (EU - RFCS)

Promoting Institution(s): UNIVERSITA DEGLI STUDI DI NAPOLI FEDERICO II, ARCELORMITTAL BELVAL & DIFFERDANGE S.A., CORDIOLI E C SPA*CORDIOLI & C SPA, EUROPEAN CONVENTION FOR CONSTRUCTIONAL STEELWORK, IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE, UNIVERSITE DE LIEGE, UNIVERSIDADE DE COIMBRA, UNIVERSITATEA POLITEHNICA DIN TIMISOARA

Coordinator(s): Raffaele LANDOLFO (UNIVERSITA DEGLI STUDI DI NAPOLI FEDERICO II)

Researchers and collaborators: Raffaele LANDOLFO, Olivier VASSART, Francesco BESANA, Véronique DEHAN, Ahmed ELGHAZOULI, Jean-Pierre JASPART, Luis SIMOES DA SILVA, Carlos REBELO, Ashkan SHAHBAZIAN, Filippo GENTILI, Trayana TANKOVA, Dan DUBINA

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE)

Period: 07/2013 to 06/2016

Relevant facilities: Computing cluster

Objectives:
The main aim of this project is to introduce in the European practice a qualification procedure for the design of moment resisting connection in seismic resistant steel frames, in compliance with EN1998-1 requirements. Further aims of the project are to qualify a set of standard for all-steel beam-to-column joints, and to develop prequalification charts and design tools that can be easily used by designers. The project is also intended as a pre-normative research aimed at proposing relevant design criteria to be included in the next version of EN 1998-1. Besides it would contribute to the advancement of knowledge in the field of seismic behaviour of steel moment resisting joints usually adopted in moment resisting frames (MR), in unbraced bays of dual moment-resisting/concentrically braced frames (MR+CB) and in moment-resisting/eccentrically-braced frames (MR+EB).

Description:
The cyclic behaviour of beam-to-column joints has a crucial role on the overall seismic response of both MR and dual frames. Recent studies highlighted the influence of joint rotation capacity on the seismic response of mid-rise MR frames designed according to EN 1998-1-1. As for dissipative zones, EN 1998 allows the formation of plastic hinges in the connections in case of partial-strength and/or semi-rigid joints, provided that the following requirements are verified: i) the connections have a rotation capacity consistent with the global deformations; ii) members framing into the connections are demonstrated to be stable at the ultimate limit state (ULS); iii) the effect of connection deformation on global drift is taken into account using nonlinear static global analysis or non-linear time history analysis. At the present time, EN 1993-1-8 provides models to compute the strength and the stiffness of connections but no reliable analytical tools are available to predict the rotation capacity and the cyclic performance in relation to the connection typology. EN 1998-1 requires design supported by specific experimental testing, resulting in impractical solutions within the typical time and budget constraints of real-life projects. As an alternative to design supported by testing, the code prescribes to find existing data on experimental tests performed on similar connections in the literature. It is clear that this procedure is unfeasible from the designer's point of view. On the other hand, although EN 1993-1-8 provides rules for full-strength joints, it is necessary to guarantee that these joints could have flexural overstrength larger than the beams which are connected, with plastic hinge located at the end of beams. As a matter of fact, due to the variability of steel strength and to the actual post-yield flexural overstrength of steel beams, these connections could not have enough overstrength. Indeed, the minimum joint extra-strength required by EN 1998 is 1.1x1.25 Mb.rd (being Mb,rd the beam plastic moment) could be largely overcome in many cases. In addition, it is necessary to give effective rules to control the column web panel. In fact, in non – dissipative joints the web should behave elastically, while in those dissipative web contribution to total plastic joint rotation should be under 30%. Hence, in such cases plastic rotation capacity must be prequalified by tests and numerically based procedures. In contrast to current European design methodology, the approach used in other countries with high seismic hazard is based on codified and easy-to-use design tools and procedures. In particular, following the widespread damages observed after Northridge and Kobe earthquakes, North American practice was directed at prequalifying standard joints for seismic resistance. The design approach based on prequalification would certainly be of interest for the European industry, especially if the spin-offs related to the use of simple and reliable design tools are considered. A number of European research projects have been carried out in the past aimed at investigating the effects of previous issues on the behaviour of steel joints, but none was devoted to the prequalification process of selected connections. Of course, the existing database of experimental results (i.e. SERICON and RECOS) represents an important starting point to deepen and examine the open issues affecting the seismic behaviour of connections, which are: Effect of different steel grades of beams and columns on connection performance; The influence of stress concentration in the welds on the low cycle fatigue; Role of panel zone yielding in shear on the connection behaviour; Geometric parameters of the connection including beam depth, flange size and weld size; Strain rate and dynamic effects; Load and deformation history. All the previous parameters affect the yield mechanisms and failure modes which are the factors controlling both the resistance and ductility or rotational capacity of the connection. The prediction of yield mechanisms, failure modes, and the resistance associated with them are far from being understood. This is a crucial

issue to be deepened to rationally use each connection type in seismic design. Following the previous considerations, it is proposed to develop a guide for the design of the connections specifically for the European market, including design rules and detailing. In line with the US practice, this project will provide an operative tool for the design of typical beam-to-column connections adopted in Europe. In such a way, designers can directly use pre-qualified connections without performing experimental test and/or literature reviews as long as the connection design, detailing and quality assurance measures are covered by the prequalification process.
Pre-qualified connections will simplify the design and certification because: (i) designers do not have to perform and present test data; (ii) the responsible authority does not have to carry out the conformity assessment each time a design includes such joints.

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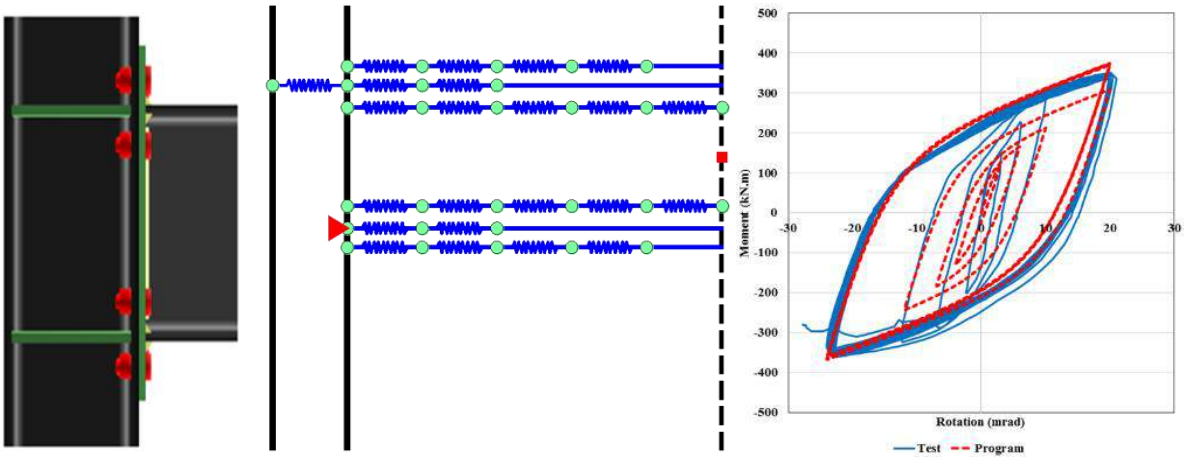

Fig. 1 Cyclic component-based method.

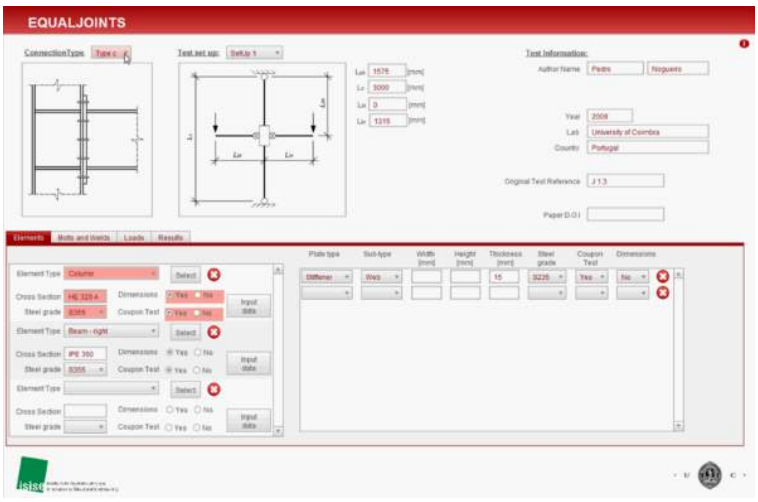

Fig. 2 Database.

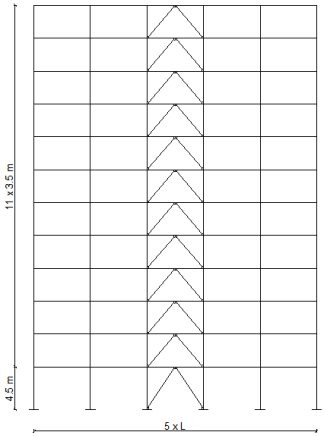

Fig. 3 CBFs pushover analysis.

Fibre Reinforced Concrete of Enhanced Properties of Durability for Urban Furniture and Infra-Structures | UrbanCrete

Financing Institution(s): ADI

Promoting Institution(s): Francisco Pereira Marinho & Irmãos, S.A.

Coordinator(s): António Marinho

Researchers and collaborators: Joaquim Barros, José Sena-Cruz, Salvador Dias, Eduardo Pereira, Miguel Azenha, Isabel Valente, António Matos, Marco Jorge, Christoph de Sousa, Mónica Vera, Fatemah Soltanzadeh, Esmaeel Esmaeeli

Partner Institutions: University of Minho (ISISE)

Period: 01/04/2014 to 31/06/2015

Relevant facilities: Laboratory equipment and computational facilities of Civil Engineering Department of UMinho

Objectives:

It is well known that the longevity and life cycle of urban furniture made of conventional reinforced concrete situated in coastal areas is especially low due to the corrosion that affects the reinforcing steel embedded in the concrete elements. In this research project, the main goal is to develop urban furniture through the use of concrete reinforced with non-metallic fibres, which leads to the total absence of steel elements, thus eliminating the referred degradation process. Besides, the self-compacting nature of the developed fibre reinforced concrete, the reduced dimensions of its aggregates and the inclusion of synthetic fibres as discrete reinforcement results in a composite material particularly adequate for urban furniture, allowing the possibility of satisfying different architectural demands, such as the appearance of the finished surface, the smoothness of the edges and the overall capability of adopting complex and/or slender geometries while effectively meeting the required structural demands. Apart from urban furniture, another goal of the project UrbanCrete is the development of infra-structures, namely manhole covers, using high performance fibre reinforced concrete (HPFRC). Manhole covers, which are typically made of steel, have been a subject of theft all over the world and particularly in Portugal, causing undesirable expenses to municipalities and endangering residents. The development of manhole covers through HPFRC aims to offer an alternative to municipalities for combating the manhole cover theft phenomenon.

Description:

The project UrbanCrete, which deals with the development of urban furniture and infra-structures using an innovative fibre reinforced concrete, initiated with a literature review that was complemented by a market research in order to gather information about competing products. In addition, the composition of the fibre reinforced concrete was studied, with selection of the most suitable constituents (namely the fibres and aggregates) and the necessary material properties where defined based on technical requirements found on standards and recommendations and by conducting numerical simulations through finite element analyses.

During the optimization of the concrete composition, special attention was dedicated to the rheological properties of the concrete and to the quality control of its surface, which are both very important requirements for the development of urban furniture, due to the need of perfect adjustment to the forms of any possible moulds during casting (different design proposals were analysed for the development of urban furniture), while maintaining the smoothness of all surfaces (avoiding the appearance of bubbles in the concrete surface).

After the analysis of several design proposals for urban furniture, some of the proposed geometrical configurations where slightly changed due to a process of structural optimization, which was conducted with recourse to numerical simulations through the software FEMIX, which was complemented by the software GiD for mesh generation (see Fig.1). The structural optimization led to the final geometrical configuration of a chair, which is currently being studied in the scope of this project. Taking into consideration the need for aesthetical quality control during casting and the necessity of producing reusable moulds (for this type of application, the same mould might be adopted during several urban furniture production processes), an important task of this project had to do with the increase of knowledge regarding the development of moulds. For the conception of the above-mentioned chair, an acrylic mould was developed (see Fig. 2), which due to its transparency allowed constant visual inspections for quality control during casting. Figure 3 illustrates the final aspect of the developed chair, which is currently being subjected to an experimental program for final evaluation of its technical properties (strength, durability, fatigue and stability requirements).

In parallel with the aforementioned research work, manhole cover prototypes using HPFRC combined with different reinforcing systems where developed and experimental research is now under course for assessment of their relevant mechanical properties. The biggest challenge concerning the development of manhole covers consists on meeting the loading requirements for vehicular areas defined according to European Standards (Class D-400). Compliance with the loading requirements is determined by a loading test (as depicted in Fig. 4), where in this particular case (Class D-400, for vehicular areas) the manhole cover need to sustain a maximum load of 400kN. Different types of infra-structures are being developed: manhole covers and grids (see numerical simulations in Fig.5), with round and square configuration. Preliminary results for different manhole cover prototypes are shown in Fig. 6.

Publications:

Nº of papers in ISI international journals: -
Nº of papers in non ISI international journals: -
Nº of papers in national journals: -
Nº of papers in international conferences: 2
Nº of papers in National conferences: -
PhD Thesis: -
MSD Thesis: -
Nº of technical/scientific reports: 7
Patents: -

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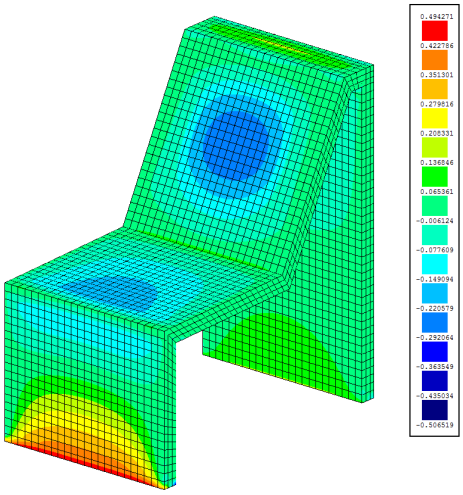


Fig. 1 Modelling the structural behaviour of urban furniture.

Fig. 2 Acrylic mould used during the casting process of a chair.

Fig. 3 Final aspect of the first urban furniture prototype.

Fig. 4 Preliminary results of loading test on manhole cover prototypes.

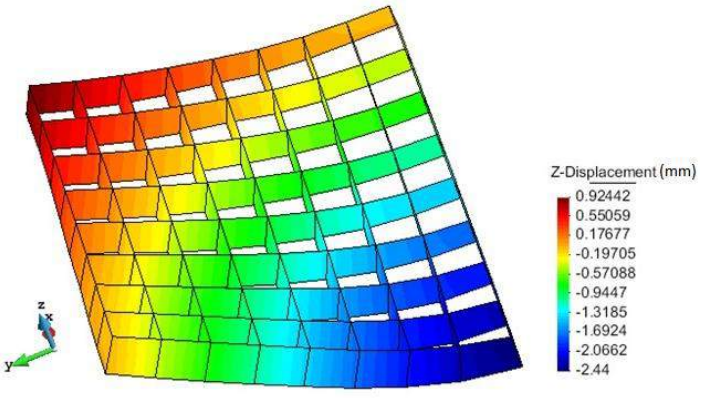


Fig. 5 Numerical simulation of a GFRP grid.

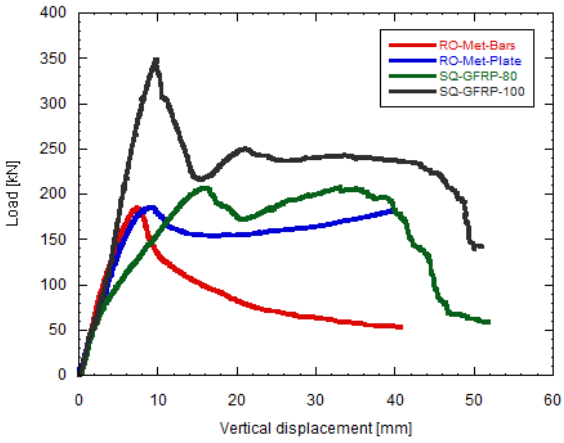


Fig. 6 Preliminary results of loading test on manhole cover prototypes.

FireLab

Financing Institution(s): QREN

Promoting Institution(s): University of Coimbra

Coordinator(s): Luís Simões da Silva

Partner Institutions: This project was co-financed by QREN, under the Programa Mais Centro and the European Union through the European Regional Development Fund.

Period: 2014

Relevant facilities: Department of Civil Engineering, University of Coimbra.

Objectives:

The objective of this project is the creation of a laboratory in the area of reaction to fire and fire resistance, which provides services in all areas of engineering and fire safety.
FireLab - Fire Engineering Laboratory of the University of Coimbra - is a center of excellence targeted towards providing services to companies, advanced technical training, consulting, research and development in fire safety, supported by the expertise of the ISISE research center. The FireLab performs certification of materials and construction solutions, in accordance with the relevant standards. The FireLab is equipped with the most modern equipment to address multiple aspects, such as detection systems, fire extinguishing systems, smoke control, fire hazard, organization and safety management, design of steel structures subjected to fire, etc.

Description:

This project intends to buy new equipment's and upgrade the laboratory spaces of the Department of Civil Engineering, University of Coimbra. Table 1 summarize the equipment's purchased. A description of the equipment's is presented next.

Table 1 – New equipment's

Equip. N.º	Description
E1	Flooring Radiant Panel
E2	Small Ignition
E3	Non-combustibility
E4	Bomb Calorimeter
E5	Thermal Conductivity Measurements
E6	2000 KN Actuator System - Double Acting
E7	High pressure hydraulic closed load control unit for actuators
E8	Thermographic Cameras
E9	High Speed Camera
E10	Data Acquisition Systems
E11	Air compressor
E12	FireFurnace building
E13	Gas furnaces system – Vertical Furnace
E14	Gas furnaces system – Horizontal Furnace
E15	Servo-hydraulic Dynamic Testing Machine – 600 KN
E16	Compression Testing Machine
E17	Furnace chamber to measure mechanical and thermal properties of materials at high temperature
E18	Electric Forklift
E19	Single Burning Item
E20	Hot Box

E1 - Flooring Radiant Panel

For measure the spread of flame of the product under thermal exposure. It is relevant to classification of the flooring material into classes A2fl, Bfl, Ffl and Dfl.
Main tests:

• Observed distance of flame spread v. Time, used to determine the critical flux at extinguishment;
• Chamber, Stack and radiant panel surface temperature;
• Heat flux profile curve;
• Smoke density v. time;

E2 - Small Ignition

This equipment is used to conduct the Eurolass test that measures the ignitability of a product when it is subjected to direct impingement of a small flame. It is relevant to the classification of a product into classes B, Bfl, C, Cfl, E and Efl for all building materials.

E3 - Non-combustibility

This test specifies the procedure for determining whether or not a product will contribute directly to the fire development. It is relevant to classification of all building products (including floorings) into classes A1, A2 and A1fl and A2fl.

E4 - Bomb Calorimeter

This equipment gives the reaction to fire for building products and measures the gross calorific value of a sample. It is relevant to material classes A and B.

E5 - Thermal Conductivity Measurements

This equipment allows to simultaneously determine thermal conductivity, thermal diffusivity and specific heat capacity from a single measurement.

E6 - Actuator System - Double Acting

For static and dynamic testing of components and structures.
Technical Data:
• Compression capacity: 2000 KN (at 250 bar);
• Tension capacity: 1000 KN (at 250 bar).

E7 - High pressure hydraulic closed load control unit for actuators

Contains 4 signal conditioners for:
• force or pressure transducer strain gauge type;
• displacement transducer LVDT or resistive type;
• deformation transducer strain gauge, LVDT'S.

E8 - Thermographic Cameras

Two thermal imaging cameras with a temperature range of -40 ºC to +2000 ºC.
Technical Data:
• IR resolution: 640 x 480 pixels;
• Image frequency: 25 Hz.

E9 - High Speed Camera

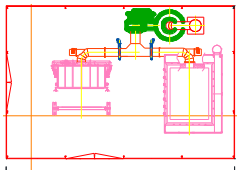
Provide 1,280 by 1,024 pixel resolution to 4,000 frames per second (fps) and reduced resolution operation all the way to 800,000 fps, with 1,280(H) by 720 (V), equivalent to 720 HD video resolution, to 6,400 fps.

E10 - Data Acquisition Systems

• 8-channel universal data logger;
• K thermocouples data logger, with 16-channels;
• Strain gauge bridge amplifier;
• Inductive displacement transducer;
• Precise load cell for tensile and compressive forces with high and dynamic oscillation width, 500 kN;
• Load cell with high nominal rated forces, for the measurement of static and dynamic pressure forces, 2MN.

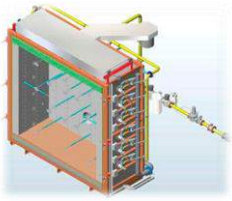
E11 - Air Compressor

For the pneumatic air tools and laboratory equipment's

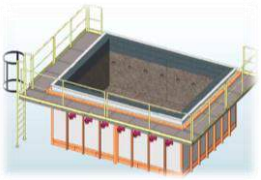


E12 - FireFurnace building
To place the furnaces.

E13/E14 - Gas furnaces system



Vertical furnace:
• Internal dimensions: 3 100 (width) x 3 100 (height) x 1 500 (length) [mm];
• Installed thermal power: 2 064 000 kcal/h;
• Maximum service temperature: 1 200ºC.



Horizontal furnace:
• Internal dimensions: 3 050 (width) x 1 500 (height) x 4 050 (length) [mm];
• Installed thermal power: 2 408 000 kcal/h;
• Maximum service temperature: 1 350ºC.

E15 - Servo-hydraulic Dynamic Testing Machine
Technical Data:
• Max. test load ± 600 KN;
• Accuracy class 0.02;
• Reproducibility error ±0.003%.

E16 - Compression Testing Machine

Technical Data:
• Test force 3000 KN;
• Ram travel 100 mm;
• Test chamber height 1000 mm.
Main tests:
• Concrete According NP EN 12390; NP EN 12504;
• Elastic modulus calculation;
• Bending tests.

E17 – Electric furnace

To measure mechanical and thermal properties of materials at high temperature, on steady and transient sate.

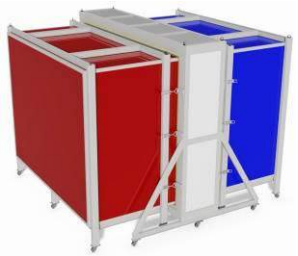
E18 - Forklift

Technical Data:
• Lift Capacity: 3000 kg
• Max lift height: 6 000 mm
• Energy: Electric
• Engine Power: 11 KW

E19 - Single Burning Item

The Single Burning Item (SBI), is a method of test for determining the reaction to fire behaviour of building products (excluding floorings) when exposed to the thermal attack by a single burning item.

E20 - Hot Box



The guarded hot box apparatus is used for determining the steady-state thermal transmittance and thermal conductance of construction elements.

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Flat slabs for multi-storey buildings using hybrid reinforced self-compacting concrete: an innovative structural system | SlabSys-HFRC

Financing Institution(s): FCT

Promoting Institution(s): University of Minho (UM)

Coordinator(s): Vítor Manuel do Couto Fernandes da Cunha

Researchers and collaborators: Joaquim Barros, Amin Abrishambaf, António Ventura Gouveia, Eduardo Pereira, Lúcio Lourenço, Bernardo Neto

Partner Institutions: University of Minho (UM), Casais SA., CiviTest Lda.

Period: April 2012 to September 2015

Relevant facilities: Servo close-loop equipments for experimental programs; FEMIX V4.0 Finite Element package

Objectives:
This project aims to contribute for the development of a new generation of flat slabs, for multi-storey buildings, made of hybrid fibre reinforced concrete, by substituting most of the conventional reinforcement of the slab with hybrid discrete fibres, and by using concrete mixes with self-compacting ability. When compared to conventionally reinforced concrete (RC) flat slabs, the proposed structural system should have an enhanced cracking behaviour and flexural stiffness for serviceability limit states, while maintaining a flexural ductile failure mode for ultimate limit states. Also, several benefits are harvested regarding construction times and quality, labour costs, sustainability during construction, cracking behaviour, as well as increased durability.

Description:
In traditional techniques for executing RC flat slabs, placement of reinforcement is one of the most time consuming tasks, which involves a lot of workforce (with frequent occurrence of injuries) and equipment. The replacement of conventional rebar by discrete fibres, with significant benefits in regard to time of construction (and with a competitive price), has been made in many applications of slabs on grade with a quite good performance. Nevertheless, conventional fibre reinforced concrete, FRC, is yet seen suspiciously by the construction professionals. For this, much contributes the high coefficients of variation, CoV, of the material's mechanical strengths. The appearance and dissemination of new advanced cement matrices with self-compacting capability contributed to an increase of the confidence level on these FRC. This confidence step-up, mainly due to lower CoV pushed forward the utilization of self-compacting FRC for slabs suspended on piles (with considerable reduction of rebar). The outcome of FRC with enhanced mechanical strengths has been pushing the span limits upwards.

The main purpose of this research project is to develop a high performance reinforcing system that can be a competitive alternative to conventional RC slabs of multi-storey buildings. The studies to be conducted include the use of hybrid fibre reinforcement with high and low E-modulus fibres. The proposed system also includes the existence of embedded beams (with conventional rebar) in the alignment of the columns, in order to assure increased stiffness and ductility. This will result in a material termed as HFRSCC: Hybrid Fibre Reinforced Self-Compacting Concrete. The research tasks comprised in the project include: i) Development of a HFRSCC mixture; ii) Material characterization of HFRSCC; iii) Assessment of the structural performance of HFRSCC; iv) Quality control and establishment of parameter estimation methodology for design purposes; v) Punching shear behaviour (experimental and numerical research); vi) Construction of a full scale prototype; vii) Guide for construction and design of HFRSCC slabs.

Within structural performance of HFRSCC, punching resistance can be a concern in this structural system. In fact, punching has a brittle failure nature, and the prediction of the punching resistance is still a challenge, even in conventional concrete reinforced slabs. The difficulties on assessing the contribution of the reinforcement mechanisms of steel fibres for the flexural and shear resistance in the critical punching perimeter increase this complexity. In a first stage,
It was aimed to assess the reliability of existing analytical models for the prediction of the punching resistance of SFRC slabs. For this purpose, a comprehensive experimental campaign with SFRC slabs failing in punching was carried out. The predictive performance of analytical models available in literature was assessed. It was developed a more practical model, which is more reliable from a physical and mechanical point of views, therefore in order to accomplish the prior premises, the concepts proposed by Model Code 2010 for the characterization of the post-cracking behaviour of FRC were introduced in the developed model.

Currently, the punching shear behaviour is being modelled by a numerical approach based upon the finite element method, FEM, framework. Regarding the numerical model, a 3D multi-directional fixed smeared crack approach, already implemented in the FEMIX computer program is being used. Within the topic of concrete's fracture process numerical modelling, a significant concern arises about the localization of the inelastic deformation (cracks) in the displacement field. Traditionally there are two main methods to model concrete cracking process, which are: the fracture mechanics and continuum mechanics approaches. In the first one, the formation and propagation of discontinuities is dealt with the introduction of discrete constitutive equations (tractions vs. displacements) at one discontinuity interface (element with zero-thickness) inside an elastic continuum medium. On the other hand, in the continuum approach the inclusion of non-linear constitutive equations (stress-strain) leads to the

strain localization phenomenon. The embedded discontinuity approach congregates the advantages from both abovementioned methods, featuring the use of non-linear local continuum constitutive equations (stress-strain), as well as, a strong discontinuity kinematics, i.e. appearance of jumps in the displacement fields. Since the embedded formulation has already proven to be efficient in a wide range of mechanical problems, it will be implemented in a near future within the FEMIX software platform. Finally, the punching shear behaviour test results will also be modelled with the latter approach.

The construction and evaluation of a full scale prototype is one of the most important outcomes of the present research project, as it will allow: (i) proving that the system actually works at real scale, with satisfactory performance both in terms of service life loads (cracking and deflections) and ultimate limit state loads (load capacity and ductility); (ii) checking the feasibility of the developed analytical and numerical models, used together with the material characterization and the quality control testing; (iii) evaluating the practical feasibility of establishing simplified design guidelines. The full scale prototype will comprise a one-storey building with six columns (3 metres tall) that support two square slab bays with 5m x 5m, and embedded RC beams spanning along column support lines. Meanwhile, in an intermediate research stage, a one fourth scale prototype of an elevated steel fibre reinforced slab structural system was built (Figure 1). The elevated slab, with a length x width x thickness of 3.7x2.1x0.075 m, is supported on 12 columns of square cross section of 0.1 mm edge. The distance between columns in the X and Y directions is 1.2 m and 1.0 m, respectively. The deformational behaviour of the structural prototype was assessed under loading conditions corresponding to serviceability limit states (Figure 1h). Within the second stage of the latter task, the behaviour of this structural system under ultimate limit conditions will be also assessed.

Publications:
One PhD. thesis, five articles in international journals, one article in national journals and five articles in the proceedings of international conferences.

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Fig. 1 The construction suspended slab prototype: (a) preparation of the foundation for the slab on grade; b) Reinforcement of the columns; c) casting the slab on grade (1st batch); d) casting the SFRSCC specimens; e) casting the columns (2nd batch); f) casting the elevated slab; g) general view of the prototype after has construction; h) Water tanks loading corresponding to the serviceability limit states.

High Strength Steel for Wind Turbines | HISTWIN+
(RFSR-CT-2014-00023)

Financing Institution(s): Research Fund for Coal and Steel – European Union (EU – RFCS)

Promoting Institution(s): TU Lullea, Sweden, Univ. Coimbra, Portugal; Univ. Aachen, Germany; Univ. Thessaloniki, Greece; European Convention for Constructional Steel Work (ECCS), Belgium; FOSTA, Germany

Coordinator(s): (Univ. Coimbra, Portugal) Luis Simões da Silva and Carlos Rebelo; (TU Lullea, Sweden) Milan Veljkovik

Researchers and collaborators: (only Univ. Coimbra, Portugal) Luis Simões da Silva, Carlos A. Silva Rebelo, Paulo Pinto, Rui Matos

Period: July 2014 to December 2015

Relevant facilities: (only Univ. Coimbra, Portugal) Structures and Structural Mechanics laboratory.

Objectives:
The HISTWIN project has been recognized as an RFCS success, http://cordis.europa.eu/coal-steelrtd/stories_en.html, due to the introduction of innovative connection details and improved design practices for Steel Wind Towers. The present proposal will make these results known to the community of designers thus facilitating the acceptance of these new concepts to the manufacturing community as well as the regulatory authorities.

Description:
In Work Package 1 "Preparation of Background Material for Workshops", an extensive collection of practical information, including a short background text and numerical examples will be prepared to show the complete structure the design process. From the load analysis to specific details of the tower design will be covered.

The objective of Work Package 2 "Public Access" is to create a "one stop shop" for the steel tower design giving easy access to literature, software and publications within the project. Links to other information relevant for the construction of steel tubular towers for the support of wind energy turbines, will be provided at the web address www.histwin.eu.

The aim of Work Package 3 "Organization of Workshops" is to disseminate the knowledge gained during the course of the HISTWIN-project to designers and practitioners. A detailed explanation of the background material, developed in WP1, and the design tools, developed in WP4, will be given.
Work Package 4 "Tools for Easy Design" has aim to create solutions easy to use in order to make the design procedure of towers for wind turbines more available for wider community of structural engineers. In addition to the development of specific software solutions to facilitate the tower design, an application for use on mobile phones will be programmed.

Publications:

Conference proceedings:

Christine Heistermann, Anh Tuan Tran, Milan Veljkovic & Carlos Rebelo (2014) "Flangeless Connections in Steel Tubular Wind Towers", International Scientific Conference and Workshop "METNET-SPb-2014" Saint-Petersburg, Russian Federation, 17-19 February 2014

Tran A.T., Veljkovic M., Rebelo C., Simoes da Silva L.., (2014) "Influence Of Geometrical Imperfections on Analyses of Door Openings in Tubular Steel Towers For Wind Turbines", Proceedings of the 7th European Conference on Steel and Composite Structures, EUROSTEEL 2014, paper 386, abstract pp., Naples, Italy.

Heistermann C., Pavlović M., Andrade P., Veljković M., Rebelo C., Simões da Silva L., (2014) "Finite Element Analysis of Lap Joints in Steel Tubular Towers", Proceedings of the 7th European Conference on Steel and Composite Structures, EUROSTEEL 2014, paper 352, abstract pp., Naples, Italy.

Matos R., Rebelo C., Simões da Silva L., Veljkovic M.., (2014) "Behavior of Pre-Stressed Bobtail® Bolts: Application in tubular wind towers", Proceedings of the 7th European Conference on Steel and Composite Structures, EUROSTEEL 2014, paper 376, abstract pp., Naples, Italy.

Matos R., Pinto P., Rebelo C., Simões da Silva L., Veljkovic M.., (2015) "Cyclic performance of single and group micropiles on loose sand", Proceedings of the: International Foundations Congress and Equipment Expo IFCEE 2015, March 17-21, San Antonio, Texas, USA.

Matos, R.; Rebelo, C. "Monitorização e avaliação do comportamento de parafusos pré-esforçados BobTail", 9º Congresso Nacional de Mecânica Experimental, Paper 110, 15-17 de Out. Aveiro, Portugal.

Journal articles:

Matos R., Pinto P., Rebelo C., Gervásio H. and Veljkovic M., "Improvement of tubular wind tower foundations using steel micropiles" (under revision in the Structure and Infrastructure Engineering, jan2015)

Matos R, Pinto P.L, Rebelo C., Veljkovic M. and Simões da Silva L. "Laboratory testing of micropiles in loose sand" (under revision in the Canadian Geotechnical Journal)

Marko Pavlović, Christine Heistermann, Milan Veljković, Daniel Pak, Markus Feldmann,Carlos Rebelo,

Luis Simões da Silva, "Connections in towers for wind converters, Part I: Evaluation of down-scaled Experiments" (submitted for publication in the Journal of Constructional Steel Research)

Marko Pavlović, Christine Heistermann, Milan Veljković, Daniel Pak, Markus Feldmann,Carlos Rebelo, Luis Simões da Silva, "Connections in towers for wind converters, Part II: The friction connection behaviour" (submitted for publication in the Journal of Constructional Steel Research)

Marko Pavlović, Christine Heistermann, Milan Veljković, Daniel Pak, Markus Feldmann,Carlos Rebelo, Luis Simões da Silva, "Friction connection vs. ring flange connection in steel towers for wind converters" (submitted for publication in the Eng. Structures)

Christine Heistermann, Marko Pavlović, Milan Veljković, Daniel Pak, Markus Feldmann,Carlos Rebelo, Luis Simões da Silva, "Influence of execution tolerances for friction connectionsin circular and polygonal towers for wind converters" (submitted for publication in the Eng. Structures)

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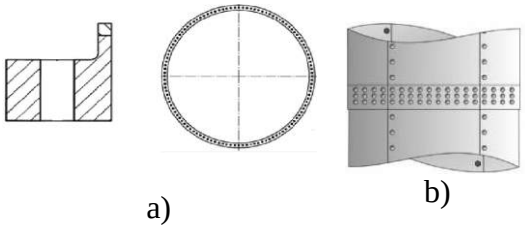

Fig. 1 Tower segment connection. a) flange connection; b) friction connection.

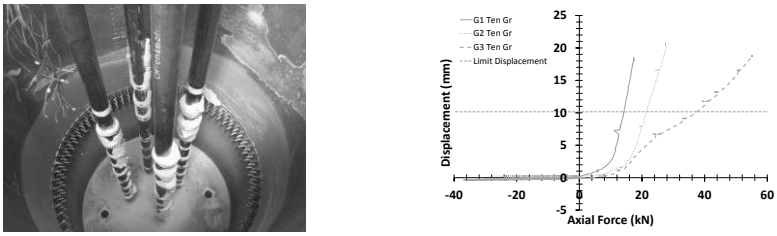

Fig. 2 Micropile experimental tests.

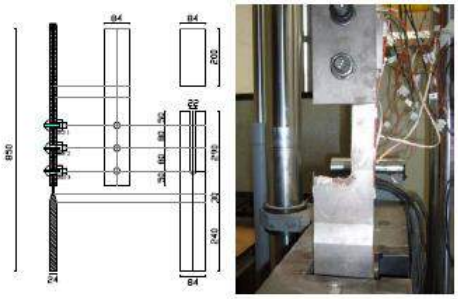

Fig. 3 Friction connection fatigue tests.

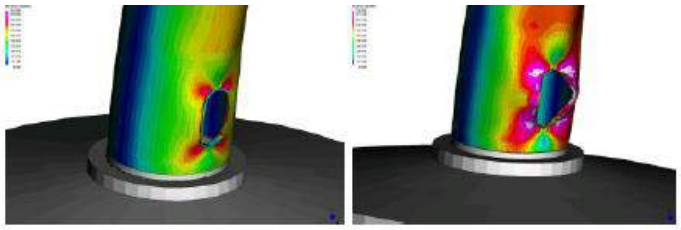

Fig. 4 Door stability.

High Strength Steel for Wind Turbines | HISTWIN2
(RFSR-CT-2010-00031)

Financing Institution(s): Research Fund for Coal and Steel – European Union (EU – RFCS)

Promoting Institution(s): TU Lullea, Sweden, Univ. Coimbra, Portugal; Univ. Aachen, Germany; Univ. Thessaloniki, Greece; Martifer Energia, Portugal; Rautarukki, Finland

Coordinator(s): (Univ. Coimbra, Portugal) Luis Simões da Silva and Carlos Rebelo; (TU Lullea, Sweden) Milan Veljkovik

Researchers and collaborators: (only Univ. Coimbra, Portugal) Luis Simões da Silva, Carlos A. Silva Rebelo, Paulo Pinto, Rui Duarte Simões, Rui Matos

Period: November 2010 to October 2013

Relevant facilities: (only Univ. Coimbra, Portugal) Structures and Structural Mechanics laboratory equipment.

Objectives:
The use of steel tubular towers for larger wind turbines and higher hub-heights is limited by economical and technological barriers in view of recent advances of the concrete industry. In the present project, new solutions for steel and hybrid towers' stability and foundations with micro steel piling will be developed. To achieve this goal, experience from the RFCS project HISTWIN (RFS-PR-05111, 2006-2009) on optimal bolted connection for the particular implementation will be used. Experimental, numerical and analytical study will lead to new market opportunities for tubular towers, where the solution with dominant use of the concrete is competitive nowadays.

Description:
The growth of installed wind farms has been exponential in recent years. Because the availability of sites to install wind farms is limited, economical considerations result in the development of larger wind turbines. Nowadays, all new onshore wind farms have installed turbines that are in the range 2.0-3.5 MW. Also, the use of sites with lower wind potential means that higher towers are required to achieve economically-feasible wind farms.

Larger turbines and higher hub-heights require higher towers. For tower heights in excess of 80 m, recent developments in concrete technology, ENERCON, http://www.enercon.de/ mean that concrete towers are quickly becoming more competitive than steel towers according to National Renewable Energy Laboratory, USA, http://www.nrel.gov/ besides presenting clear technical advantages in terms of their dynamic properties because of increased mass.

Current onshore steel wind towers are limited by the maximum diameter that can be transported. Since welding on site is not an option, there is currently no experience or practical guidelines that allow the transportation of curved steel segments and their subsequent assembly in-situ into conical segments using bolting. Secondly, typical direct foundations for wind towers require large amounts of concrete (a typical foundation for a 80 m high tower has a diameter of 17 m and a volume of concrete of 400 m3). These quantities tend to increase exponentially with the height of the tower. No guidelines exist for the use of alternative solutions such as steel micro piles, namely in terms of stiffness and dynamic behaviour.

In the framework of the recently completed HISTWIN RFCS research project, significant knowledge has been gained with respect to use of a novel friction connection that replaces the classical flanged connection between tower segments, The friction connection with long open slotted holes and Tension Controlled Bolts has shown big advantages to be gained in comparison to the flange connection. Thesame consortium who has worked on the HISTWIN project, which represents the state-of-art in this research area, is proposing removing existing technical barriers within this proposal.

In this project, the following added value is expected: (i) Extension of the concept of slotted friction-grip bolted connections for the longitudinal joining of steel segments; "modular tower" and its positive effect on local stability is expected. (ii) Development and validation of alternative steel-intensive piled foundations. (iii) Optimization and automated production of the internal fittings (accessoires) in the steel tower. (iv) Optimization and automatic welding procedures of the tower openings; after theoretical studies in the HISTWIN project, it's implementation will be experimentally verified on the down-scaled specimens, WP3. (v) Comparative life-cycle evaluation of steel and hybrid (steel-concrete) towers, done by a consultancy company (SC2) and the academic partners in order to have both perspectives involved. (vi) Polygonal shape of cross section will be considered in the "modular tower" numerically and experimentally, and in comparison to circular cross-section.

Publications:

Reports:
HISTWIN2 – first period report 2010
HISTWIN2 – midterm report

Conference proceedings:

Matos, R. M. M. P. de et al, Ensaios de Fadiga de Ligações Metálicas por Atrito para Torres Eólicas Metálicas, VII CMM, Lisboa, 2009;

Matos, R. M. M. P. de et al, Avaliação da Resistência à Fadiga de Ligações Metálicas Recorrendo aos Modelos de Aproximação Local, Reabilitar 2010, Lisboa, 2010;
Fontoura, B., Matos, R., Jesus, A.,Rebelo, C., Correia,J., Silva, A., Simões da Silva, L., Comparação

da resistência à fadiga entre o aço S355 e o aço de alta resistência S690, 2º ASCP, Coimbra, 2011

Matos, R., Fontoura, B., Rebelo, C., Jesus, A., Veljkovic, M., Simões da Silva, L., Fatigue Behavior of Steel Friction Connections: Experimental and Numerical Results, Eurosteel 2011, Budapeste, 2011;

Fontoura, B., Matos, R., Jesus, A., Rebelo, C., Simões da Silva, L, Veljkovic, M., Avaliação da resistência à fadiga de ligações por atrito em aço estrutural de alta resistência S690, VIII CMM, Guimarães, 2011.

Rebelo, C., Simões, R., Matos, R., Simões da Silva, L., Veljkovic, M. and Pircher, M.: Structural monitoring of a wind turbine steel tower, 2012, Proc. 15th International Conference on Experimental Mechanics, Porto, 22-27 July, 2012

Matos, R., Cruz, J., Rebelo, C. and Veljkovic, M.: Feasibility Tests on Single Shear Lap Friction Connections for Wind Towers, 2013, Proc. IX Congresso de Construção Metálica e Mista & I Congresso Luso-Brasileiro de Construção Metálica Sustentável, Matosinhos, 24-25 October, pp: 665-673, paper 74

Matos, R., Pinto, P., Rebelo, C. and Veljkovic, M.: Laboratory Testing of Single Micropiles. 2013, Proc. IX Congresso de Construção Metálica e Mista & I Congresso Luso-Brasileiro de Construção Metálica Sustentável, Matosinhos, 24-25 October, pp: 685-694, paper 64

Matos, R. and Rebelo, C.: Dynamic Measurements of a Steel Wind Tower, 2013, Proc. ICOVP 2013 – 11th International Conference on Vibration Problems, Lisbon, 9-12 September, pp: 308 (digital paper nr. 470)

Moura, A., Rebelo, C. and Gervásio, H.: Análise comparativa de torres eó1icas em aço e híbridas aço-betão para alturas e potências variáveis, 2013, II Congresso Luso-Africano de Construção Metálica Sustentável, Maputo, Mozambique, July 19 (in portuguese)

Journal articles:

Rebelo, C., Veljkovic, M., Simões da Silva, L., Simões, R. and Henriques, J., "Structural monitoring of a wind turbine steel tower – Part 1: system description and calibration", *Wind and Structures: an International Journal*

Rebelo, C., Veljkovic, M., Matos, R. and Simões da Silva, L., "Structural monitoring of a wind turbine steel tower – Part 2: monitoring results", *Wind and Structures: an International Journal*

Jesus, A., Matos, R., Fontoura, B., Rebelo, C., Simões da Silva, L. and Veljkovic, M., "A Comparison of the Fatigue Behaviour between the S355 Mild Steel and the S690 High Strength Steel", *Journal of Constructional Steel Research*

Heistermann, C., Veljkovic, M. Simões, R., Rebelo, C. & Simões da Silva, L.: Design of slip resistant lap joints with long open slotted holes, 2013, *Journal of Constructional Steel Research*, 82, p 223 – 233, 11 p.

Rebelo, C., Moura, A., Gervásio, H., Veljkovic, M. and Simões da Silva, L.: Comparative life-cycle assessment of tubular wind towers and foundations. Part 1 – Structural design, *Engineering Structures*

Gervásio, H., Rebelo, C., Moura, A., Veljkovic, M. and Simões da Silva, L.: Comparative life-cycle assessment of tubular wind towers and foundations. Part 2 – Life-cycle analysis, *Engineering Structures*

MSc Thesis:

Alves, C.: Fatigue behavior of wind towers: comparative analysis of flange connections of hybrid steel-concrete wind towers, March 2013, University of Coimbra

Figueiredo, G.: Structural behavior of hybrid lattice – tubular steel wind tower, July 2013, University of Coimbra

Pires, P.: Design of concrete-steel transitions in a hybrid wind turbine tower, July 2013, University of Coimbra

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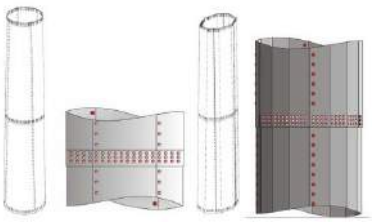

Fig. 1 Circular vs. polygonal tubular cross section of the steel modular tower, two segments of modularized tower are shown.

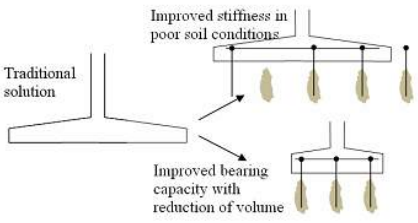

Fig. 2 Improvement of slab foundations with steel micro-piles.

Fig. 3 Experimental small-scalled micropile load tests and numerical evaluation.

Improved and innovative techniques for the diagnosis and monitoring of historical masonry

Financing Institution(s): FCT

Promoting Institution(s): University of Minho (UMinho)

Coordinator(s): Francisco Manuel Carvalho Pinto Fernandes, José Luís Ferreira da Silva Ramos

Researchers and collaborators: Francisco M. Fernandes, Luís F. Ramos, Paulo Mendes, Graça Vasconcelos, Paulo B. Lourenço, João Roque, Rafael Aguilar

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE), Centro Algoritmi (Algoritmi/UM).

Period: May 2010 to October 2013

Relevant facilities: Laboratory equipment and facilities of Civil department of UMinho.

Objectives:

In this project, promoted by University of Minho, a Portuguese team from Civil and Electronic Departments of University of Minho are developing and improving several non-destructive techniques and inspection methods for adequately diagnosing historical masonry. One objective aims at improving the acquisition system and processing of sonic data by automating readings and increase the volume of data acquired simultaneously. Additionally, it intends to develop a new technique based on the geoelectrical technique, but developed exclusively for use in old masonry. Moreover, it intends to improve the widely known flatjack technique by a new one, constituted by tubes, in order to surpass the flatjack´s limitations. Finally, this project intends to explore the potential of global damage identification and monitoring, through which it will be possible to identify the locations were damages or defects occurred during its lifespan.

Description:

The diagnosis of historical masonry constitutes a significant challenge for all the technicians involved. Currently, despite the enormous advent of techniques and technology, much is still needed in terms of improvement of inspection methods and survey techniques onsite. Several techniques were proposed in the framework of this research project to be improved and tested for applicability. In special, two new techniques were developed and one was subjected to a patent process.

In one phase, this project intended to significantly improve the sonic velocity technique, which is characterized by being a slow technique that requires a lot of time to carry out and to process. Additionally, it requires two operators that, due to that fact, could produce different results due to variations in the impact location and energy of the hammer use to cause impact waves. In this way, a linear array of accelerometers was developed in order to read several signals along different straight lines simultaneously increasing the volume of data obtained and decreasing the differences between signals at a same level. In order to replace the manual instrumented hammer, a mechanical device (solenoid and electronic interface) was developed to create controlled and configurable impacts to generate uniform and repeatable mechanical waves, this way eliminating errors from the operator. In addition, it allows a high repetition rate of impacts, resulting in a significant increase of the number of impacts (which is something rater difficult to do by an operator). Finally, an algorithm is being developed to automatically analyze sonic data to search for important signals and, automatically, calculate the velocity, significantly saving time and errors during processing.

A second phase aimed at developing a geoelectrical device that could produce tomographic reconstructions of transversal cross-sections of masonry multi-leaf walls and columns. An initial study confirmed that current commercial geoelectrical systems were not adequate for this task. Therefore, a specific device was developed specifically for masonry. A prototype was built using modular systems (voltmeters, voltage and current controllers, signal generators, etc.). A series of tests in laboratory specimens and on real structures were carried out. The inversion algorithm necessary to produce the tomograms is still being developed and improved for masonry and for the low values of current and voltage obtained. However, it seems that the material has to have a certain amount of moisture for the current to pass.

Moreover, in a third phase, due to the wide acceptance and usefulness of the flatjack technique, a new method was developed and patented in order to surpass the limitations of the flatjack, as well as improving the type of results obtained and its applicability on masonry. The new method is based on PVC, latex or rubber tubes instead of the metallic plates from the original flat jack. These tubes will be inserted in holes with 20 mm of diameter instead of the large cuts necessary to introduce the steel plates of the original flat jack. This new technique will allow its use in a wider variety of masonries (regular and irregular) and at different heights simultaneously. In the same way, it inflicts less damage in the masonry, which are very small holes in the joints. Studies are still ongoing to verify its applicability and repeatability of results. So far, PVC tubes were discarded and special fabric socks were added to help in conditioning the tube and avoiding early burst. An additional objective is to gather information along the transversal constitution of the wall. For that, the tubes will have to be instrument along its axis.

Finally, acoustic emission was tested as a passive inspection technique that allows, along the lifespan of a structure, the detection of the occurrence and growth of cracks. This technique was applied in a tower (known to be slowly moving) from the church of São Torcato, in Guimarães, around a specific number of cracks in order to monitor its growth, or the occurrence of new ones. However, the few weeks the device was installed, few events were recorded.

Publications:

Ramos, L.F., Miranda, T., Mishra, M., Fernandes, F.M. e Manning, E. (2015) "A bayesian approach for NDT data fusion: the Saint Torcato Church case study." NDT&E International, 84(1) , pp. 120-129. doi: 10.1016/j.engstruct.2014.11.015

Ramos, L.F., Manning, E., Fernandes, F., Fangueiro, R., Azenha, M., Cruz, J. e Sousa, Ch. (2013). "Tube-jack testing for irregular masonry walls: Prototype development and testing." NDT&E International, 58, pp. 24-35. doi: 10.1016/j.ndteint.2013.04.004

Reports:

Report Nº1 - Improved Techniques for the Diagnosis and Monitoring of Historical Masonry: Numerical Modelling of Flat-Jack and Tube-Jack Tests. Authors: Rafael Aguilar, Luís. F. Ramos, Leandro Marques, Francisco M. Fernandes.

Report Nº2 - Improved Techniques for the Diagnosis and Monitoring of Historical Masonry: Sonic Tests Array. Authors: Sílvia Reis, Luís. F. Ramos, Paulo Mendes, Francisco M. Fernandes.

Report Nº3 - Non-destructive testing of the Casa de Bragan?a Foundation Headquarters in Lisbon, Portugal. Authors: Elizabeth Manning, Luís. F. Ramos, Francisco M. Fernandes.

Report Nº4 - Improved Techniques for the Diagnosis and Monitoring of Historical Masonry: Electrical Impedance Tomography for Imaging and diagnosis of Concert. Authors: João Ferreira, Luís. F. Ramos, Paulo Mendes, Francisco M. Fernandes.

Report Nº5 - Improved Techniques for the Diagnosis and Monitoring of Historical Masonry: Tube-Jack Development. Authors: Elizabeth Manning, Luís. F. Ramos.

Conference proceedings:

Alcantara, N., Ramos, L.F., Mendes, P., Fernandes, F. "Finite Element Simulations for the Comprehension of Physical Phenomena Involved in Electric Impedance Tomography of Masonry Structures." 8th International Conference SAHC 2012, 15th-17th October, Warsaw, Poland.

Manning, E.C., Ramos, L.F, Fernandes, F.M., Sousa, C., Azenha, M. "Tube-jack testing for irregular masonry: preliminary testing." 8th International Conference SAHC 2012, 15th-17th October, Warsaw, Poland.

Manning, E., Ramos, L.F., e Fernandes, F.M. (2014) "Direct Sonic and Ultrasonic Wave Velocity in Masonry under Compressive Stress." 9th International Masonry Conference, 7, 8 e 9 de julho, Guimarães, Portugal.

Manning, E.C., Ramos, L.F. and Fernandes, F. "Tube-Jack Testing: Regular Masonry Wall Testing." 9th International Conference SAHC 2014, Mexico City, Mexico, 14–17 October 2014

Fernandes, F.M., Ramos, L.F., Manning, E., Ferreira, J., Mendes P. "Multi-technique approach for the assessment of historical masonry constructions." 10th International Conference on Damage Assessment of Structures, 8th – 10th July, Dublin, Ireland.

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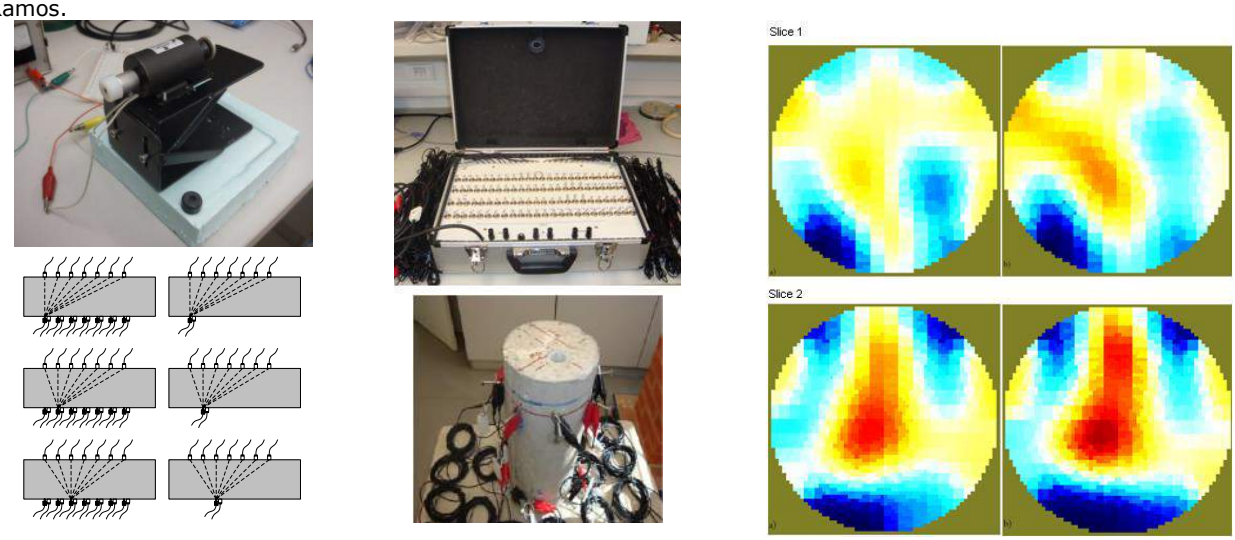


(a) (b) (c)

Fig. 1 Technologies developed: (a) Sonics improvement with a mechanical solenoid for impact and deployment schematics; (b) electric resistivity prototype for masonry walls and (c) tomography results in concrete specimen.

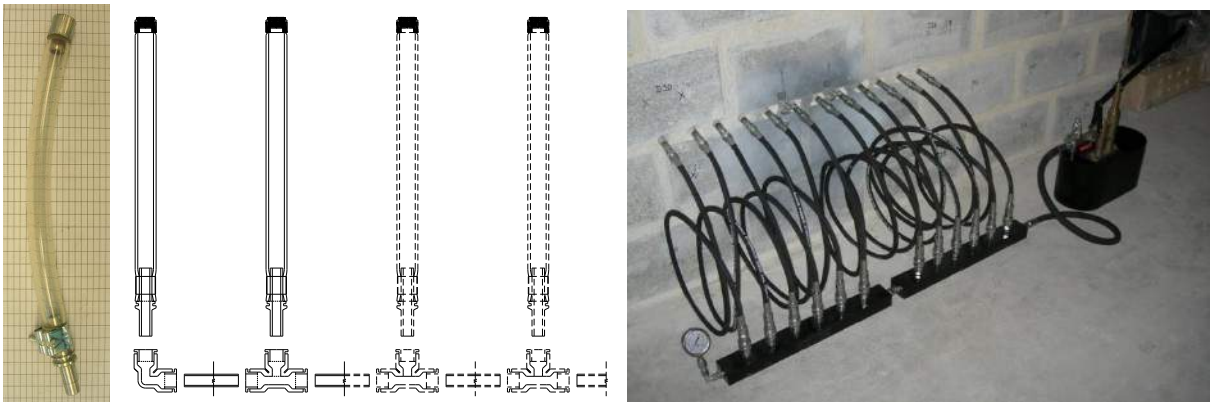


Fig. 2 Tube-jack prototypes: basic design and current prototype.

Innovation in reinforcing systems for sustainable pre-fabricated structures of higher durability and enhanced structural performance | DURCOST

Financing Institution(s): FCT

Promoting Institution(s): University of Minho (ISISE)

Coordinator(s): Joaquim Barros

Researchers and collaborators: Joaquim Barros, Amin Abrishambaf, António Ventura Gouveia, Eduardo Pereira, Fatemeh Soltanzadeh, Hadi Mazaheripour, Hamidreza Salehian, Jorge Costa, José Sena Cruz, Mahsa Taheri, Miguel Azenha, Rui Miguel Ferreira, Salvador Dias

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE).

Period: 14/06/2010 to 13/12/2013

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho.

Objectives:

The present project intends to contribute for the development of a new generation of high durable and sustainable reinforced concrete (RC) structures, by combining the benefits that Fibre Reinforced Polymer (FRP) and steel bars can provide, the former due to their corrosion immunity and high tensile strength, and the latter derived from their high ductility. To overcome the susceptibility of steel stirrups to corrosion, they are replaced by discrete steel fibres, developing high shear strength High Performance Fibre Reinforced Concrete (HPFRC). Additionally, experimental and analytical research with pre-fabricated hybrid reinforced pre-stressed beams is executed to develop a guideline for the construction and design of this type of structures. The development of a constitutive model to be implemented into FEMIX computer FE modelling program, capable of simulating the behaviour of these elements from their very early age up to their working conditions, is also an objective.

Description:

Steel reinforcements of the concrete elements in aggressive environmental conditions are generally affected by corrosion, which is often responsible for deterioration and damage processes developing in reinforced concrete (RC) members. Since the rehabilitation of corroded RC structures is generally an expensive solution, demolition of such structures is a relatively frequent option, though resulting in several unfavourable impacts in terms of economic, social and environmental aspects. The steel stirrups are one of the most susceptible elements to corrosion, which limits the long-term performance of RC structures. Additionally, the producing and placing of these conventional shear reinforcement is very labor-intensive and causes to increase the production time and cost of concrete elements. Thus, the present study introduces a new design framework for constructing the highly durable and structurally effective prefabricated concrete beams by replacing the conventional stirrups with the discrete steel fibers. These elements were produced by means of developing a HPFRC, with a relatively high dosage of steel fibers, aiming to suppress the steel stirrups without occurring shear failure.

Further enhancements on the durability and sustainability of concrete elements can be obtained by taking the benefits of non-corrodible fiber reinforced polymer (FRP) bars. However, the higher deformability of FRP reinforced concrete member, especially GFRP reinforced concrete member, brought the attention of designers to the accomplishment of the serviceability limit state requirements for FRP-RC members. In the present project, a new generation of FRP-steel hybrid reinforcing systems for the construction of pre-fabricated FRC beams is developed. In this end, the FRP bars are applied with a certain pre-stress and they are also applied as near as possible of the tensile surface in order to have the highest internal arm and, therefore, the highest contribution for the resisting bending moment. However, the minimum thickness of the concrete cover for the FRP bars and the material and geometric characteristics of the FRP bars need to be evaluated in order to guarantee a stable transference of stresses from FRP to the surrounding concrete. In this aspect, the developed HPFRC of high strength and high compactness will collaborate to constitute a proper medium for enhanced bond behaviour for FRP bars. Moreover, steel bars are placed with higher concrete cover in order to be immune of corrosion….

Experimental program

After conducting the extensive researches on the following subjects:

i) Development of the HPFRC and material characterization;

ii) Assessment of the FRP-FRC bond behaviour (Fig. 1), and

iii) Investigation of the shear behaviour of the developed HPFRC (Fig.2),

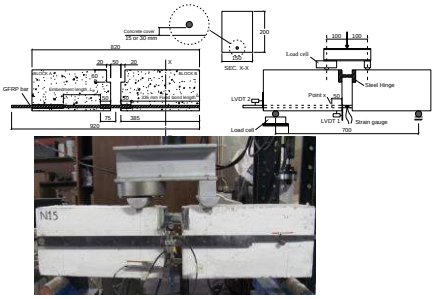


Fig. 1 Experimental test on assessment of bond behaviour between GFRP bars and FRC.

the research was continued by means of developing the aimed HPFRC beams, flexurally reinforced with hybrid GFRP-steel system of reinforcements. The effectiveness of the applied innovative system for developing these elements without transversal reinforcements were studies in terms of the

structural performance, and specially the shear resistance of the beams, by means of testing two series of short–span (a/d<3) and slender (a/d≥3) beams.

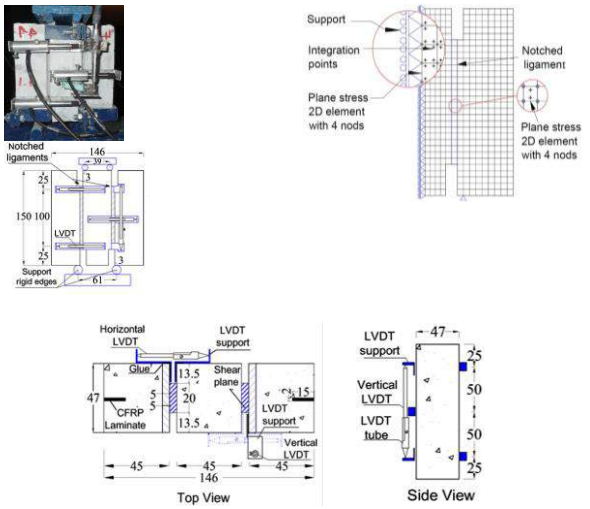
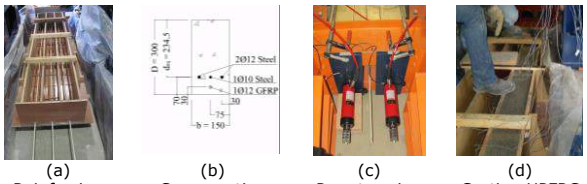


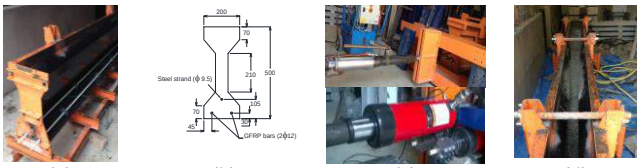
Fig. 2 Experimental test on assessment of shear behaviour of HPFRC and numerical simulation.

The construction procedure of the short-span elements and slender members are described in figures 3 and 4 respectively. The procedure for producing both series of the specimens, involved the following steps: 1. installation of the GFRP and steel bars (figures 3a and 4a), 2. prestressing the reinforcements (figures 3c and 4c), casting and curing the elements (figures 3d and 4d) and finally releasing the applied normal force after 3 days of casting the specimens.



(a) Reinforcing Installation (b) Cross section (c) Pre-stressing procedure (d) Casting HPFRC

Fig. 3 Fabrication process of the short-span beams.



(a) Reinforcing Installation (b) Cross section (c) Pre-stressing procedure (d) Casting HPFRC

Fig. 4 Fabrication process of the slender beams.

During the test program of the first series of specimens, the structural behavior of six short-spam beams of rectangular cross section was investigated, in terms of load-versus-deflection response, cracking pattern and failure mode. The prestress level applied to the GFRP bars was the main variable studied in this experimental program. The three-point flexural test setup adopted in the present study is illustrated in Fig.5.

The second series of the specimens composed of nine quasi-real scale I-shape slender beams, developed by high strength concrete with 0, 90 and 120 Kg/m^3 discrete steel fibers. Moreover the beams were produced by distinct level of prestress. The four-point loading test was executed using these elements for assessing the potentialities of the new types of materials for the development of an innovative structural system, as presented in Fig.6. During this series of tests the structural performance of the HPFRC beams without stirrups were compared with that of plain high strength concrete beams with conventional shear reinforcements. These studies aimed to introduce the best fiber volume fraction and the adequate prestress level in both applied GFRP bar and Steel strand for developing the beams without transversal reinforcements, which presents the relatively high shear resistance.

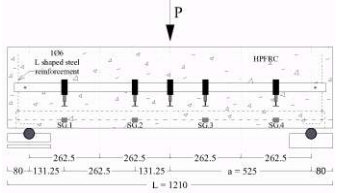


Fig. 5 Beam configuration and test setup (First series).

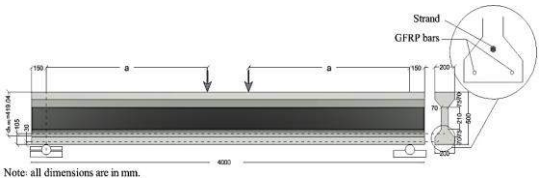


Fig. 6 Beam configuration and test setup (Second series).

Summary of the results: first series of tests

- Including the prestressed GFRP bar into the hybrid steel/GFRP flexural reinforcing system of the proposed study in this project resulted a significant improvement of the shear capacity compared to the beams with the passive GFRP bars. Consequently a significant increase of the energy absorption is found by prestressing the beams.
- In all the beams, it was observed that the ductility factor enhanced significantly by increasing the level of prestressing.

Summary of the results: second series of tests

- The obtained results have evidenced that using the HPFRC and adopting a prestress level of 70% for the steel strand and 30% for the GFRP bars, a quite high load carrying capacity can be achieved (this even exceeded the load at yield initiation of the strand with the ratio of 1.17) with a very ductile response in the case of the slender beams without transversal reinforcements, since the deflection at failure was about 3 times higher the deflection at serviceability limit states.

Publications:

Nº of papers in ISI international journals: 9
Nº of papers in international conferences: 11
Nº of papers in National conferences: -
Book Chapters: 1
PhD Thesis: 2
Nº of technical/scientific reports: 7

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Innovative carbon fibre reinforced polymer laminates with capacity for a simultaneous flexural and shear/punching strengthening of reinforced concrete elements | CuTinov

Financing Institution(s): ADI (FEDER - Programa Operacional Fatores Competitividade)

Promoting Institution(s): ALTO

Coordinator(s): Filipe Dourado (CLEVER Reinforcement Iberica); Joaquim Barros (UM-ISISE)

Researchers and collaborators: Joaquim Barros. Eduardo Pereira, J. Sena-Cruz, Salvador Dias, Hadi Baghi, João Laranjeira, Mohammad Mastali, Mohammadaki Rezazadeh, Mohammadreza Hosseini, António Matos, Marco Jorge.

Partner Institutions: University of Minho (ISISE)

Period: January 2014 to June 2015

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho.

Objectives:

The objective of this project is to develop and to assess by experimental research, the effectiveness of an innovative carbon fibre reinforced polymer (CFRP) laminate with the main advantage of assuring simultaneously the flexural and shear/punching strengthening for reinforced concrete (RC) elements. This investigation also expects to develop and to experimentally assess the performance of a new hybrid strengthening technique, combining the best attributes of the near surface mounted (NSM) and embedded through section (ETS) techniques, based on the use of the innovative CFRP laminate. The new laminate efficiency is evaluated by performing numerical simulations and parametric studies, aiming to optimize the new strengthening solution proposed in this project. Furthermore, the development and calibration of analytical models based on experimental results will support the development of design methodologies for the new strengthening technique using the new laminate for RC beams and slabs. As final objective, a technical guidebook describing the procedures to execute the innovative strengthening and the design rules for their application in RC elements will be elaborated.

Description:

While planning a strengthening intervention on a RC structure, the increment of both flexural and shear load carrying capacity may be required, regardless of the selected strengthening process. In fact, if a significant bending moment is provided, the existing shear reinforcement is typically insufficient to withstanding the magnitude of loads to be applied, and shear/punching strengthening interventions may be compulsory. The development of the innovative CFRP laminate proposed to be applied by the new hybrid technique (NSM-ETS technique) aims to address these concerns, by assuring simultaneously the flexural and shear/punching strengthening in a single intervention, delaying premature failure modes, and being a faster and economic solution. These main advantages results from the laminate U configuration.
A comparative technical and economic analysis about the application of the new hybrid strengthening technique, using the innovative CFRP laminates, and alternative solutions that use traditional materials for reinforcing concrete elements was performed. This analysis evidenced the technical and economic feasibility of the proposed NSM-ETS technique.

To industrially transform the CFRP laminates produced by CLEVER in the new type of laminate with a U configuration, the transformation line, schematically represented in Fig. 1 is being developed.

To assess the strengthening performance of the new hybrid NSM-ETS technique using the innovative CFRP laminate, an experimental program is being carried out with RC beams strengthened simultaneously in flexure and shear (Fig. 2), RC slabs strengthened simultaneously in flexure and punching (Fig. 3).

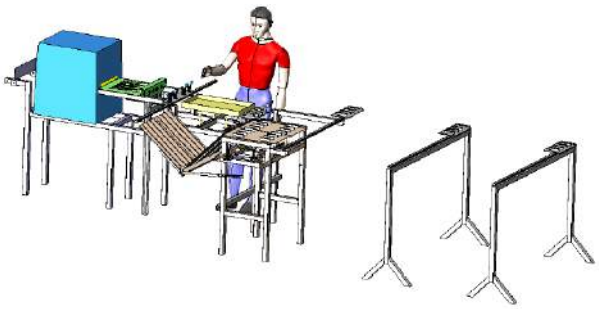

Fig. 1 Transformation line.

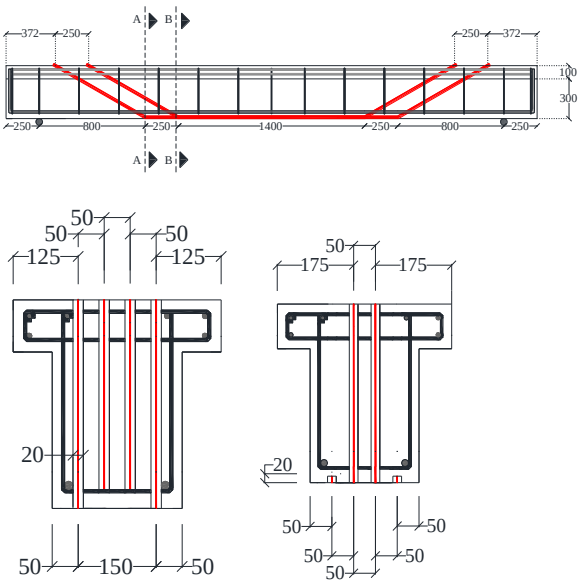

Fig. 2 Experimental program with RC beams.

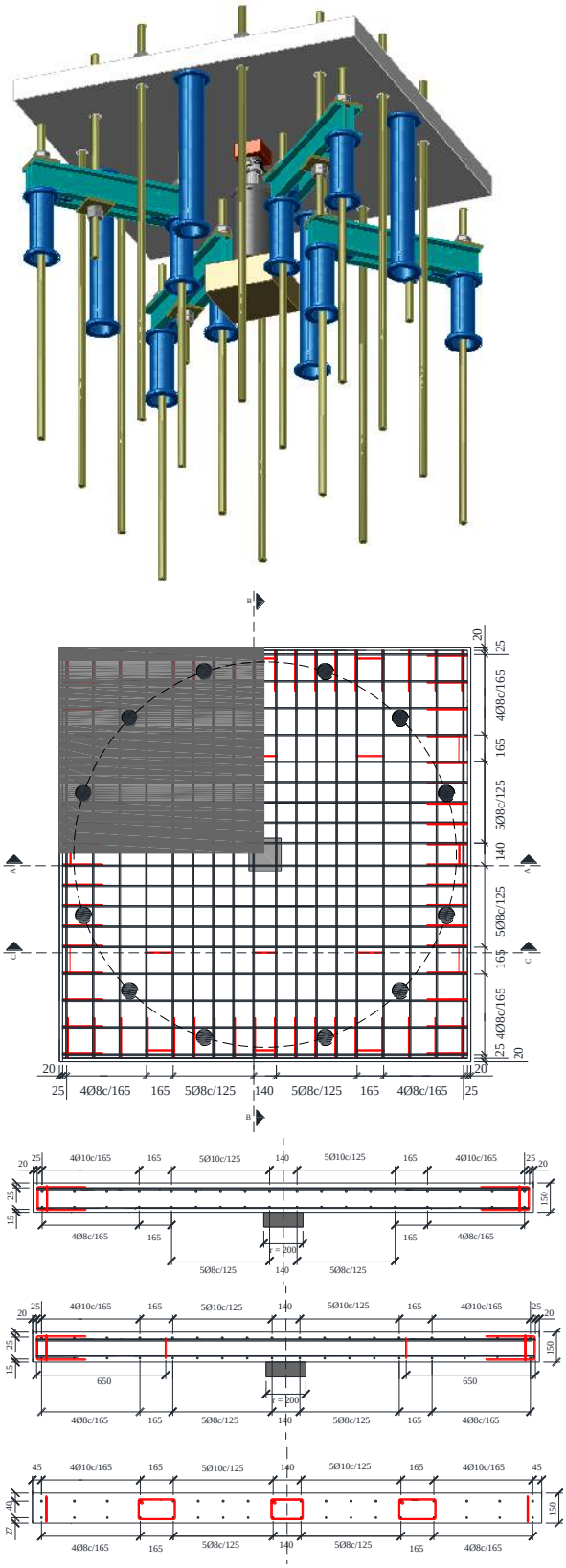

Fig. 3 Experimental program with RC slabs.

The NSM-ETS strengthening configurations were optimized based on advanced numerical simulations carried out (Fig. 4). Furthermore, the number and distance between laminates applied by NSM-ETS technique, as well as the inclination angle of laminate extremities, were assessed by performing a parametric study. Two numerical finite element (FE) approaches using FEMIX and ABAQUS software's, capable of simulation the nonlinear behaviour of the constituent materials, were used in these simulations. The results evidenced that the U shape CFRP laminates can decrease the stress concentration at the extremities of NSM CFRPs and ETS CFRPs, resulting in a higher resistance to the occurrence of premature failure modes, before achieving the ultimate tensile strain of the CFRP, when compared to NSM CFRPs or with ETS CFRPs.

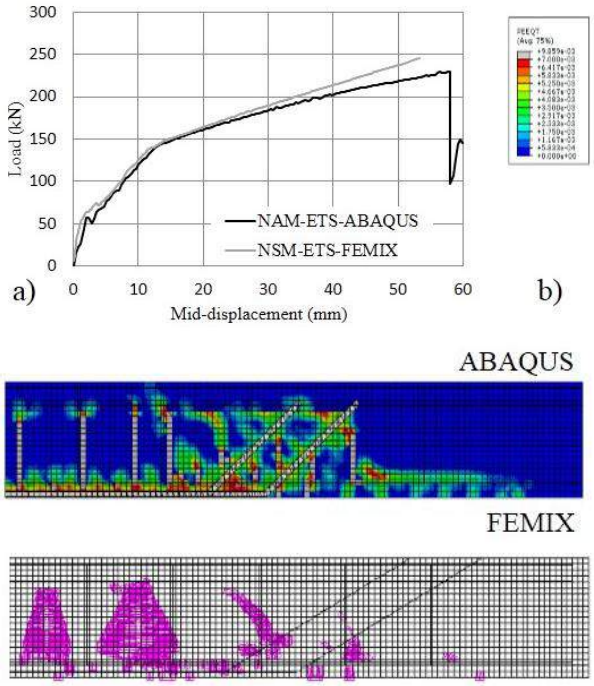

Fig 4 Numerical simulations

The ultimate flexural capacity of beams and slabs with and without NSM-ETS CFRP reinforcement was analytical predicted based on sectional analysis, using the principle of static equilibrium and strain compatibility of section, by adopting recommendations from a harmonised standard NP EN 1992-1-1 (2010) and from the American Concrete Institute ACI 318M (2008) and ACI 440.2R (2008). The new strengthening technique revealed the possibility of increasing in about 87 % and 67 % the load carrying capacity of the corresponding reference beams and slabs, respectively.

Publications

Nº of papers in ISI international journals: -
Nº of papers in non ISI international journals: -
Nº of papers in national journals: -
Nº of papers in international conferences: -
Nº of papers in National conferences: -
MSD Thesis: 2
Nº of technical/scientific reports: 3

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Innovative fire protective coatings for steel structures | Steel Prost

Financing Institution(s): European Comission

Promoting Institution(s): European Comission

Coordinator(s): Luís Alberto Proença Simões da Silva

Researchers and collaborators: Alessandra Marmondi, Ana Pilar, Carlos del Castillo, Corinna Haferkorn, Edoardo Lucini, Javier Sacristan Bermejo, Jose Manuel, Leon Hladnik, Luís Simões da Silva, Lucio Carlucci.

Partner Institutions: Acciona S.A. , AIN - Associacion de la Industria Navarra, Bersch & Fratscher GmbH, Construction Cluster of Slovenia, ECCS - European Convention for Constructional Steelwork, ITRI Ltd, Talleres Ruiz, Tecnologias Avanzadas Inspiralia.

Period: May 2010 - October 2012

Relevant facilities: Laboratory equipment of Alcea and other.

Objectives:

Provide a solution to current surface treatment limitations, by developing a second generation of fire-protective coatings that are:

easier to paint on, covering a larger area faster, having improved adhesion and quick drying properties.

This will be achieved through 3 core innovations:

- 1.Development of low cost fire-retardant agents using novel tin-based technology, based on nontoxic halogen-free additives
- 2.Combination of the above fire retardant agents with further nanoparticle additives to confer the paint outstanding adhesion to the metal, and increase abrasion and wear resistance properties;
- 3.Design and optimisation of a procedure for fast curing of the coating using existing heating source technologies such as infra-red (IR). The proposed technology is expected to reduce steelwork treatment cost in constructional projects on a 25% for on-site applications and 50% for off-site application.

Description:

Current methods to provide fire protection of light steel structures include the nowadays most efficient approach of intumescent paints, which are typically applied on-site on a mounted structure using brushes or spray guns. Such treatments are generally achieved through the preparation of the surface by grit/shot blasting, followed by the application of a primer, and followed by the application of several layers of intumescent coatings. This methodology has a number of drawbacks for a large community of end users, including:

1.Drying times of intumescent coatings are very long, resulting in high cost associated to labour, site disruption, and space required for painting;

2.As a consequence of those significant costs and burdens, the reality is that many end users, particularly SMEs, end up applying fewer layers than required, uneven or irregular layers, or none at all, breaching therefore current legislation, facing serious penalties and fees and endangering the security of their own installations.

Target Stakeholders - Directly interested: coatings producers, steel structures and components producers, installers; - In-directly interested for STEELPROST technology:

- investors and designers of steel structures,
- investors and designers of other structures made of other materials or a combination of different materials where the structure and/or components have to be protected against fire civil engineering structures (tunnels, railway, road infrastructure) industrial structures, use of new and advanced materials like composites of different kind, glass, different insulation materials, Wood (prefabricated walls, prefabricated houses)

Dissemination Strategy - An important number of Workshops and activities took place in order to disseminate SteelProst results during the length of the project.

Dissemination topics: Fire Resistance performance, Mechanical Resistance performance, Quick drying and coating issues, Fire Resistance evaluation, Savings and advantages related to SteelProst project.

The three SteelProst Associations, ECCS, SGG and AIN have implemented actions in order to exploit generated foreground. Networking activities include: Presentation to members, Articles, Networking activities for searching Demo project collaborators inside ECCS, Networking for exploitation in alternative markets.

Training activities play a key role on the exploitation and Dissemination of SteelProst foreground.

Final Dissemination Plan - Conferences, exhibitions and shows of relevance worldwide, such as:Pacific Structural Steel Conference ,ASCE Structural Engineering Conference, North American Steel Construction Conference , International Conference on Protection of Structures against Hazard, European Meeting on Fire Retardant Polymers, and Fire Safety and Protective Coatings Conference.

- ECCS organized conferences, such as Additives for Coatings "Innovation in Formulation

ACC will liaise with the European Technology Platform for Steel and disseminate project results.

Scientific journals, such as: Journal of Construction and Building Materials, Journal of Building and Environments, Journal of Constructional Steel Research, Journal of Engineering Structures, Gradbenik, Steel Construction Magazine, Fire Safety Journal.

Other direct advertisement methods: Media, Mailing list distribution of brochures, Newsletters to Chambers of Commerce, Regional Development Agencies and adequate Associations, Workshops for technology transfer to alternative markets

Publications:

Articles
Steel Construction Magazine. This article discloses the savings related to the use of advanced fire design tools (draft).
Slovenian Construction Magazine Gradbenik, general dissemination for the steel designers and other potential industrial end users (October 2012)

Posters
Novel High Mechanical Resistant Intumescent Coatings, Lueje, Eva Martinez and Javier Sacristan Bermejo R&D Department - ACCIONA Infraestructuras

Smart and Functional Materials in Formulations: Paints, Coatings, Films and Tapes by Inspiralia related to the advances obtained in drying issues for nano formulated high solids intumescent coating under different conditions

Contacts:

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Email: eccs@steelconstruct.com
URL: http: www.steelconstruct.com

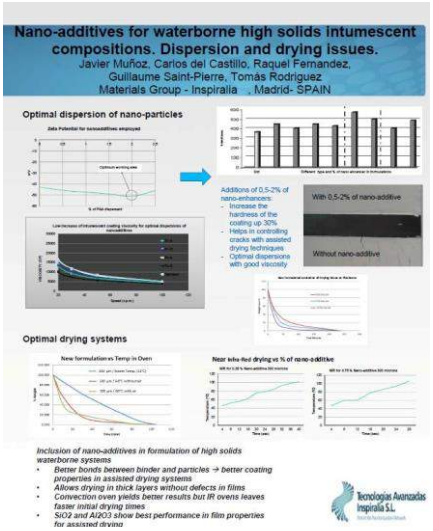

Fig. 1 Participation at networking session.

Fig. 2 WORKSHOP ON NEW APPROACHES TO HIGH T° COATINGS.

Innovative material with ultra high ductility for the rehabilitation of built heritage | InoTec

Financing Institution(s): COMPETE / QREN (n.º 23024)

Promoting Institution(s): CiviTest

Coordinator(s): Lúcio Lourenço (Civitest), Joaquim Barros (Uminho)

Researchers and collaborators: Lúcio Lourenço, Delfina Gonçalves, Inaldo Vasconcelos, Joaquim Barros, Daniel Oliveira, Sena Cruz, Miguel Azenha, Isabel Valente, Eduardo Pereira, António Matos, Marco Jorge, Cristina Frazão, João Almeida, Fatemeh Soltanzadeh, Tiago Valente and Inês Costa.

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE).

Period: October 2012 to June 2015

Relevant facilities: Laboratory equipment, software and facilities of Civil Department of UMinho.

Objectives:
The objective of this project is the development of a material reinforced with a relatively high percentage of synthetic fibers (non corrodible material) with a tensile strain hardening behavior (herein designated by SHCC). The development of this SHCC allows a new rehabilitation technique for built heritage based on the shotcrete of two outer thin SHCC layers connected with fiber reinforced polymer connectors, able of increasing significantly the in-plane and out-of-plane load carrying capacity and energy dissipation capacity of structures vulnerable to seismic events.

Description:
The traditional schist masonry constructions are part of the vast universal architectural heritage. Their resistance under seismic actions is particularly reduced and for this reason their maintenance is a primary need for the community. However the studies on these issues are still scarce, therefore the development of effective procedures, able to increase the load carrying capacity towards the seismic actions is of primary interest.

In recent past, the CiviTest has collaborated with the Structural Composite Research Group of Minho University (SC_UM) in the development of fibre reinforced cement based materials for the increase of the load carrying and deformational capacities of fragile behaviour structures.

The research carried out revealed to be possible the development of a material reinforced with a relatively high percentage of synthetic fibres (non corrodible material) with a tensile strain hardening behaviour, which means that the tensile strength his higher than the stress at crack initiation and the tensile failure occurred at strain level higher than 2%, with the formation of diffuse crack patterns. It was also verified that this material can be tailored to have excellent bonding to natural stones, concrete, clay and mortar bricks, and timber elements, therefore it can have the requisites for its use in the rehabilitation of structures made by these types of fragile materials, such is the case of masonry-based structures of reduced strength to seismic events.

The expertise of SC_UM on the conception of high performance SHCC, and the experience of CiviTest on the development and experimental characterization of fibre reinforced shotcrete are the fundaments for the development of a SHCC and a new rehabilitation technique based on the shotcrete of two outer thin SHCC layers connected with polymer fibre reinforced connectors, able of increasing significantly the in-plane and out-of-plane load carrying capacity and energy dissipation capacity of structures vulnerable to seismic events.

The project is in the intermediate stage of its development, with an extensive experimental program with prototypes for the assessment of the effectiveness of the strengthening technique for structures susceptible to intense damage if subjected to loading conditions representative of seismic event.

Publications:

Nº of papers in ISI international journals: -
Nº of papers in non ISI international journals: -
Nº of papers in national journals: 1
Nº of papers in international conferences: 1
Nº of papers in National conferences: 1
PhD Thesis: -
MSD Thesis: 2
Nº of technical/scientific reports: 4
Patents:

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Fig. 1 SHCC composition. a) components; b) glass fibers; c) final aspect.

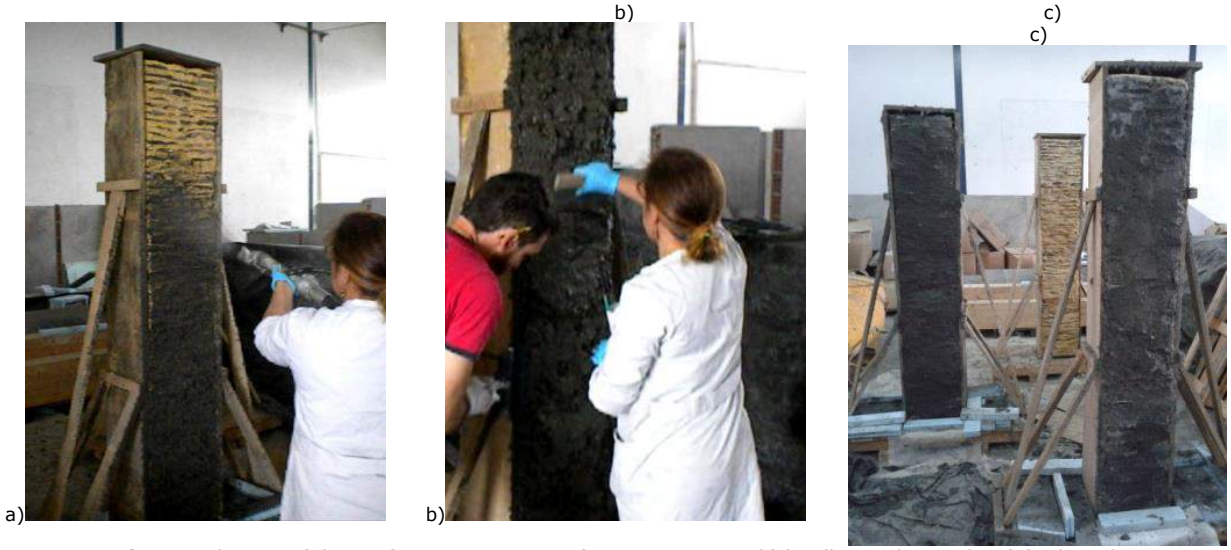

Fig. 2 Application of the reinforcement system. a) spray operation; b) levelling with spatula; c) final result.

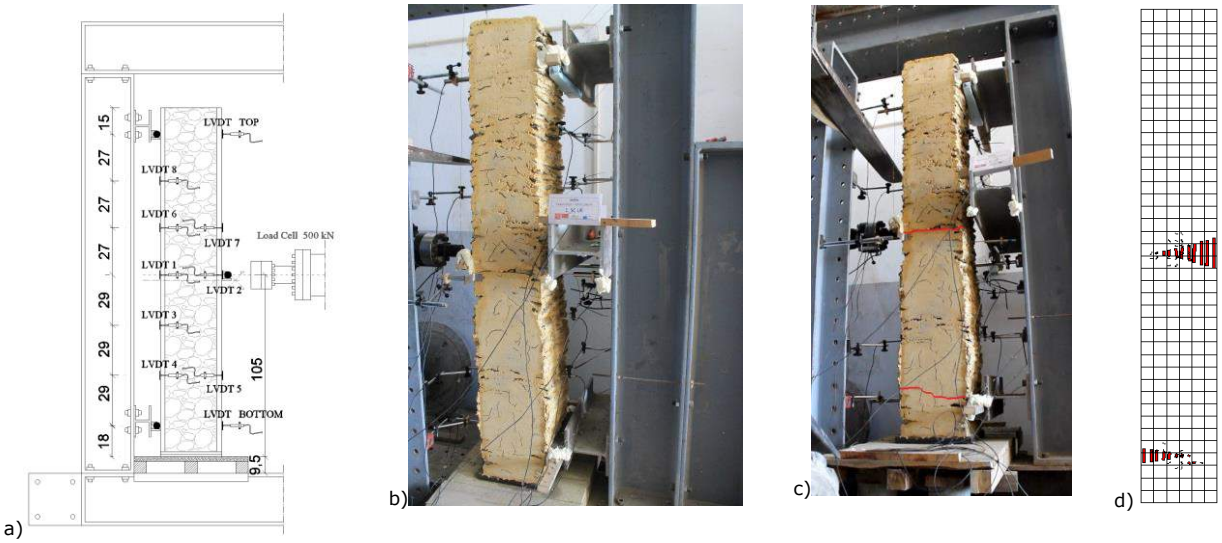

Fig. 3 Experimental evaluation of the reinforcement system in columns. a) test setup (scheme); b) test setup; c) real crack pattern; d) crack pattern (FEM)

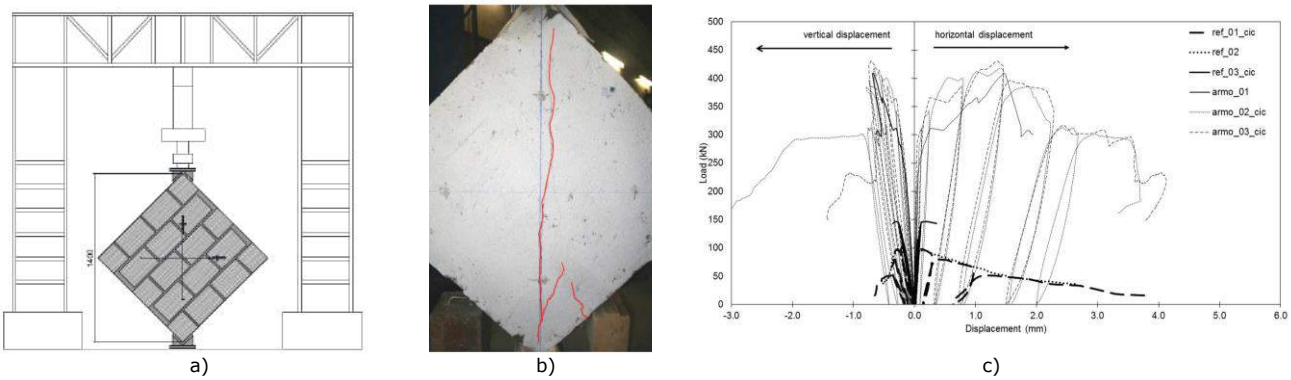

Fig. 4 Experimental evaluation of the reinforcement system in walls. a) test set-up for the direct tensile test; b) crack pattern at the surface of specimen; c) Load vs displacement responses of strengthened specimen.

Innovative method for continuous monitoring of concrete viscoelastic properties since early ages | VisCoDyn

Financing Institution(s): FCT

Promoting Institution(s): University of Minho (UMinho)

Coordinator: Miguel Azenha

Researchers and collaborators: Miguel Azenha, Luís Ramos, Jacinto Silva, José Granja, Ricardo Oliveira

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE)

Period: March 2014 to June 2015

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho.

Objective:

The intent of this work is to explore the possibility of using dynamic approaches to continuously assess viscoelastic properties of concrete, with the proposal of a new methodology termed VisCoDyn. This innovative implementation can be achieved through the submission of a concrete specimen (e.g. a beam) to a known dynamic excitation. The project intends to show that a relationship may be established between viscoelastic parameters obtained in this type of experiment and those that are typically obtained in classic creep testing.

Description:

Creep of reinforced concrete has been attracting a great deal of attention recently due to the long term deflections that largely overcame the design values of several bridges throughout the world. The resulting serviceability problems cause very expensive repairs to be necessary. The importance of adequate knowledge of concrete creep behaviour is also recognizable in several other situations: (i) disproportionate creep deflections due to premature loading; (ii) need for adequate deflection prediction and prestress compensations during the construction of staged cantilevers; (iii) inaccuracies in the estimation of self-induced stresses in concrete at early ages.

Even though the importance of concrete creep is widely recognized, the design code approaches are relatively simplified, and research efforts still struggle with experimental difficulties both at very early ages of testing (less than 72h of age) and at long term (decades). In fact, it is probably due to current experimental limitations and relatively scarce comprehensive sets of data focused on these two opposing time spans, that the existing models for creep behaviour tend to exhibit limitations in such concern.

The above reasoning frames the social-economic and sustainability relevance of contributing to a better knowledge on concrete creep, particularly in experimental methods that allow overcoming the limitations of existing approaches. This is precisely the focus of this exploratory research project: to devise an innovative testing procedure that allows new insights into the viscoelastic behaviour of concrete. The intent is to explore the possibility of using dynamic test approaches to continuously assess viscoelastic properties of concrete, with the proposal of a new methodology termed VisCoDyn

In terms of concrete science, no references were found to focus in the subject of the present research, highlighting its innovative character. Probably, the main reason for the absence of previous studies in this field is the fact that it requires the infrequent simultaneous presence of know-how on material testing, structural simulation models, modal analysis/identification, signal processing and viscoelasticity.

The new methodology, VisCoDyn, comprises testing a concrete beam since very early ages, which is placed in simply supported conditions. The beam is then subjected to a known sinusoidal harmonic force that begins being applied right after the demolding, and ensures continuous testing along time. The deformational response of the composite beam is measured and the time delay in regard to the excitation is calculated. Such time delay can be directly related the evolving viscoelastic properties of concrete.

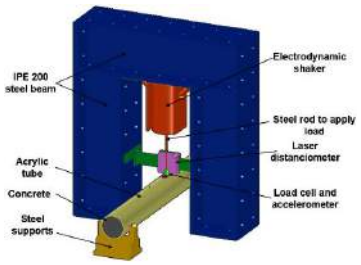

Fig. 1 VisCoDyn experimental configuration.

Project task list:

Task 1 - Equipment acquisition, training and software development
Task 2 – Assembly of the experimental setup and preliminary testing
Task 3 - Experimental program and round-robin testing
Task 4 - Analytical and numerical evaluation of creep data
Task 5 - Dissemination of results and connection with industry

Publications:

Conference proceedings

Azenha, Miguel; Oliveira, Ricardo; Granja, José; Monitorização contínua das propriedades viscoelásticas do betão desde as primeiras idades: um novo método baseado em ações dinâmicas, JPEE 2014 – 5ªs Jornadas Portuguesas de Engenharia de Estruturas, 26-28 November, Lisbon, Portugal (2014)

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Innovative systems for earthquake resistant masonry enclosures in RC buildings | INSYSME

Financing Institution(s): European Commission

Promoting Institution(s): University of Padova

Coordinator(s): Paulo Lourenço

Researchers and collaborators: Paulo Lourenço, Graça Vasconcelos, Luis Miguel Silva

Partner Institutions: Ruredil S.p.A., SDA-engineering GmbH, Tiles and Bricks Europe (TBE), Andil Assolaterizi, CTCV, APICER, TUKDER, Ziegel, Vavouliotis – Gounaris - Mitakis S.A., SCI H.I. Struct S.R.L., University of Kassel, University of Pavia, National Technical University of Athens, University of Minho, Midle Esat Technical University

Period: October 2013 to September 2016

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho.

Objectives:

The project aims at developing innovative systems for a wide range of masonry enclosures, by improving their overall technological performances and in particular those related to the earthquake behaviour. The project also aims at developing sound design rules, in order to update national and European standards and to make engineering design easier and more reliable. To reach these goals, the project is structured into two main steps, in a three-year time. In the first step, new construction systems for enclosure walls will be developed, and their technical and economic feasibility will be assessed performing parallel experimental and numerical studies. The progress towards successful completion of this phase will constitute a milestone for the subsequent project prosecution. In the subsequent step, on the basis of the obtained experimental and numerical results, design methods for this kind of elements will be developed, and the proposed solutions will be completely validated by demonstrations of design and construction of prototype walls in real buildings. Procedures for quality assessment through on-site testing, software for design and guidelines for end-users, will ensure full usability of the developed knowledge and technologies.

Description:

Infill masonry panels, if properly distributed and considered in the seismic design of structures, can have a beneficial effect. They increase the stiffness of the structure, result in reduced displacement demands, and contribute to the dissipation capacity of the structure, offering significant extra shear resistance to the earthquake. Hence, for existing rc buildings, constructed before the advent of current seismic codes, severe damage or even collapse can be attributed to poor original design or deficient construction detailing. In some other cases, damage and collapse of rc buildings is caused due to improper consideration or neglecting of the influence of infill walls on the surrounding rc elements. One cause of adverse effects is associated with the infills leaving a short portion of the column clear. In addition, the irregular arrangement of infill walls along the height of the building causes an abrupt change of the building stiffness, resulting in the possible activation of soft-storey mechanisms. Moreover, the asymmetric distribution of the infill masonry walls on the building plan can introduce torsional effects, and hence, induce large displacements of rc columns.

The principal objective of the project is thus to develop optimized masonry enclosure solutions for enhanced earthquake resistance, respecting local materials and construction practice, and considering the various levels of seismic input and environmental requirements related to the different countries. Possible types of innovative masonry enclosure systems to be developed, with reference to materials and construction details, may be divided in three major groups: (i) systems built of conventional components, following original design methods, (ii) systems built of conventional components and applying sophisticated enhancement techniques (e.g. through application of reinforcement, connectors/fasteners, joints, angles, shelves), following original design methods, and (iii) systems built of innovative components (such as clay masonry units of particular shape, sliding mortar, various steel components), following original design methods. Solutions related to various constructive types and conceptual design will be considered, in particular, (i) enclosures included in the frame, and rigidly attached to it (rigid infill), (ii) enclosures included in the frame, allowing relative displacements between the wall and the frame (separated infill), and (iii) external enclosure systems, attached to the frame or to backup infill walls, having the possibility of controlled relative movement (veneer walls). It should be noticed that the developed solutions should refer to integrated, but easy to be built and cost-effective systems, so as they can be commercialized and largely applied in constructions.

In Portugal two distinct solutions for earthquake resistant masonry infills walls have been developed, namely two different systems have been developed which are characterized by having a monolithic connection between the masonry wall and the frame, and using innovative materials, particularly new masonry units and some reinforcements (Fig. 1). The idea is (1) to use tongue and groove masonry units with vertical reinforcement properly attached to the RC frame and (2) use dry stack masonry units aiming at taking advantage of the sling at bed joints that promote enhanced dissipative mechanisms. The experimental program on the in-plane and out-of-plane static cyclic loading to mechanically validate the solutions under development is being designed and planned. The number of specimens for each solution to be tested was already defined: tests on bare frame, in-plane cyclic tests; out-of-plane cyclic testing and combined in-plane and out-of-plane testing. For the out-of-plane cyclic testing an automated control system connected to an airbag

will be used. The RC frames were designed according to current seismic regulations and were casted. The construction of masonry infill walls in the RC frames is being prepared.

Publications:

Conference proceedings

Silva, L., Vasconcelos, G. Lourenço, P.B. Innovative systems for earthquake resistant masonry enclosures in rc buildings – Insysme preliminary work at university of Minho, 6th International Conference on Mechanics and Materials in Design, 26-30 July, Azores, 2015. (Accepted for publication).

National Journals

Vasconcelos, G., Lourenço, P.B. Soluções para paredes de alvenaria de enchimento com comportamento melhorado à acção sísmica, Construção Magazine, nº 64, pp. 52-53, 2014.

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Fig. 1 Clay unit for one of the solutions under developing.

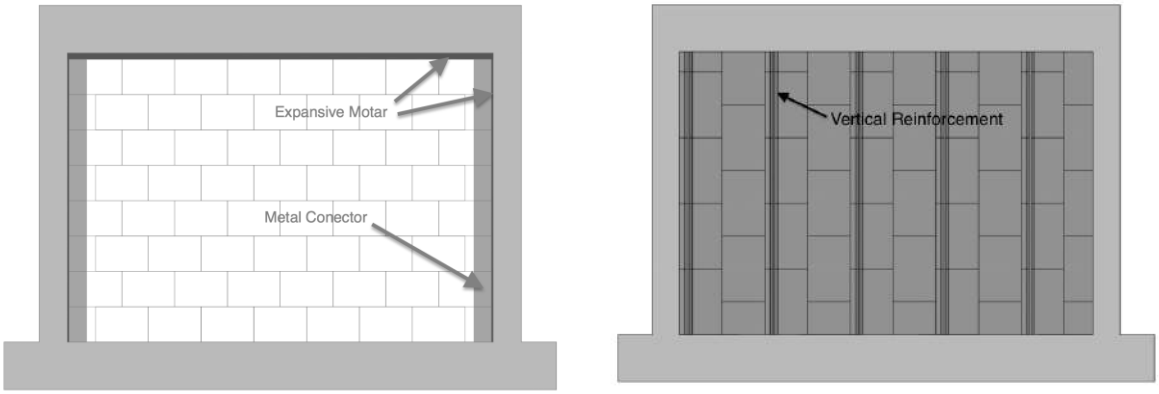

Fig. 2 Overview of the solution for masonry infills walls under development.

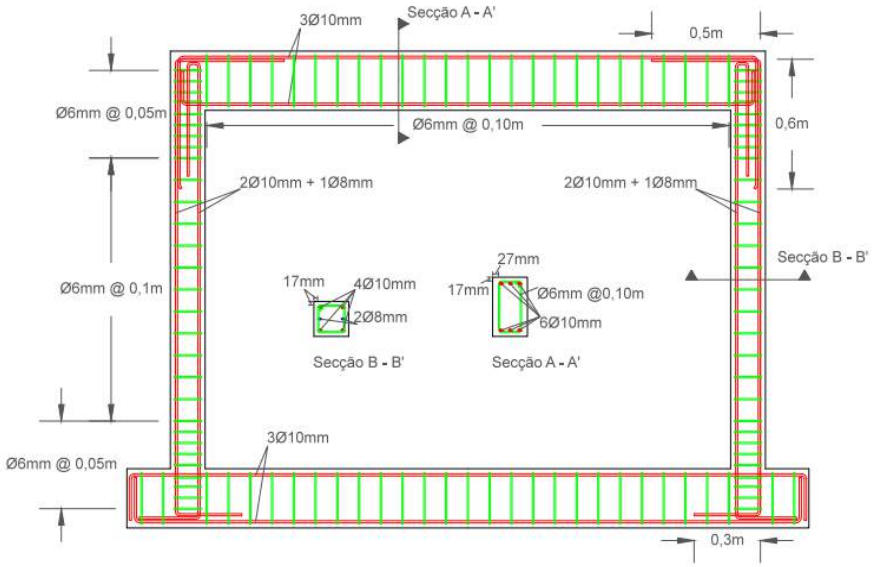

Fig. 3 Design of the reinforced concrete frame for experimental tests.

Institute of Science and Innovation for Bio-Sustainability | IB-S

Financing Institution(s): Programa Operacional Regional do Norte (ON.2)

Promoting Institution(s): University of Minho (UMinho)

Coordinator(s): Paulo Lourenço and Cândida Lucas

Researchers and collaborators: ISISE and CBMA

Partner Institutions: -

Period: 2012-

Relevant facilities: The IB-S premises include two infrastructures currently being built in the University of Minho at the Campus of Gualtar (Braga) and Campus of Azurém (Guimarães) (Fig. 1). The building in Braga hosts bio-prone activities, while the building in Guimarães hosts engineering experimentation. These infrastructures comprise about 3.000 m^2 of laboratories and other technical facilities. The building of Braga includes an artificial stream facility, several laboratories for experimental biology, bioinformatics, mathematical modeling and a multifunctional space for scientific meetings, seminars and exhibitions. The building of Guimarães includes a laboratory for sustainability and innovation in construction, an outside space for long-term tests in construction and several versatile laboratories for bio-inspired and natural materials, sensors and monitoring, sustainable energy and energy efficiency.

Objectives:

The Institute of Science and Innovation for Bio-Sustainability (IB-S) originated as a new consortium between two research units from the University of Minho, the Molecular and Environmental Biology Research Centre (CBMA) and the Institute for Sustainability and Innovation in Structural Engineering (ISISE). The IB-S main purpose is the development of cutting-edge research and innovation in Sustainability Sciences with special focus on the combined sustainability of built and natural environments. IB-S is directly supported by the Rectorate from the University of Minho. The IB-S gathers experts on structural engineering, material sciences, molecular biology, ecology, mathematical modelling, microbiology, biotechnology, energy, electronics, communications, monitoring and sensor development, non-destructive testing, life cycle analysis, risk management, repair and strengthening, innovative materials and construction technologies, earthquake engineering and safety and durability. This highly multidisciplinary team allows IB-S to tackle broader topics in the field of Sustainable Sciences where Civil Engineering and Biology can contribute together or separately. The IB-S embodies cutting-edge R&D activity in close collaboration with the business community directed to the innovation on sustainability issues, namely the development of solutions for complex problems for which presently there are scarce technical tools available.

Description:

Mission

The mission of IB-S is to contribute to the development of a new social paradigm based on knowledge that produces wealth while ensuring that biological systems remain diverse. Innovative solutions will be developed for conservation and/or rehabilitation of natural and built environments. This entails the development of interdisciplinary practices, gathering specialists from diverse backgrounds to tackle complex problems in the scope of Sustainability Sciences. The IB-S houses teams of biologists, engineers, physics, mathematicians and others that will share laboratories side by side with spin-offs and companies in an innovative and stimulating work environment.

R&D(&I) activities of IB-S are in line with the need to increase the technological intensity of the industry in a sustainable manner, more socially and environmentally concerned. This broad objective addresses today's major societal challenges, and comes in agreement with the European Union Horizon 2020 policy. Also, IB-S strategic axes are aligned with the priority domains within the scope of the smart specialization strategy defined for the Portuguese region where it is located (North Region).

With a strategic decision on the implementation of IB-S, the University of Minho expects to achieve excellence in a mandatory area for our future. Applying sustainability principles and practices are often impossible due to the lack of adequate tools. Efficient technical solutions are not available to solve many of the sustainability issues in the planet. From these, the built environment is one of the major challenges for humankind in the next decades in need of a technical at multiple levels of novel materials, sensors, structures, networks and planning, always bearing in mind the respect for nature and long-term sustainability of resources. Challenges are such as maintaining built heritage, or guaranteeing the quality of basic human needs, like clean water and energy, within the intensively occupied regions without unaffordable efforts.

The main R&D areas of IB-S were set based on the following principles:

- Linkage with the "smart specialization strategy" for the North region of Portugal;
- Strong multidisciplinary approach taking advantage of the research expertise available within the scope of Sustainable Sciences;
- Validation by partners from private companies composing the Strategic Council of IB-S.

Functional Structure
IB-S is under the direct responsibility of the Rector of the University of Minho. The core of its functional structure is composed by:

Executive Director - Tiago Miranda - ISISE
Vice-Executive Director - Cláudia Pascoal - CBMA

Executive Committee:
Cândida Lucas (IB-S founding member) - CBMA
Paulo Lourenço (IB-S founding member) – ISISE

Strategic Council
The Strategic Council is an advisory body, whose roles are: assisting with the scientific strategic planning and other relevant decisions concerning the IB-S activities, and evaluation of the overall outcomes of the Institute.

The Strategic Council is also responsible for actively contributing to bridge researchers and industrials, shaping their vision according to global market demands and tendencies. This should allow products and services to more easily get into markets, levering growth and employment.

The Strategic Council is chaired by the Rector of the University of Minho and it is currently composed by the following members from the industry:

Construction: Mota-Engil; DST; MCA
Energy: EDP; New Energy Solutions
Venture Capital: BES Ventures; Pathena
Materials: Corticeira Amorim
Distribution and logistics: Sonae Sierra
Architecture: Topos Atelier

Research
The IB-S research is based in the two main axes, namely Sustainability and Energy. These cross with three main research clusters:

- **Urban rehabilitation**

Urban sustainability, urban metabolism, sustainable buildings, energy efficiency, bio-construction, eco-bio-materials and bio-inspired materials, intelligent materials and structures, material recycling, waste treatment/management.

- **Industrial ecology / natural resources**

New ways of producing, managing and optimizing natural resources, industrial waste, biodiversity management, and production processes. New tools for assessing environmental impacts and ecosystems services, and for ecosystem planning and restoration.

- **Sea, Coast and Ports/Environmental Management and Energy**

Exploitation of maritime resources, environmental management and protection/maintenance of coastal areas, off-shore solutions for energy production (wind and waves), coastal protection structures and optimized materials for maritime construction.

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i) ii)

Fig. 1 Infrastructure of IB-S: i) Azurém; ii) Gualtar.

IB·S INSTITUTE OF SCIENCE AND INNOVATION FOR BIO-SUSTAINABILITY

Large Valorisation on Sustainability of Steel Structures | LVS^3

(RFCS – Research Fund for Coal and Steel)

Financing Institution(s): RFCS – Research Fund for Coal and Steel

Promoting Institution(s): ArcelorMittal

Coordinator(s): Olivier Vassart (ArcelorMittal)

Partner Institutions: ArcelorMittal - ARCELORMITTAL BELVAL & DIFFERDANGE SA; UL - UNIVERZA V LJUBLJANI; CVTU - CESKE VYSOKE UCENI TECHNICKE V PRAZE; NTUA - NATIONAL TECHNICAL UNIVERSITY OF ATHENS; UPT - UNIVERSITATEA POLITEHNICA DIN TIMISOARA; University of Naples - UNIVERSITA DEGLI STUDI DI NAPOLI FEDERICO II; VGTU - VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS; ITB - INSTYTUT TECHNIKI BUDOWLANEJ; Tecnalia - FUNDACION TECNALIA RESEARCH & INNOVATION; Miscolci Egyetem - MISKOLCI EGYETEM; University of Coimbra – FCTUC; BFS – bauforumstahl; Tallinna Tehnikaulikool - TALLINNA TEHNIKAULIKOOL; CTICM - Centre Technique Industriel de la Construction Metallique; University of Liège; BmS - STICHTING BOUWEN MET STAAL; SBI - Stiftelsen Svensk Stålbyggnadsforskning – Stålbyggnadsinstitutet; AC&CS - ADVANCED COATINGS & CONSTRUCTION SOLUTIONS SCRL; Club Asturiano de la Innovación CAI

Period: July 2013 to December 2014

Relevant facilities: N/A

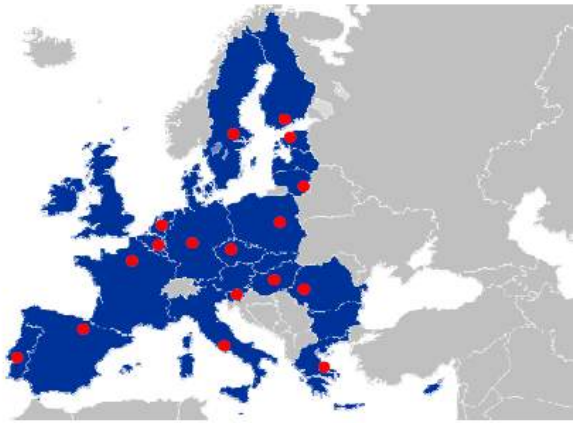
Objectives:

The technical objective of this project was to disseminate the knowledge acquired in the recent years about the environmental impact assessment of steel and composite buildings.
During the last decade, a lot of research projects have been funded to develop methodologies, systems and products aiming at improving the thermal efficiency as well as the global environmental footprint of steel buildings.
The new standard EN15804 intended for environmental calculation of buildings takes now into account the fact that steel is a recyclable material (Module D).
So the objective of this project was to summarise all this acquired knowledge into different documents (Background, Design guide, leaflet, User-friendly Software), to translate all these training and teaching support into the different European languages and finally to disseminate amongst Europe by the organisation of workshops in different countries.

Description:

The project was divided into 3 main parts:
- Creation of supporting documents (background, design guide, leaflet, Software, presentation…)
- Translation of documents into national languages.
- Dissemination of the knowledge into the different European countries.

In order to achieve the objectives of the project, the different parts were divided into the following work packages:
WP1: Realisation of documentation in English and software about the environmental assessment of steel and composite buildings
1.1 Preparation of the design guide
1.2 Preparation of the background documentation
1.3 Preparation of a 6 faces leaflet summarising the key messages relating to the environmental impact of steel and composite structures
1.4 Adaptation of the AMECO software
1.5 Adaptation of the Iphone and Ipad simplified calculation Software
1.6 Preparation of the PowerPoint presentations
WP2: Translation of the documentation and software interface:
The different versions of the documents (background document, the design guide, leaflet and the PowerPoint presentations), prepared in the frame of WP1, were translated in the different languages of the partners. Moreover, the Software Interfaces were translated in the different languages of the partners.
WP3: Training for partners involved in seminars:
The task of this WP was the organisation of an internal Workshop during which partners that have prepared the documents presented and explained the global approach as well as the Software based on the WP1 data. This ensured that all the seminars provided the same harmonised information.
WP4: Organisation of Seminars
The main task of this WP was the organisation of seminars in each of the participating countries.
Each partner was responsible for the organisation of the seminar in his country. This was organised on a University campus or in a conference centre.
The audience consisted of designers, architects, developers, future steel users such as students and professors, decision makers and authorities. During the seminar, printed documents as well as USB Keys that contain all data were distributed.



WP5: Post dissemination activities
After the seminars, all data was prepared for further dissemination. A homepage with all these data was created from which documents may be downloaded for free.

Publications:

Reports:
Background document (available from http://www.steelconstruct.com/site/)
Design guide (available from http://www.steelconstruct.com/site/)

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Email: hger@dec.uc.pt
URL: http://www.isise.net

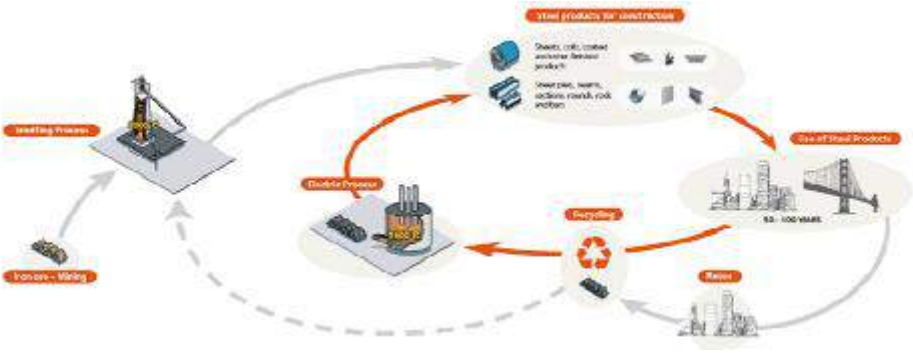

Fig. 1 Life cycle of steel structures.

Long-term structural and durability performance of concrete elements strengthened with the NSM technique | CutInDur

Financing Institution: FEDER funds through the Operational Program for Competitiveness Factors - COMPETE and National Funds through FCT - Portuguese Foundation for Science and Technology

Promoting Institution: University of Minho (UMinho)

Coordinator: José Sena-Cruz

Researchers and collaborators: José Sena Cruz, Miguel Azenha, Rui Ferreira, Vincenzo Bianco, Patrícia Silva, Pedro Fernandes, Mário Coelho, Tiago Teixeira

Partner Institutions: Not applicable

Period: March 2011 to September 2014

Relevant facilities: Laboratory equipment and facilities from the structural lab of UMinho (LEST); servo close-loop equipment, data acquisition and control equipment for experimental programs; universal testing machine; climatic chamber; tanks; FEMIX and DIANA softwares.

Objectives:

The main objective of present research project is to contribute to the knowledge on durability performance of the NSM technique with CFRP laminates under various specific application environments, load conditions and chemical degradation. The project involves three components: an experimental program, a numerical simulation and design recommendations. The experimental program was supported by accelerated ageing tests using two distinct scales: bond test specimens and flexural tests with slabs of quasi-real scale. With these specimens the following effects were studied: chlorides, sustained stress (creep), freeze-thaw, wet/dry, thermal cycles, and fatigue. The test results obtained from the experimental programs are used for predicting the service life of NSM technique supported in some numerical models.

Description:

Over the last two decades, extensive research has been developed on the strengthening of reinforced concrete (RC) structures using the externally bonded reinforcement (EBR) technique with fiber reinforced polymer (FRP) materials. This technique yielded several scientific publications, design guidelines and practical projects, worldwide. More recently, the near-surface mounted (NSM) FRP reinforcement technique has attracted an increasing amount of research, as well as practical applications. The NSM technique consists of inserting FRP bars into saw cuts grooves made in the concrete cover of the elements to be strengthened. The FRP is fixed to concrete with a groove filling material, e.g. epoxy adhesive. The NSM technique became a real alternative to the EBR one, due to the several advantages, namely: (i) reduction of amount of site installation work; (ii) less prone to the debonding; (iii) easier to anchor into adjacent members to prevent debonding failures; (iv) higher strengthening effectiveness; (v) more protected by the concrete cover and so are less exposed to accidental impact and mechanical damage, fire, and acts of vandalism; (vi) the aesthetic of the strengthened structure is virtually unchanged; (vii) in some cases, the ultimate strength of FRP can be reached. When compared with the EBR, the existing knowledge on the NSM reinforcement is much more limited. However, international institutions, such ACI (American Concrete Institute) recently included in the document ACI 440.2R-08 design guidelines for the flexural strengthening with the NSM technique and fib (Federation Internationale du Béton) TG 9.3 are currently considering revisions to their documents to include NSM-related provisions.

The project involves three components: an experimental program, a numerical simulation and design recommendations. The experimental program will be supported by accelerated ageing tests using two distinct scales: specimens for bond tests and slabs of quasi-real scale (see Fig. 1). With these specimens the following effects were studied: moisture, chlorides, creep, freeze-thaw, thermal cycles and fatigue (see Fig. 2). The results obtained from the experimental programs are used for predicting the service life of structures strengthened with the NSM technique supported in numerical models. These numerical models were implemented in the finite elements software designated FEMIX. 2D and 3D models were used in the simulation of the structural elements. The concrete is simulated using an elasto-plastic multi-fixed smeared crack model. The FRP is assumed as linear elastic until the ultimate stress is reached. Adequate models are used to simulate the interfaces FRP bar/epoxy (BEI) and epoxy/concrete (ECI). The degradation effects referred before are reflected in the constitutive models of concrete, FRP, epoxy, BEI and ECI. Design recommendations are elaborated using the results obtained in the experimental programs and in the parametric studies performed by numerical simulations. Some results of creep and fatigue tests are shown in Figs. 3 and 4. Fig. 5 shows a panoramic photo of the durability tests.

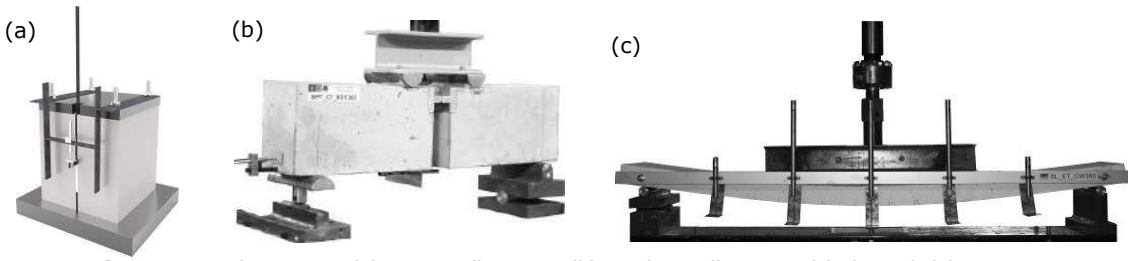

Fig. 1 Test configurations: (a) Direct pullout test; (b) Bending pullout test; (c) Flexural slab test.

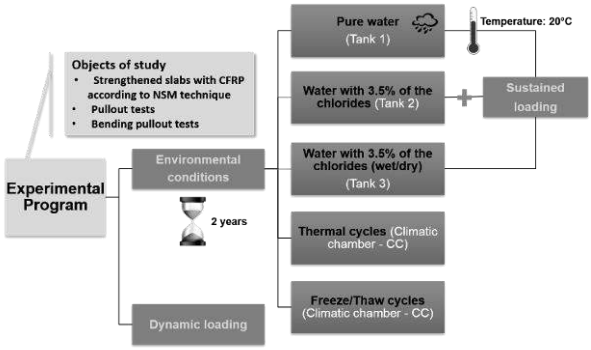

Fig. 2 Experimental program.

Creep results of slabs

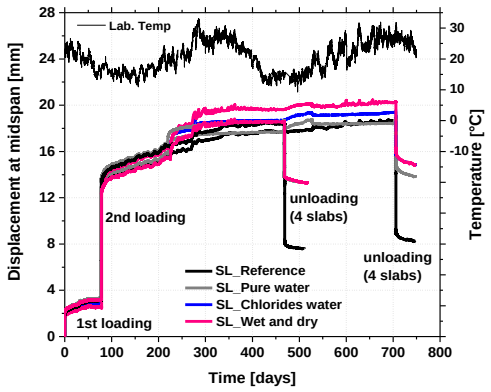

Fig. 3 Creep of slabs submitted to different environmental conditions.

Fatigue results of direct pullout test

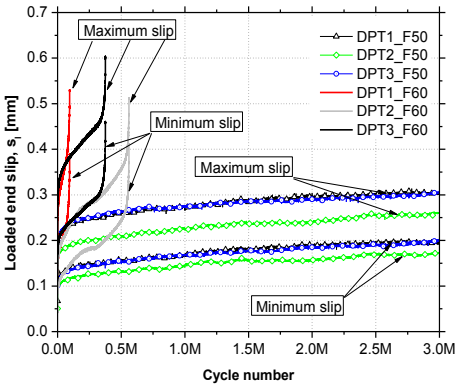

Fig. 4 Loaded end slip of pullout specimens versus cycle number for different load levels.

Publications:

Seminar - 1
Book - 1
PhD thesis - 3
MSc theses – 6
Papers in International Journals - 7
Papers in International Conferences - 8
Papers in National Conferences - 7
Reports – 7

Detailed results can be found in: www.sc.civil.uminho.pt

Awards

In the scope of the conference FRPRCS 11, held in Guimarães from 26-28 June, in the contest "Best Poster Award" the team of CutInDur won the prize for the best poster on the theme "Creep behavior of concrete elements strengthened with NSM CFRP laminate strips under different environmental conditions."

In the "I Workshop of the PhD Students in Civil Engineering" Patricia Silva won the prize for the best poster "Long-term behavior and durability of reinforced concrete slabs strengthened with NSM CFRP flexurally strips".

In the scope of COST Action TU1207, held in Kaiserslautern, Germany (23 October of 2014), in the contest "Best Poster Award" the team of CutInDur won the prize for the best poster on the theme "Long-term structural and durability performance of concrete elements strengthened with the NSM technique."

Acknowledgements:
This work was supported by FEDER funds through the Operational Program for Competitiveness Factors - COMPETE and National Funds through FCT - Portuguese Foundation for Science and Technology under the project CutInDur PTDC/ECM/112396/2009. The authors also like to thank all the companies that have been involved supporting and contributing for the development of this study.

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Fig. 5 Panoramic photo of the durability tests.

New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk | NIKER

Financing Institution(s): European Commission (FP7)

Promoting Institution(s): University of Padova, Italy

Coordinator(s): Claudio Modena (UniPd) and Paulo B. Lourenço (UMinho)

Researchers and collaborators: Paulo B. Lourenço, Daniel V. Oliveira, Graça Vasconcelos, Luís Ramos and Francisco Fernandes (only UMinho researchers listed)

Partner Institutions: Università Degli Studi di Padova (Italy), Federal Institute for Materials Research and Testing (Germany), Institute of Theoretical and Applied Mechanics (Czech Republic), National Technical University Athens (Greece), Politecnico di Milano (Italy), Universidade do Minho (Portugal), Universitat Politecnica de Catalunya (Spain), University of Bath (UK), Gazi University (Turkey), Ecole Nationale d'Architecture (Morocco), Cairo University (Egypt), Israel Antiques Authority (Israel), Bozza Legnami (Italy), Cintec International (UK), Interprojekt (Bosnia and Herzegovina), S&B Industrial Minerals (Greece), ZRS Ziegert Seiler Ingenieure (Germany), Monumenta (Portugal)

Period: January 2010 to December 2012

Relevant facilities: Laboratory facilities: shaking tables; strong floors and reaction walls; several universal hydraulic tension-compression load frames, closed-loop servo-controlled actuators and data acquisition and control equipment; climatic chambers; diverse day-to-day laboratory equipment - Computational facilities: advanced FE numerical tools.

Objectives:

The NIKER project proposes the development of a new integrated methodology aiming at improving the general safety level and reducing the loss of artistic value of Cultural Heritage assets. Such a methodology relays on a multidisciplinary approach for the development of innovative materials and systems for low-intrusiveness, compatible interventions.

Thus, on the basis of real application conditions, the project aims at developing and validating complete and diversified innovative technologies and tools for systemic improvement of seismic behaviour of Cultural Heritage assets.

Description:

NIKER is a collaborative research project funded by the European Commission under the 7th Framework Programme, aiming at the protection of Cultural Heritage from earthquake-induced risk.

The project tackles the problem of earthquake-impact on Cultural Heritage assets starting from consideration that efficient protection can only be achieved on the basis of the "minimum intervention" approach.

The NIKER project encompasses the active participation of eighteen partners, representatives of Universities, Research Centres, Public Organizations, and Private Companies from twelve Countries of Europe and the Mediterranean Basin. The NIKER achievements are listed below in a synthetic way:

- Creation of a new structured database that links earthquake induced failure mechanisms, construction types and materials, interventions and assessment techniques;
- Development of advanced materials and improved techniques for intervention on structural elements;
- Development of innovative intervention techniques for connections (wall-to-wall; floor-to-wall; roof-to-wall), able to dissipate seismic energy (stick-slip based prototype and a hysteretic dissipation prototype) with embedded early warning systems for deformation and accelerations;
- Experimental validation of proposed technological solutions for vertical structural elements (walls and pillars) and horizontal structural elements (floors, roofs and vaults);
- Experimental quantitative characterization of the behaviour of connections before and after strengthening, including the development of quasi-static cyclic procedures and shaking table test set-ups;
- Development of test set-ups and testing strategies for sub-assemblies and experimental characterization of the seismic behavior of original substructures and substructures strengthened with integrated interventions (combination of interventions on horizontal and vertical structures and connections) by shaking table tests;
- Integration, validation and assessment of intervention techniques by experimental evaluation of overall seismic response of model buildings on shaking table;
- Derivation of reliable constitutive models for connections and substructures;
- Development of integrated methodologies that include i) monitoring as knowledge-based assessment and early warning tool; ii) creation and update of reliable structural models; iii) selection, design, and application of minimized interventions; iv) evaluation of execution of intervention; v) step-by-step procedure in the application of interventions;
- Implementation of the project results into guidelines for an integrated applicability of the proposed methodologies and subsequent transfer into codes of practice and standards.

Publications:

PhD theses:

Poletti, E. (2013) Characterization of the seismic behaviour of traditional timber frame walls, PhD Thesis, University of Minho, available at http://hdl.handle.net/1822/28845

Silva, R. (2013) Repair of earth constructions by means of grout injection, PhD Thesis, University of Minho, available at http://hdl.handle.net/1822/28793

Ghiassi, B. (2013) Durability analysis of bond between composite materials and masonry substrates, PhD Thesis, University of Minho, available at http://hdl.handle.net/1822/28878

Araújo, A. (2014) Modelling of the seismic performance of connections and walls in ancient masonry buildings, PhD Thesis, University of Minho

ISI papers:

Valluzzi, M.R., Oliveira, D.V., Caratelli, A., Castori, G., Corradi, M., de Felice, G., Garbin, E., Garcia, D., Garmendia, L., Grande, E., Ianniruberto, U., Kwiecień, A., Leone, M., Lignola, G.P., Lourenço, P.B., Malena, M., Micelli, F., Panizza, M., Papanicolaou, C.G., Prota, A., Sacco, E., Triantafillou, T.C., Viskovic, A., Zając, B., Zuccarino, G. (2012) Round Robin test for composite-to-brick shear bond characterization, Materials and Structures, 45(12), 1761-1791, 10.1617/s11527-012-9883-5

Ghiassi, B., Marcari, G., Oliveira, D.V., Lourenço, P.B. (2012) Numerical analysis of bond behaviour between masonry bricks and composite materials, Engineering Structures, 43, pp. 210-220, 10.1016/j.engstruct.2012.05.022

Silva, R.A., Schueremans, L., Oliveira, D.V., Dekoning, K., Gyssels, T. (2012) On the development of unmodified mud grouts for repairing earth constructions: rheology, strength and adhesion, Materials and Structures, 45(10), 1497–1512, 10.1617/s11527-012-9853-y

Ghiassi, B., Oliveira, D.V., Lourenço, P.B., Marcari, M. (2013) Numerical study of the role of mortar joints in the bond behavior of FRP-strengthened masonry, Composites Part B, 46, pp. 21-30, 10.1016/j.compositesb.2012.10.017

Ghiassi, B., Oliveira, D.V., Lourenço, P.B. (2014) Hygrothermal durability of bond in FRP-strengthened masonry, Materials and Structures, 47(12), pp. 2039-2050, 10.1617/s11527-014-0375-7

Moreira, S.M., Ramos, L.F., Oliveira, D.V., Lourenço, P.B. (2014) Experimental behavior of masonry wall-to-timber elements connections strengthened with injection anchors, Engineering Structures, 81, pp. 98-109, 10.1016/j.engstruct.2014.09.034

Araújo, A.S., Oliveira, D.V., Lourenço, P.B. (2014) Numerical study on the performance of improved wall-to-wall connections in traditional masonry buildings, Engineering Structures, 80, pp. 501-513, 10.1016/j.engstruct.2014.09.027

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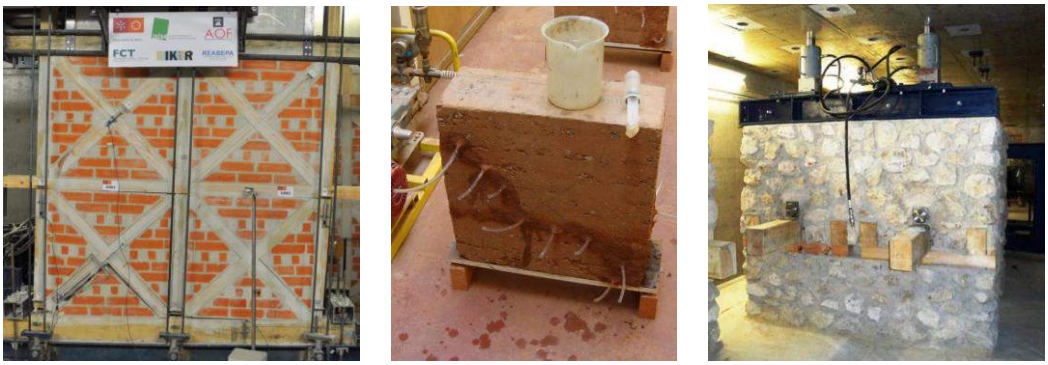

Fig. 1 Experimental activities on half-timbered walls, rammed earth and structural connections.

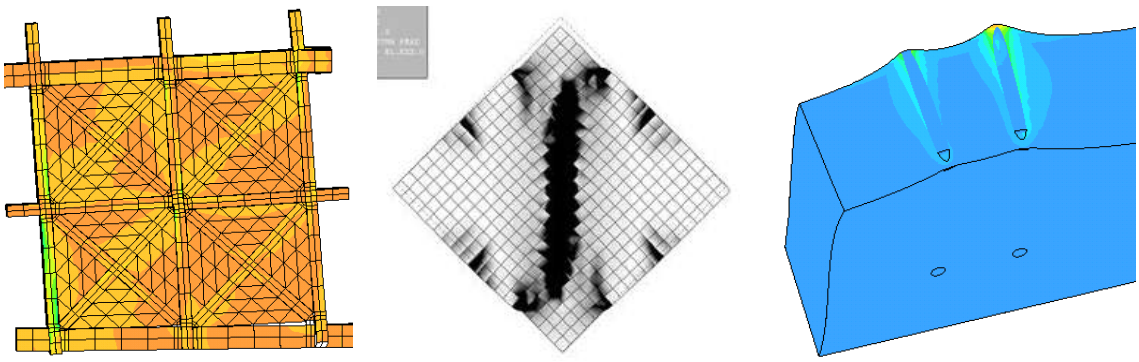

Fig. 2 Numerical activities on half-timbered walls, rammed earth and structural connections.

Optimization of frames for effective assembling | FRAMEUP

(RFCS – Research Fund for Coal and Steel)

Financing Institution(s): RFCS – Research Fund for Coal and Steel

Promoting Institution(s): Lulea University of Technology (LTU)

Coordinator(s): Milan Veljkovic (LTU)

Researchers and collaborators: M. Veljkovic, P. Andrade, J. P. Jaspart, J. F. Demonceau, L. V. Long, M. A. Hernandez, L. S. Silva, C. Rebelo, R. Simoes, H. Gervásio, G. Vicente, N. Lundholm, A. Lundholm, M. Feldmann, D. Pak, D. Pyschny, C. Remde, S. Herion

Partner Institutions: Lulea University of Technology, Sweden; University of Liège, Belgium; ACCIONA Infraestructuras S.A., Spain; University of Coimbra, Portugal; PartConstruction AB, Sweden; RWTH Aachen University, Germany; V&M Deutschland GmbH, Germany.

Period: July 2011 to June 2014

Relevant facilities: Laboratories with modern equipment for mechanical testing and instrumentation, computational equipment of civil engineering departments.

Objectives:

The project aims to develop and test a new concept of execution technique for a skeletal system with 3D modules structurally integrated, and to establish the structural performance of the joints developed for this application. The new execution technique starts with the assembling of the roof and the top floor at ground level, in order to get a rigid body which will be lifted up by lift towers and jacks. Then the procedure is successively repeated to assemble the lower floors. With this execution method the protection of the structure against the weather adversity, as rain and moisture, is assured by the own structure. The research intends to define the limits of application where the concept is competitive when compared to the existing building alternatives taking into account a complete sustainability assessment.

Description:

The idea under investigation in this project is the TOP-DOWN CONSTRUCTION, i.e., the technique of starting the construction by the roof and lift it enabling the assembly of the lower floor, repeating the lifting process as times as required to finish the building.

The research will be developed in 5 stages. In the first stage it will be developed the concept of a new type of execution technique for a skeletal system primarily used to construct buildings with prefabricated steel 3D modules. The concept will be tested by computer simulations using a tool for virtual engineering which allows the identification of the possible conflicts in the execution process, including the transfer of the modules from the trucks to the skeletal system which is an integral part of the new execution technique. The execution technique starts with the assembling of the roof and the top floor in order to get a rigid structure that will be lifted up by jacks. Each storey is assembled at the ground level and then lifted up to create place for the next storey. This method will allow the protection of every storey, completed with 3D modules with a traditional composite slab or with a concrete deck, from the atmospheric precipitation and moisture damage during the assembling phase. This method using jacks instead of cranes expects to be safer and drier. It also provides the reducing of the construction site area and the minimization the neighbourhood disturbance.

The second stage involves the development, testing and the establishment of the structural performance of a new type of joints. The joints will be carried out for tubular cross sections of columns and beams. The joints will be designed in order of supporting all the acting forces (erecting and service stages) and improving the required time of assembling and disassembling.

In the third stage, the limits of application of the execution technique will be evaluated concerning the structural safety and feasibility, including a robustness assessment of the building.

The fourth stage consists on the construction of the pilot building with 3 storeys and respective monitoring during execution and service phases.

At the last stage it is intended to achieve a holistic view of the optimized building technology with 3D modules using the innovative erection technique. The type of innovative execution technique used is influenced by the architectural demands which determine the structural solution. Therefore, the following buildings with 2D prefabricated walls will be compared with the 3D modulus integrated into the skeletal system:

- buildings with composite slab floors and light-weight walls,
- buildings with hollow core decks and light-weight walls.

Special focus will be given to the comparison of the evaluation criteria for life cycle analysis (LCA) with the same system boundaries and life cycle costs (LCC) focusing on energy efficiency (thermal performance) of the building alternatives considered. Monitoring of the energy consumption will be performed on a pilot building and results will be compared with available calculation methods.

Publications:

Reports:
FRAMEUP_annual report No1-2012-03-30

Conference proceedings
Guiomar S. F. Vicente, Rui A. D. Simões, Carlos A. S. Rebelo, Luís S. Silva and Milan Veljkovic - " Moment resisting bolted joints connecting steel tubular sections". Proceedings of Eurosteel 2014 - 7th European Conference on Steel Structures, 10-12 September 2014, Naples, Italy.

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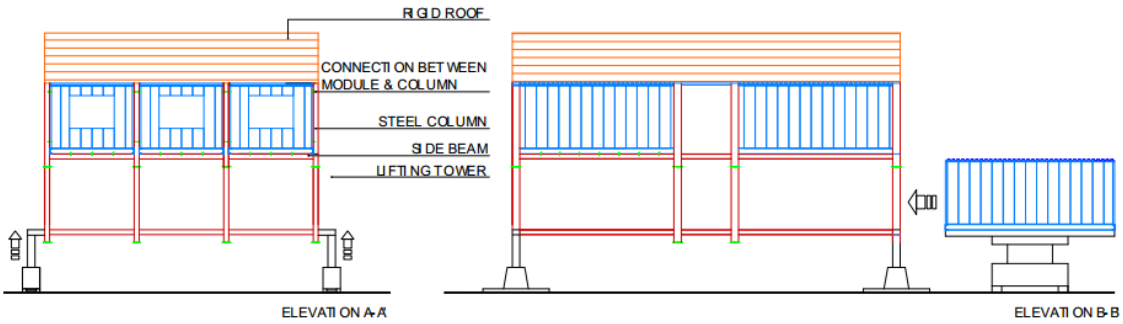

Fig. 1 Top-down construction (2D sketch).

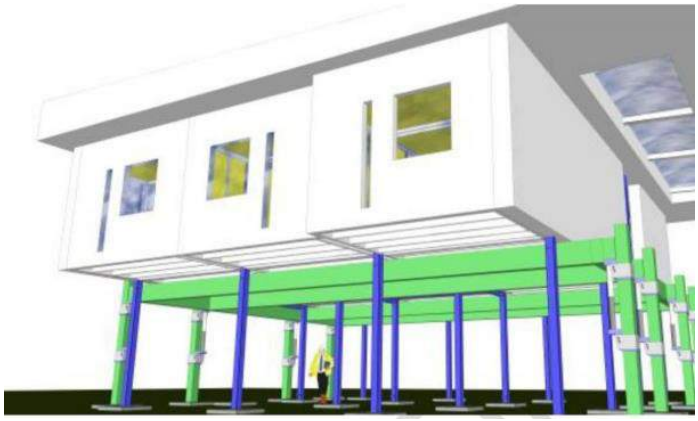

Fig. 2 Top-down construction (3D sketch).

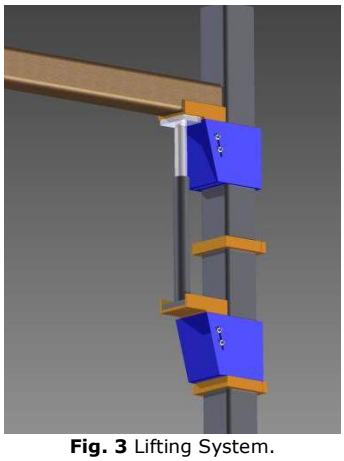

Fig. 3 Lifting System.

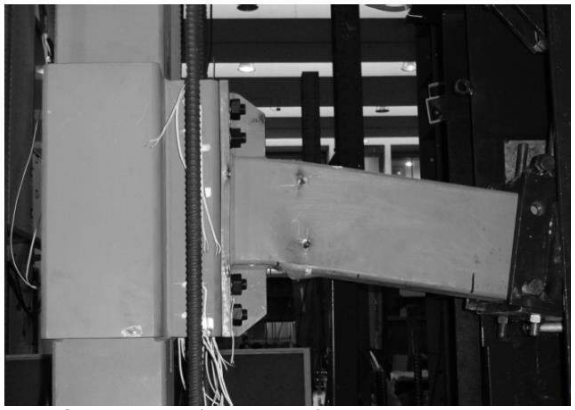

Fig. 4 Beam-column joint after a monotonic test.

Fig. 5 Test in a beam-column joint at high temperatures.

Painéis de Fachada em Betão Eco-Eficiente de Base Geopolimérica com Incorporação de Resíduos | EcoFachada

Financing Institution(s): ADI

Promoting Institution(s): PréGaia-PréFabricados, Lda e Universidade de Coimbra

Coordinator(s): Eduardo Júlio & Paulo Santos

Researchers and collaborators: Eduardo Júlio, Paulo Santos, Luís Ferreira, Inês Barata, Cláudio Martins, Jorge Coelho, Paulo Maranha Tiago

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE)

Period: October 2010 to October 2013

Relevant facilities: Laboratory equipment and facilities of Civil Engineering Department of University of Coimbra

Objetivos:

Os principais objetivos deste projeto e os principais problemas a tratar são: (1) Desenvolver um FRC adequado à "super-pele"; (2) Desenvolver um sistema robusto e economicamente viável de monitorização da "super-pele"; (3) Estudar o comportamento da ligação FRC/NC (betão corrente), visando a utilização deste método na reabilitação de estruturas existentes; (4) Estudar o comportamento da ligação FRC/LWAC (betão de agregados leves), visando a sua utilização em elementos novos prefabricados, cuja utilização tem tendência a aumentar na construção, tendo o LWAC vantagens óbvias nesta situação; (5) Modelar numericamente o comportamento estrutural de elementos de betão com uma "super-pele" em FRC, atendendo a que só com uma abordagem combinada experimental-numérica é possível compreender em profundidade os fenómenos envolvidos; (6) Testar a eficácia do conceito em protótipos, considerando as situações de reabilitação e de construção nova; (7) Partindo das bases científicas da ideia, submeter uma proposta de desenvolvimento de produto, em cooperação com a indústria.

Description:

Nowadays, sustainability should be a major R&D priority in the construction sector. Within this research topic, the main goal of this project is the development of a new product: precast façade panels with geopolymer concrete integrating industrial wastes. Indeed, the use of these façade panels improves the thermal behaviour of buildings and the replacement of cement by an eco-efficient material such as metakaolin, reduces the CO2 emissions per m^3 of concrete produced. Additionally, when the cement is replaced by industrial wastes with pozzolanic properties, such as those resulting from coal-fired power-plants, besides the reduction of pollution inherent to the production of raw materials, also promotes the recycling of industrial waste. In this research project the performance of the new developed panels was characterized, including the thermal behaviour, mechanical resistance and durability.

Publications:

Papers

I. Barata, A. Fonseca, C. Costa, L. Ferreira, E. Júlio, J. Coelho, Insights into the thermo-mechanical properties of films cast from emulsion terpolymers, Progress in Organic Coatings 77 (4), 790-797 (2014)

L. Ferreira, H. Costa, I. Barata, E. Júlio, P. Tiago, JFJ Coelho, Precast alkali-activated concrete towards sustainable construction, Magazine of Concrete Research 66 (12), 618-626 (2013)

L. Ferreira, I. Barata, E. Júlio, J. Coelho, P. Tiago, Produção de Painéis de Fachada com Betão Ativado Alcalinamente, Construção Magazine 52, 12-15 (2012)

Conference proceedings

L. Ferreira, I. Barata, E. Júlio, J. Coelho, Formulação de Argamassas Ativadas Alcalinamente, Encontro Nacional BETÃO ESTRUTURAL - BE2012, 9 (2012)

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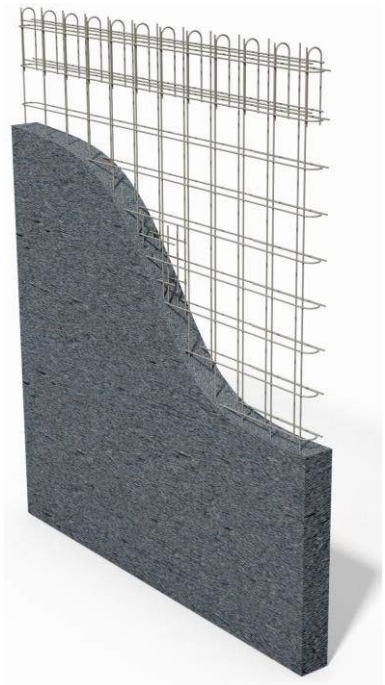


Fig. 1 Model of the new panel prototype.

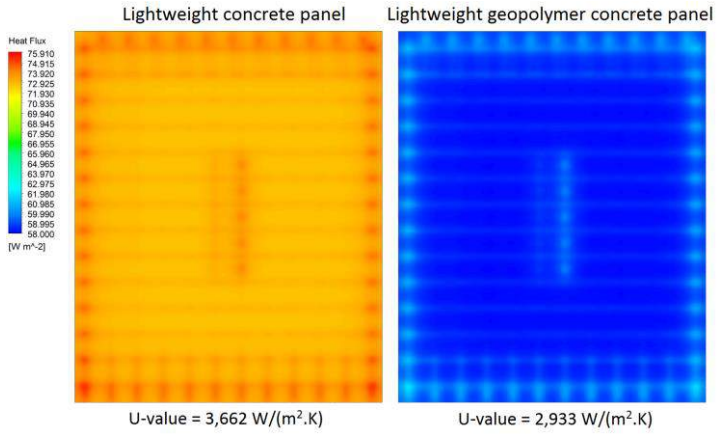


Fig. 2 Heat flux and thermal transmittance values (U).

Performance of reinforced concrete structures strengthened in flexural with an innovative system using prestressed NSM CFRP laminates | PRELAMI

Financing Institution(s): FCT

Promoting Institution(s): University of Minho (UM)

Coordinator(s): Salvador Dias

Researchers and collaborators: Joaquim Barros, José Sena-Cruz, Vincenzo Bianco, Gláucia Dalfré, Inês Costa, Mohammad Ali Rezazadeh, Mohammad Reza Hosseini

Partner Institutions: University of Minho (UM), Clever Reinforcement iberica - Materiais de Construção Lda (S&P).

Period: April 2011 to September 2014

Relevant facilities: Servo close-loop equipments for experimental programs; FEMIX V4.0 Finite Element package

Objectives:
In the present research project it is assessed the performance of Reinforced Concrete (RC) structures (beams and slabs) strengthened in flexure using an innovative system with Carbon Fibre Reinforced Polymer (CFRP) laminates. This system is based on the application of CFRP laminates with a certain prestress into thin slits open on the concrete cover of the structural elements to strengthen. The present project intends to develop a strengthening system, economically and technically viable, that assures the optimal use of durable and high strength materials (CFRP) in order to significantly improve the overall performance of the strengthened RC structures.

Description:
Existing studies confirm that among the strengthening techniques with passive CFRP materials, Near Surface Mounted (NSM), based on the installation of CFRP laminates into thin slits opened on the concrete cover of the elements to be strengthened, is the most effective. However, adopting a better use of the high performance of the CFRP, it is still possible to innovate the NSM technique in order to improve the performance of strengthened RC structures. Exploratory numerical and experimental work carried out by the research group that is part of this project concluded that between the phase of the concrete crack initiation and yielding of the steel longitudinal reinforcement, the effectiveness of existing NSM technique can be extraordinarily increased if CFRP laminates are applied with a certain prestress level. The prestress applied to the CFRP can also be used to recover part of the deformation of the structure, leading to closure of existing cracks, with consequent benefits in terms of durability and structural integrity. The prestress can also contribute to increase the shear capacity of the RC elements.

In the first part of the project it was created the strengthening system that includes the development of the devices to apply the NSM prestress technique (Fig. 1). The loss of prestress in the CFRP is too dependent on the creep behaviour of the adhesive due to the mechanism formed of micro struts and ties in the stress transference between laminate and surrounding concrete through the adhesive. Therefore a special attention was given in the creep behaviour of the adhesives (Fig. 2).

The assessment of the NSM CFRP-adhesive-concrete bond was performed in the early age of the epoxy adhesive in terms of the time optimization in the process of the laminates stress transfer to the surroundings. The prestressing transfer length was defined as well as the evaluation of the prestress losses.

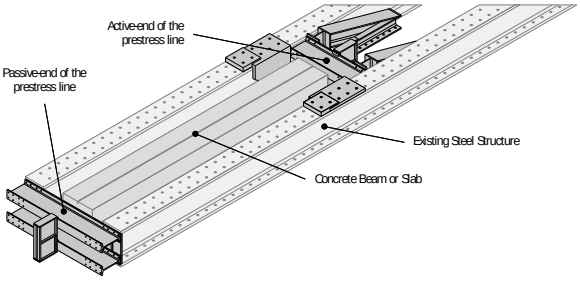


Fig. 1 Prestress system.

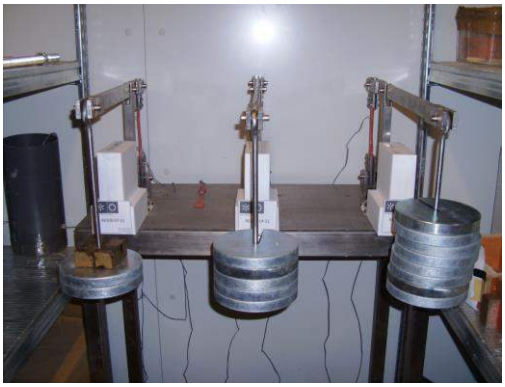
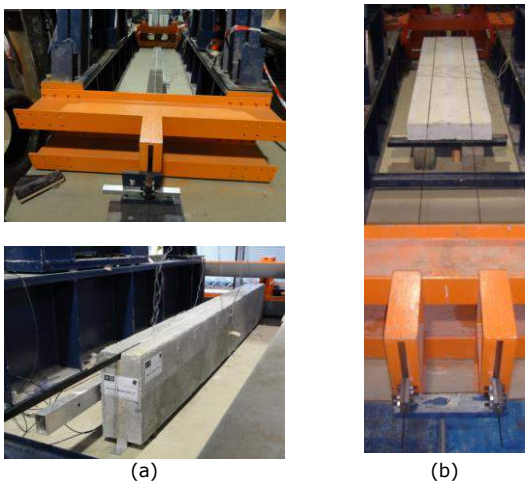


Fig. 2 Creep table.

The project investigated the experimental behaviour of RC structures (beams and slabs) flexural strengthened with the developed innovative NSM system (Figs. 2, 3 and 4). The prestress level, the concrete quality, the percentage of longitudinal steel reinforcement and the level of damage in the structure prior to the strengthening are parameters that were assessed.



(a) (b)

Fig. 2 (a) RC beam with one prestressed NSM CFRP laminate, and (b) RC slab with two prestressed NSM CFRP laminates.

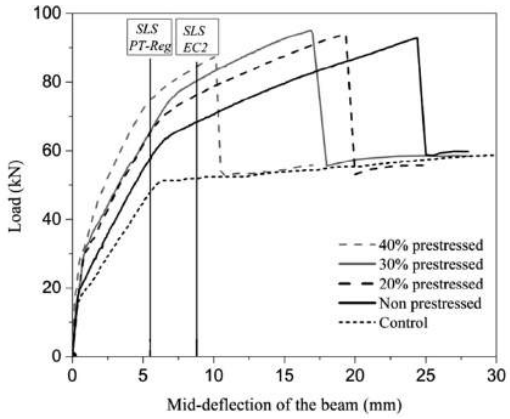


Fig. 3 Force *vs.* mid-span deflection of RC beams (Control beam without CFRP; beams with NSM CFRP laminates with different level of prestress: 0%, 20% and 40%).

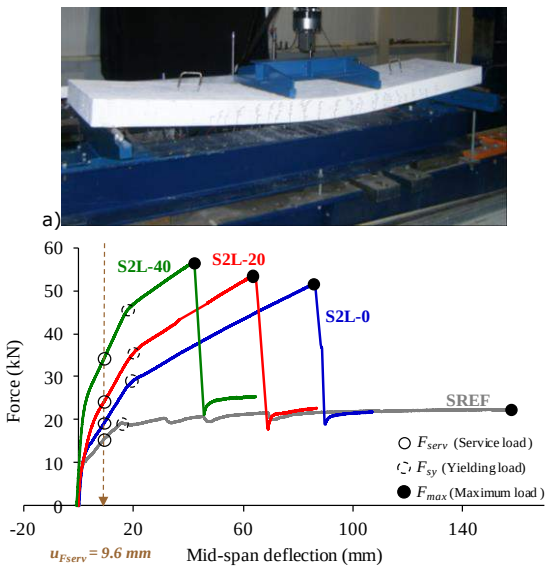


Fig. 4 (a) Four point bending tests, (b) Force *vs.* mid-span deflection (Reference slab without CFRP (SREF); prestressed slabs: 0% (S2L-0), 20% (S2L-20) and 40% (S2L-40).

Due to the susceptibility of the long-term behaviour of adhesives and the concrete-adhesive and adhesive-laminate interfaces to the fatigue loads, and since the technique to develop is quite appropriated for RC bridge decks, where fatigue is an important load case, flexural fatigue tests were be carried out in order to evaluate the influence of the cyclic load, the amplitude and the average load applied to the RC elements, in terms of the effectiveness of the technique.

Based on the experimental results obtained in the project and the results of numerical studies, application of rules and design of the strengthening system with prestressed NSM CFRP laminates were done.

Experimental and numerical research were also done in the Prelami Project for the evaluation of the performance of a NSM hybrid flexural strengthening technique that combines non-prestressed and prestressed CFRP laminates in the same application (Fig. 5) in order to provide a good balance in terms of load carrying and ultimate displacement capacity to the strengthened elements.

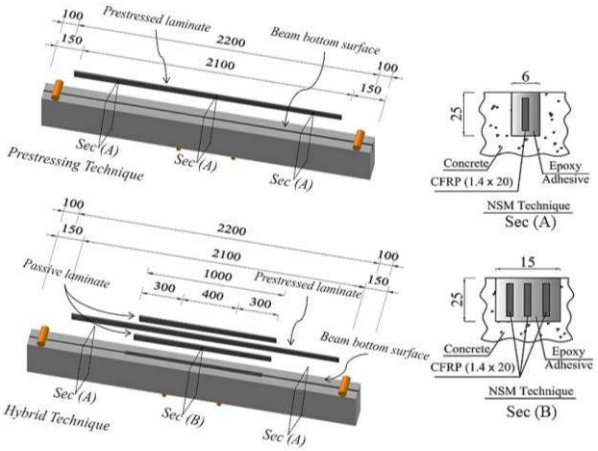


Fig. 5 CFRP reinforcement details of hybrid and prestressing NSM techniques (dimensions in mm).

Publications:

Books: 1
International journals (ISI): 9
International journals (N/ISI): 1
International conference: 7
National conference: 4
Reports: 3

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Pre-fabricated thin panels using advanced materials for structural rehabilitation | PrePAM

Financing Institution(s): FCT

Promoting Institution(s): University of Minho (UMinho)

Coordinator(s): Joaquim Barros

Researchers and collaborators: Ali Edalat Behbahani, Eduardo Pereira, Esmaeel Esmaeeli, Hadi Baghi, Joaquim Barros, Jorge Costa, José Sena Cruz, Lúcio Lourenço, Isabel Valente, Miguel Azenha, Rajendra Kumar Varma, Salvador Dias, Vítor Cunha

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE).

Period: 01/04/2011 to 31/08/2014

Relevant facilities: Laboratory and computational facilities of Civil Departments of UMinho and UAveiro.

Objectives:

The Objective of this project is to develop a new technique, using Strain Hardening Cementitious Composite (SHCC) and Carbon Fiber Reinforced Polymer (CFRP), for increasing the shear and flexural capacity of Reinforced Concrete (RC) beams. The effectiveness of new technique is assessed by some experimental programs. This technique is called Hybrid composite Plate (HCP). HCP is a thin plate of SHCC reinforced with CFRP laminates. Due to the excellent bond conditions between SHCC and CFRP laminates, these reinforcements provide the necessary tensile strength capacity to the HCP, while the high post-cracking tensile deformability and resistance of SHCC avoids the occurrence of premature fracture failure of this cement composite in the stress transfer process between these two materials when the HCP is crossed by a shear crack. Advanced numerical simulations are performed by using a FEM-based computer program, whose predictive performance was demonstrated by simulating the experimental tests carried out.

Description:

In the PrePam project the effectiveness of Hybrid Composite Plates (HCPs) for the shear and flexural strengthening of the RC beams and beam-column joint was assessed by some experimental programs. HCP is a thin plate of Strain Hardening Cementitious Composite (SHCC) reinforced with Carbon Fiber Reinforced Polymer (CFRP) laminates. To bond the CFRP laminates into the SHCC plate, slits were opened on the surface of the plates and the CFRP laminates were embedded into the SHCC plates using an appropriate epoxy adhesive (Fig. 1).

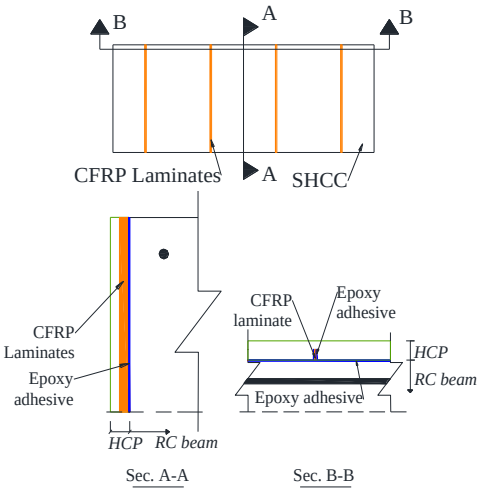

Fig. 1 Configuration of the HCP for strengthening of RC beams.

The HCPs are bonded to the substrate using epoxy adhesive. The strengthening contribution of the HCPs is limited by the tensile strength of the concrete of the strengthened beams (Fig. 2). Therefore, mechanical anchors are used to fix the HCPs to the beams and joint. They prevented a premature debonding of the HCPs and a certain concrete confinement is introduced in the zone of the joint to be strengthened, resulting favorable effects in terms of shear strengthening.

Fig. 2 Debonding of the HCPs.

Structural concept

The beam-column joints tested under cyclic load (Fig. 3) and beams under monotonic (three point bending) test (Fig.4).

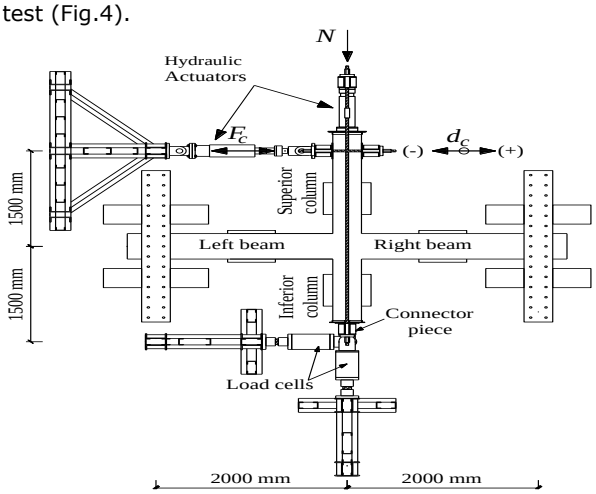

Fig. 3 Test setup adopted for beam column joints.

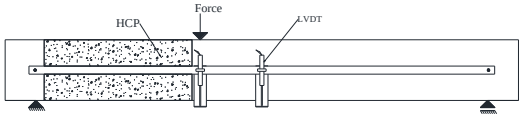

Fig. 4 test setup for shear test.

Construction process

The HCPs were applied to their corresponding substrate 5 days after the application of the CFRP laminates in order to guarantee a proper curing of the adhesive. To apply the SHCC/HCPs to the corresponding substrate, the following procedures were executed: 1) a 1-2mm roughness with sandblast was executed in the concrete substrate to improve the bond conditions between SHCC/HCPs and substrate; 2) some holes were drilled through web of the beam with for the installation of mechanical anchors as illustrated in Fig. 5; 3) the surfaces of the beams were cleaned by compressed air; 4) an epoxy adhesive (S&P220) layer of a thickness of about 1mm was homogenously applied in the surfaces of the concrete substrate and of the HCPs that would be in contact; 5) the HCPs were fixed to the concrete substrate of mechanical fasteners composed of bolts and nuts.

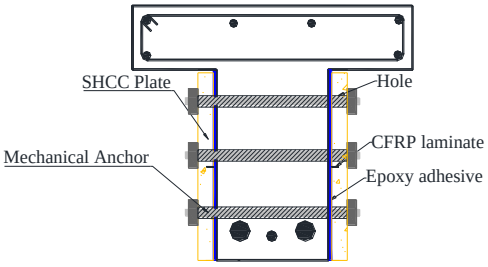

Fig. 5 position of the bolts inside of the RC beams.

Hysteretic and monotonic responses

The beam column-joints under cyclic load showed a superior performance in terms of hysteretic response (Fig.6), energy dissipation capacity, lateral load carrying capacity, beams flexural resistance and degradation of the secant stiffness than the corresponding values recorded when these specimens were tested in their virgin state (Fig .7)

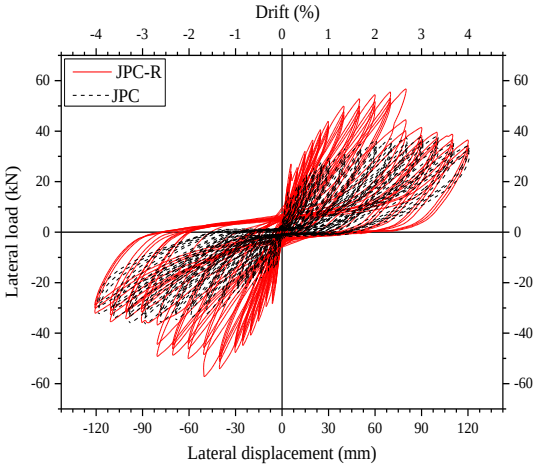

Fig. 6 Hysteretic responses.

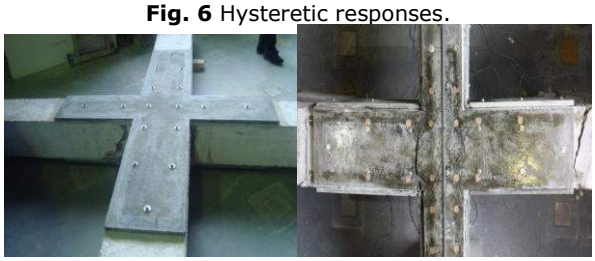

Fig. 7 Beam column joint before and after test.

HCPs were efficient for the increase of the shear capacity of the RC beams. The results showed that the load carrying capacity of the strengthened beam with HCPs was around 2 times of its reference beam (without HCPs) (Fig. 8).

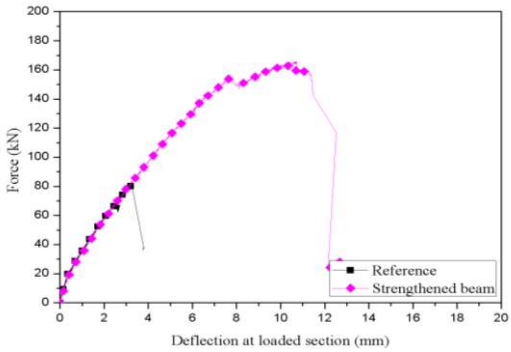

Fig. 8 Load deflection.

Numerical Simulation

Advance numerical simulations have been carried out to contribute for a better understanding of the effectiveness of the shear strengthening technique with HCPs. These simulations have fitted with high accuracy the deformational and the crack pattern of the tested beams (Fig. 9).

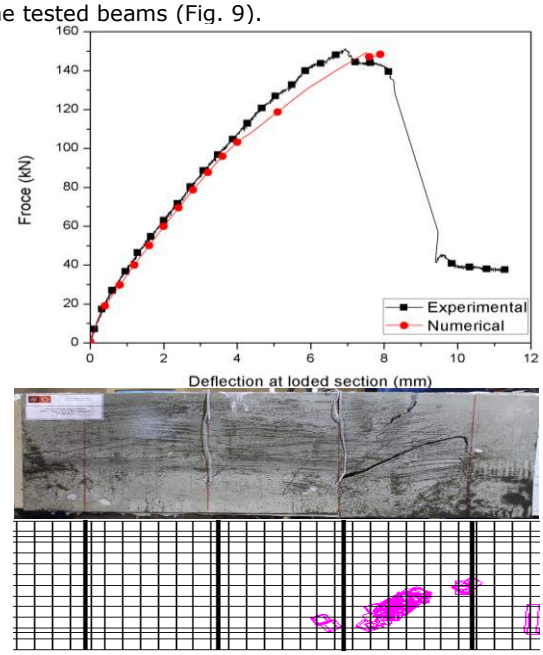

Fig. 9 the result of the numerical simulation.

Publications:

Nº of papers in ISI international journals: 8
Nº of papers in non ISI international journals: -
Nº of papers in national journals: -
Nº of papers in international conferences: 9
Nº of papers in National conferences: 7
PhD Thesis: 3
MSD Thesis: -
Nº of technical/scientific reports: 1
Patents: 1

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www.civil.uminho.pt/composites
www.sc.civil.uminho.pt/

Produção de Tijolos Térmica e Estruturalmente Mais Resistentes por Introdução de Nanomateriais | SeTiverNano

Financing Institution(s): Adi

Promoting Institution(s): PreCeram Indústrias de Construção, S.A. e Universidade de Coimbra

Coordinator(s): Teresa Vieira & Paulo Santos

Researchers and collaborators: Teresa Vieira, Eduardo Júlio, Paulo Santos, João Paulo Gouveia, Inês Grilo, Ivânia Marques, Cláudio Martins

Partner Institutions: Centro de Engenharia Mecânica da Universidade de Coimbra (CEMUC), Institute for Sustainability and Innovation in Structural Engineering (ISISE)

Period: September 2010 to September 2012

Relevant facilities: Laboratory equipment and facilities of Civil and Mechanical Engineering Departments of University of Coimbra.

Objetivos:

As lamas de anodização e lacagem são o principal resíduo produzido na indústria de tratamento da superfície do alumínio. Após uma detalhada caracterização, que envolveu a composição química, o tamanho de partícula, a distribuição do tamanho de partícula, o fator de forma e a estrutura e superfície, a lama foi adicionada (5% m/m) à argila convencional utilizada para produzir tijolos na indústria cerâmica PreCeram (Pombal).

A fiabilidade do processo de reciclagem foi avaliada sob o ponto de vista tecnológico e ambiental. O *scale up* foi realizado na fábrica de tijolo, após uma simulação do processo em laboratório. As características das cerâmicas avaliadas incidiram sobre o teor de água total necessário para a extrudir, a retração após secagem e total, a absorção de água, a densidade aparente e real e o desempenho mecânico e térmico. As propriedades do tijolo final foram avaliadas de acordo com as normas técnicas e requisitos de mercado. Após extrusão da mistura argila/lama e cozedura, o novo tijolo apresentava uma melhoria do isolamento térmico de cerca de 30%.

O uso de lama é tecnologicamente fiável, resultando em melhorias no desempenho térmico do tijolo sem afetar significativamente os parâmetros do processo de produção e as restantes propriedades do novo tijolo. Este trabalho de investigação tem o objetivo de implementar uma cooperação sustentável entre empresas e desenvolver um melhor produto a partir de resíduos, conseguindo-se assim atingir soluções ambientalmente corretas. Teve-se uma especial atenção ao impacte ambiental que pudesse ser causado durante a manipulação das lamas e durante a produção do novo tijolo, levando-se para isso a cabo uma avaliação da emissão de SO2. A quantidade total de lama produzida pode ser inteiramente reciclada como aditivo no tijolo.

Descrição:

Os tijolos são um material de construção milenar e moderno, pois continuam a ser usados, com vantagens sobre outros materiais, na Construção Civil. Atualmente, tem-se-lhe prestado maior atenção, não só por razões ambientais, como também por razões estruturais, em particular associadas à possibilidade de serem uma reserva de robustez em condições extremas.

A adição de diferentes materiais, muitos deles resíduos, tem contribuído para alguma melhoria do desempenho térmico do tijolo mas, em geral, em detrimento da resistência do material. No entanto, apesar das novas geometrias induzirem uma alteração à resistência térmica, ela não atinge, mesmo quando aditivada, os valores impostos pela UE.

Os tijolos de geometrias otimizadas e mesmo aditivados, para além de ainda estarem aquém dos valores de condutibilidade térmica almejados, revelam contribuírem para uma perda da sua pouca resistência estrutural. Além disso, embora nos edifícios, os panos de alvenaria não estrutural, como é o caso dos de tijolo, tenham como objetivo principal organizar os espaços, têm-se revelado, em certas condições, uma reserva de robustez dos edifícios, i.e., atuam como reserva de capacidade para suportar eventos não previstos nos regulamentos e combinações de ações.

Ensaios preliminares, realizados em laboratório, em tijolos maciços produzidos a partir de mistura manual de argilas com lamas nanocristalinas secas, permitiram detetar uma redução significativa da condutibilidade térmica da argila, sem perdas significativas da sua resistência estrutural. A dispersão da lama na matéria-prima convencional, por processos de mistura mais eficientes, semelhantes aos usados na indústria do tijolo, deverá permitir realçar o carácter nanométrico das lamas nas propriedades finais do tijolo, e assim incrementar significativamente o seu desempenho térmico e como reserva estrutural, à semelhança do que ocorre noutros compósitos de matriz cerâmica nanoreforçados. Foi este o principal objetivo do presente projeto de investigação.

Publications:

Papers

I. Grilo, P. Santos, J.P. Gouveia, E. Júlio, Melhoramento do comportamento mecânico e térmico de tijolos de alvenaria cerâmica aditivada com resíduos da indústria do alumínio, Construção Magazine (ISNN: 1645-1767), nº52, pp. 21-23 (2012)

I. Marques, M.T. Vieira, Reciclagem de lama residual de anodização e lacagem em tijolo – Caso de estudo em indústrias Portuguesas, Construção Magazine (ISNN: 1645-1767), nº52, pp. 29-33 (2012)

Conference proceedings

I. Grilo, P. Santos, J.P. Gouveia, E. Júlio, Avaliação do desempenho mecânico e térmico de tijolos de alvenaria cerâmica aditivada com lamas residuais de alumínio, CINCOS´12 – Congresso de Inovação na Construção Sustentável, (ISBN: 978-989-95978-2-2) pp.257-268, Aveiro, Portugal, 20-22 de Setembro de 2012.

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URL: http://www.isise.net

Fig. 1 Experimental tests performed: new ceramic material.

Fig. 2 Experimental tests performed: new ceramic brick units.

Reducing the vulnerability of cultural heritage buildings to blast loading | CH-SECURE

Financing Institution(s): FCT

Promoting Institution(s): University of Minho (UMinho)

Coordinator(s): Paulo B. Lourenço

Researchers and collaborators: Paulo B. Lourenço; João M. Pereira; Ebrahim Hashemi

Partner Institutions: Mechanical & Materials Technologies Centre (CT2M); Laboratory of Energetics and Detonics (LEDAP)

Period: March 2012 to August 2015

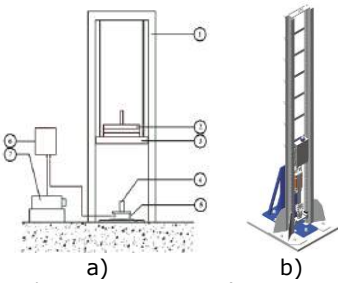
Relevant facilities: Drop Weight Towers; Fast video equipment; dynamic acquisition equipment; DIANA software with user supplied subroutines; Servo close-loop equipment; Reaction wall

Objectives:

This project focus on cultural heritage buildings, which possess specific problems associated with a high vulnerability, very high hazard and low damage limits in renderings due to the capacity to accommodate small deformations. The present work ranges from risk assessment to elaboration of recommendations, through experimental testing and applications. By learning from blast effects, both strengthening measures and recommendations will be proposed, to prevent sudden collapse and damage, enabling people to evacuate the buildings before failure and reduce casualties, and protect the value of the culture heritage. Significant contributions will be made with this work respecting to: (a) risk assessment methodologies and applications; (b) experimental characterization of historic materials and structural components; (c) design criteria and design rules; (d) innovative usage of controlled airblast for dynamic identification of structures and indication of weak structural and non-structural elements. With this work it is intended to introduce this topic, which has a considerable lack of experience, at a national level, allowing future developments.

Description:

The first aspect to be tackled in this project was the experimental characterization of materials under high strain rates. Different building materials were considered for study under impact loading, to study strain rate effects. The considered materials were the usual components of existing masonry structures (clay brick and lime mortar), plus modern strengthening materials (Fibre Reinforced Polymers, FRP). Two different Drop Weight impact machines (Figure 1) were used for compression testing (Figure 1a) on brick (Figure 2), mortar and masonry specimens; and pull-out testing (Figure 1b) on brick and concrete specimens reinforced with GFRP (Glass-FRP) and CFRP (Carbon-FRP) strips, respectively. Regarding the uniaxial compression testing, the influence of the strain rate was studied on: (a) Ultimate strength (Figure 3); (b) Strain at ultimate strength; (c) Young's modulus; and (d) Fracture energy. Empirical relations of dynamic increase factors (DIF) for these materials and these material properties were developed. Regarding the pull-out testing (Figure 4a), the influence of the deformation rate (slip rate) was studied on: (a) maximum force (Figure 4b); (b) maximum slip; and (c) effective bond length. Empirical relations of DIF for these properties were developed.



a) b)

Fig. 1 Drop Weight impact towers: a) compression testing; b) pull-out testing.

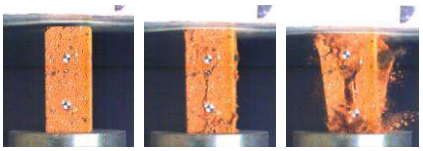


Fig. 2 High speed video sequence for brick under impact compression test.

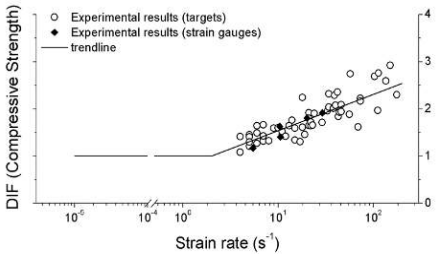
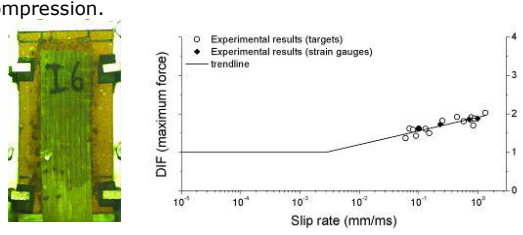


Fig. 3 DIF for Compressive strength of brick under uniaxial compression.



a) b)

Fig. 4 Dynamic pull-out testing: a) high speed video; b) DIF for maximum force for pull-out tests.

The vulnerability of the masonry envelop under blast loading is considered critical due to the risk of loss of lives. The second aspect under the scope of this project was the experimental assessment of the behaviour of masonry walls subjected to blast loading. A new test setup (Figure 5a) was developed for this purpose. Using confined underwater blast wave generators (WBWG), applying the extremely high rate

conversion of the explosive detonation energy into the kinetic energy of a thick water confinement, allows a surface area distribution avoiding also the generation of high velocity fragments and reducing atmospheric sound wave. URM infill walls (Figure 5b) were tested with WBWG, using water plastic containers having in its centre a detonator inside a cylindrical explosive charge. Besides the usage of pressure and displacement transducers, pictures with high-speed video cameras were recorded to enable processing of the deflections and identification of failure modes.

a) b)

Fig. 5 Structural element testing: a) out-of-plane setup for walls under blast loading; b) URM wall under WBWG loading.

The information gathered in the two previous tasks was used to develop numerical tools. Viscoplastic constitutive models capable of accommodating the strain rate dependency of material were developed. These constitutive models are based on the modern framework of incremental theory of multisurface plasticity, adequately considering the post-peak behaviour, and were developed both for interface composite model and macroscale orthotropic model. These subroutines were implemented and validated in an explicit dynamic finite element commercial code – ABAQUS (Figure 6). These models were used to perform parametric studies and to build empirical tools such as Pressure-Impulse diagrams (Figure 7) which relate the applied load with the damage level of these structural elements.

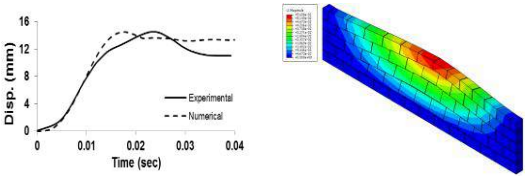


Fig. 6 Development of numerical tools: a) comparison between numerical and experimental displacement of URM infill wall; b) masonry wall panel under impact using interface strain rate dependant constitutive model.

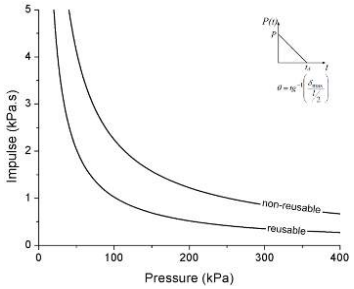


Fig. 7 Example of Pressure-Impulse diagram for URM wall panels.

Different case studies, for both risk assessment and structural safety evaluation, were performed. First, a specific risk assessment methodology was applied in the context of public transportation networks, involving one of the largest transportation operators in Portugal. From the selected element in the Operators' network the elements with the highest risk associated with external explosion due to terrorist action were highlighted. Secondly, several structural safety assessments were performed on historical masonry buildings, both nationally (Figure 8) and internationally (Figure 9). These structural safety assessments involved several explosion scenarios in the vicinity of the building.

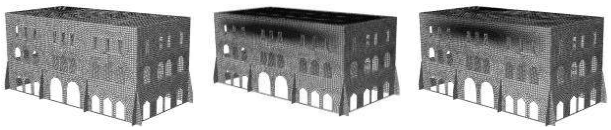


Fig. 8 Rossio Station - deformed shape evolution due to external explosion far from the structure.

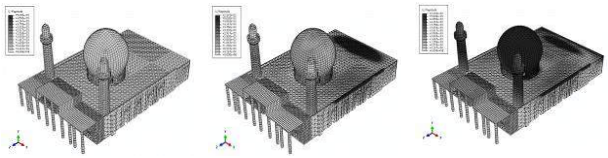


Fig. 9 Al-Askari holy shrine - deformed mesh evolution due to external explosion close to the structure.

At the end of this project it is expected a preparation of a manual specific for cultural heritage protection, with: (a) effective protective measures; (b) recommendations on prevention of progressive collapse; (c) Design charts; (d) a review of post-disaster action to protect cultural heritage.

Relevant Publications:

International journals

Rafsanjani, SH., Lourenço, PB., Peixinho, N., Dynamic interface model for masonry walls subjected to high strain rate out-of-plane loads, International Journal of Impact Engineering, Vol. 76, pp. 28-37, 2015.

Pereira, JM., Lourenço, PB., Risk assessment due to terrorist action on public transportation networks: a case study in Portugal, International Journal of Protective Structures, Vol. 5(4), pp. 391-416, 2014.

Theses

High strain rate constitutive modelling for historical structures subjected to blast loading, Seyedebrahim H. Rafsanjani, PhD Thesis, University of Minho, Portugal (expected in the first semester of 2015).

Security Evaluation and Design of Structures Subjected to Blast Loading, João M. Pereira, PhD Thesis, University of Minho, Portugal, 2014.

Experimental characterization of composite reinforcements subjected to impact and fire, João P. Pinhão, MSc Dissertation, University of Minho, Portugal, 2014 (in Portuguese).

Dynamic properties of clay brick and mortar at different strain rates, Abel Dias, MSc Dissertation, University of Minho, Portugal, 2013 (in Portuguese).

Experimental characterization of masonry subjected to impact loading, Ivo Silva, MSc Dissertation, University of Minho, Portugal, 2012 (in Portuguese).

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Rehabilitation of Building Floors with Lightweight High Performance GFRP Sandwich Panels| RehabGFRP

Financing Institution(s): FCT

Promoting Institution(s): Instituto Superior Técnico - University of Lisbon (IST-UL)

Coordinator(s): Fernando A. B. Branco (IST-UL), Joaquim A. O. Barros (UMinho)

Researchers and collaborators: Joaquim Barros, José Sena Cruz, Isabel Valente, Mohammad Mastali, Salvador Dias, Vítor Cunha

Partner Institutions: University of Minho (ISISE), IST-University of Lisbon (CEris), IPC – Institute for Polymers and Composites (PIEP)

Period: May 2011 to August 2014

Relevant facilities: Laboratory, equipment and facilities of: Civil Engineering Department of IST-UL, Civil Engineering Department of UMinho, PIEP

Objectives:

A new generation of composite sandwich slab is proposed as a solution for the rehabilitation of slabs in old masonry buildings. An innovative solution was developed during this research formed by four components: a Deflection Hardening Cement Composite (DHCC) layer on the top compression skin, a Glass Fiber Reinforced Polymer (GFRP) skin at the bottom tension surface, GFRP ribs to transfer shear from top to bottom layers, and foam core for thermal-insulation purposes. The DHCC layer contributes significantly to the load carrying and deflection capacity due to its stiffness, compressive strength and toughness, offers resistance to the occurrence of buckling phenomena in the GFRP ribs, improves the performance of this structural concept against impact and fire, and constitutes an excellent medium for the application of finishing materials, like ceramics or timber. Each component can be considered as relatively weak by itself, but together they provide a strong and lightweight structural system. The main aim of this project was to design and test full-scale specimens of innovative hybrid GFRP-DHCC sandwich panels for the replacement of degraded building floors. This innovative GFRP and hybrid GFRP-DHCC sandwich panel are developed to increase strength and ductility and to allow an easy application of floor covering materials.

Description:

Rehabilitation of slabs in old masonry buildings is gaining increasing attention. In fact, rehabilitation of these structural elements with traditional materials introduces significant dead loads in constructions, increasing their seismic vulnerability, and poses constructive problems associated to transport, elevation and placement operations on narrow accesses. Glass fiber reinforced polymer materials (GFRP) may be successfully used in sandwich panels, resulting in a new generation of structural elements that present several advantages over traditional ones, namely, higher mechanical performance, lightness, lower immediate and long term costs, better behavior in terms of insulation, lower maintenance and higher durability. Sandwich panel elements formed by composite materials are generally composed of FRP top and bottom skins that assure the flexural capacity and stiffness. A foam core material is used in the middle layer to transfer shear stresses between the FRP skins. Due to their high strength-to-weight ratio and energy absorption characteristics, sandwich panels have been commonly used in aerospace and automotive industries. Civil infrastructures and transportation applications are more recent applications of sandwich structures. The typical sandwich panels used in structural applications consist of two thin and stiff outer skins that have in between them a thick and relatively flexible core, bonded with an adhesive. The skins provide flexural stiffness and strength to the panel, while the core provides shear stiffness, composite action and stress transference between the skins, and increases moment of inertia of the panel, as well as thermo-insulation.

Fig. 1 presents the geometry of the sandwich slab developed in the scope of the research project. Each component can be considered as relatively weak by itself, but together they provide a strong and lightweight structural system. An important aspect is the transfer of shear forces between the GFRP ribs and the deflection hardening cement composite (DHCC) layer. In this case, the simply perforated shear connectors are obtained by executing openings in the upper part of the GFRP ribs. These openings are filled with DHCC during casting, forming DHCC dowels that are capable of transferring the mobilized shear forces. Another important aspect related to the sandwich slab is the adhesive bond between the foam and the skin layers. This adhesive bond is introduced for enhancing the transference of shear forces between layers, by contributing in this way for the desired composite action.

Experimental tests were performed to characterize the materials used in the proposed hybrid sandwich panels. DHCC material was developed using different PAN fibers. The developed DHCC material indicates a very ductile flexural behaviour by forming multiple cracks. Implementation of tensile tests for GFRP coupons of ribs and skins revealed that the corresponding stress-strain response is composed of an initial linear stage followed by a phase with a degree of nonlinearity that depends on the arrangement and percentage of fiber reinforcement with respect to the direction of the applied load. The Polyurethane foam core can offer some resistance to the lateral buckling of the ribs, as well as to provide some support to the DHCC layer. Additionally, it also helps to improve thermal insulation of the proposed hybrid sandwich panels. The results gathered from compressive test present very high plastic deformation with low compressive strength.

The process of manufacturing the slabs was developed in two phases that include (Fig. 2): 1) Fabrication of GFRP body (GFRP ribs and skin) with pre-installed foam cores, by using vacuum assisted resin transfer

molding (VARTM) process; and 2) Casting the DHCC material in order to form a top compressive layer of the sandwich panel. The proposed slabs were assessed under flexural tests (Fig. 3) and the experimental results indicate that up to the deflection corresponding to serviceability limit state (L/250), no relevant damage is formed. This hybrid sandwich slab has a dead weight less than 1 kN/m^2, which is about 1/3 of the dead weight of conventional slabs used in residential buildings.

Investigations on hybrid sandwich panels with simply perforated shear connectors indicate formation of a high concentration stress area around the shear connectors, and the maximum ductility obtained in the slabs was dependent on the shear connector shape. A novel indented shear connector was proposed to be used in the hybrid sandwich panels with the aim of improving ductility. Therefore, eight slabs were manufactured and tested under different loading conditions in order to evaluate efficiency and performance of the proposed new shear connectors. According to the gathered experimental results, employing the innovative shear connectors in the hybrid sandwich panels resulted in higher post-peak residual strength in comparison to using simply perforated shear connectors.

In addition to experimental program planned in the research project, robust three dimensional FEM models were developed for the proposed hybrid GFRP-DHCC sandwich panels (Fig. 4). According to the results obtained, using the interface constitutive model for defining contact behaviour between DHCC layer and foam cores or GFRP rib had important role in achieving a robust numerical simulation. Additionally, a parametric study was performed in order to reveal the effects of each parameter on global behavior of full scale hybrid sandwich panels.

Since the studied hybrid sandwich panels are proposed to be used as slabs, investigations about long term deformability and its effects on flexural and shear performance over time were required. Therefore, a comprehensive study was executed to determine the effects of long-term deformability on performance of hybrid sandwich panels under shear and flexural loads (Fig. 5). To fulfill this aim, four hybrid GFRP-DHCC sandwich panel slabs were used to induce shear and flexural creep tests in the first stage.

An analytical model was developed afterwards to predict the hybrid GFRP-DHCC sandwich panel slab behaviour under long-term loading.

Finally, in the second stage, the hybrid GFRP-DHCC sandwich panel slab previously submitted to long-term loading was assessed under shear and flexural static loads. As the DHCC material contains fly ash particles within the mixture and the degree of hydration in fly ash is low, some particles remain unreacted in early age, but over time, all particles reacted in the DHCC material. Following reaction of all fly ash particles in the DHCC material along time, there was an increase in load carrying capacity, in stiffness provided by shear connectors, and in the composite action between layers.

Publications:

Papers:

M. Mastali, Isabel B. Valente, Joaquim A. O. Barros, Delfina M. F. Gonçalves, Development of innovative hybrid sandwich panel slabs. Part I: Experimental results, Submitted to Journal of Materials and Design.

Reports:

Report Nº1 – Design process of hybrid GFRP-ECC sandwich panel", 2013, Report N.º 13-DEC/E-02, University of Minho, Portugal.

Conference proceedings:

M. Mastali; I. B. Valente; J. A. O. Barros, New composite slab system for the structural rehabilitation of traditional buildings, 11th INTERNATIONAL SYMPOSIUM ON FIBER REINFORCED POLYMERS FOR REINFORCED CONCRETE STRUCTURES (FRPRCS11), Guimarães, Portugal (2013)

M. Mastali; J. A. O. Barros; I. B. Valente, Laje sandwich em polímero reforçado com fibra de vidro e argamassa de ultra elevada ductilidade para a reabilitação estrutural, JPEE2014, Lisbon, Portugal (2014).

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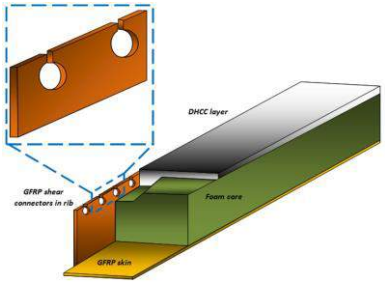

Fig. 1 Schematic view of the innovative hybrid sandwich panel.

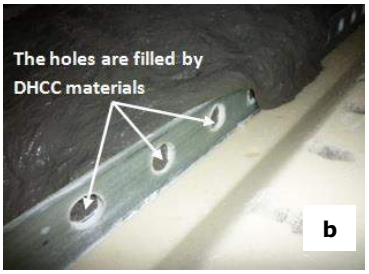

Fig. 2 Manufacture process of hybrid slabs: a) VATRM process; b) Casting of DHCC materials.

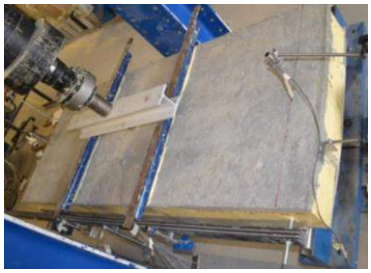

Fig. 3 Assessment of hybrid slabs under static four point bending test.

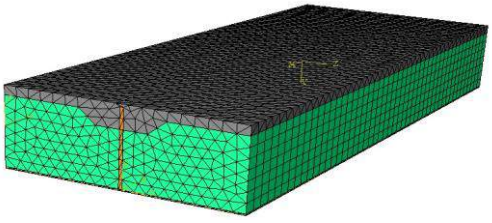

Fig. 4 Robust three dimensional FEM models of hybrid slabs.

Fig. 5 Assessment of hybrid slabs under long term loading.

Robust Connections for Impact and Fire Loading | IMPACTFIRE

Financing Institution(s): FCT

Promoting Institution(s): University of Coimbra (UCoimbra)

Coordinator(s): Aldina Santiago

Researchers and collaborators: Aldina Santiago; Carlos Rebelo; Cécile Haremza; Constança Rigueiro; Diogo Martins; Emanuel Saraiva; Gonçalo Ferraz; Fernanda Lopes; João Paulo Rodrigues; João Ribeiro; Luís Simões da Silva; Miguel Serra; Milan Veljkovic; Pedro Barata; Rui Alves; Rui Simões; Sandra Jordão; Steffania Strezza.

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE); Soares da Costa, S.A.; Lulea Technical University (LTU).

Period: April 2011 to September 2014

Relevant facilities: Laboratory equipment and facilities of Civil Department of UCoimbra.

Objectives:

The objective of this project is to study the behaviour of bolted steel joint under impulsive accidental loadings and to develop a procedure to design of robust steel joints capable of withstanding accidental impulsive loading, which may arise mainly from impact and explosions. Special attention will be paid to the combined scenario of fire after impulsive loading. The project was organised on 6 Tasks. This project followed a clear thread from the characterization of impulsive loading to the elaboration of design methods and recommendations through experimental testing of connections and joint components under impact and fire loading. Their results were used to support and validate numerical models, which provide a means of carrying out parametric studies to complement experimental work. On the other hand, these tests will provide a means of testing the accuracy of a new design method that will extend the component based approach for the static design of steel joints to accidental design.

Description:

Generally, structures are designed to withstand a number of dead and live loads whose intensity is known and predictable using statistical approaches. When an extreme event occurs, the loads have normally a severe intensity and complexity and causes extraordinary consequences. The complexity of the loads makes also a complex response of the structure and normally this type of scenario is linked to progressive collapse. As an example, the WTC attack has highlighted troublesome weakness in design and construction technologies of structural connections which exhibited poor performance caused by brittle failure. Structural details played very a significant behavioral role when the structure is subject to impulsive loads. Moreover, the short duration of the load application (typically less than 1 second) introduces high strain rates on the elements by changing the material behavior and hence the response of the structure.

Impactfire project was focused on the behavior of robust steel joints capable of withstanding accidental loads, especially impact and explosion. Throughout the project special attention was given to the sequence of fire after loading impact, current situation in accident scenarios.

In an initial stage of the project, it was revised the current knowledge on connections subjected to impulsive: design methodologies available in codes and previous studies. The studied loads (fire and impact) were also characterised in order to obtain the data needed for the applied loading in the joints that was tested in the second and third tasks of the project. Regarding the thermal loading an extensive experimental campaign was carried out to understand the thermal behaviour of columns under localised fires, which is a common accidental situation after the impact of a vehicle on structures. The results showed that a localised fire leads to a non-uniform heating scenario for a steel column, resulting in an asymmetric distribution of temperatures throughout the column height.

The experimental programme on joints included tests on components (T-stub with 2 bolt-rows per line; T-stub with 4 bolt-rows per line and reverse channel under tension), as well as test on an isolated beam-to column bolted end plate joints in bending. The quasi-static tests were carried out using the available equipment; however for the fire tests and impact tests, special devices were designed and developed at UCoimbra. For the fire tests, a furnace was constructed using electrical resistances, while an innovative layout using a pneumatic cylinder was developed to apply the dynamic load (Fig. 1a). Additionally, to assess the influence of the high strain rate on the material response, preliminary uniaxial tensile tests and Hopkinson bar tests were also performed (Fig. 1b). The experimental results were used to support and validate numerical models, which provide a means of carrying out parametric studies to complement experimental work (Fig. 2). A damage model was developed and included in the stress-strain behaviour of the steel in order to establish the failure of the specimens in the numerical analysis.

The results obtained from T-stubs under fire loading showed a reduction of the strength and initial and post-limit stiffness with the increase of the temperature. Concerning the post-limit behaviour, the strain hardening decreases with the temperature, and for the highest temperatures, a horizontal plateau is developed. The ductility shows a different tendency; the minimum values were reached for the lowest temperatures and the highest values for temperatures above 600ºC.

The results obtained from the studies on impact loading showed that high strain rates induce an increase of the plastic and ultimate resistance but a decrease in the ductility capacity. The strain rate is directly related with the dynamic increase factor (DIF) of the material, so, i) with increasing of DIF_{steel}, less ductile failure modes are activated in the joint components; ii) for the same failure mode, stiffer

components exhibit higher increment for the same DIF.
On the other hand, the experiments and numerical results also provided a means of testing the accuracy of new design methods. Two methodologies were developed to analyse the behaviour of T-stubs under impact: a simplified method and a non-linear analytical approach. Using the simplified method, the calculation of the T-stub resistance when subject to rapidly applied dynamic loads is based on the procedure presented in EC3-1-8, and the implementation of elevated strain rate effects is achieved through the enhancement of steel's and bolt's strengths with their DIFs. The non-linear analytical approach is based on previous studies available in the literature to the evaluation of the entire non-linear response of the T-stub, which were enhanced by a time dependency, allowing the computation of the induced strain rate on each time step, thus a different DIF for each increment is calculated for steel and bolts.

Main outputs:

PhD and MSc Theses

Cécile Haremza, "Robustness of open car parks under localised fire", Doutoramento em Construção Metálica e Mista, UCoimbra, 2015.

Diogo Martins, "Variação das propriedades mecânicas com a temperatura", MIEC, UCoimbra, 2012.

Emanuel Saraiva, "Variação das propriedades mecânicas do aço relacionadas com problemas de impacto em estruturas", MIEC, UCoimbra, 2012.

Stefania Trezza, "Previsione del comportamento ultimo di t-stub con 4 bulloni per fila: analisi teorico-sperimentale", MIEC, USalerno, 2013.

Gonçalo Ferraz, "Thermal analysis of steel columns exposed to localised fires", MCMM, UCoimbra, 2014.

João Ribeiro, "Assessment of the behaviour of T-stub joint under impact loading", MCMM, UCoimbra, 2014.

Papers

Latour M., Rizzano G., Santiago A. and Simões da Silva L., "Experimental analysis and mechanical modeling of T-stubs with four bolts per row". *Journal of Constructional Steel Research,* 101, pp. 158–174, 2014.

Barata P., Ribeiro J., Simões Rigueiro C., Santiago A., Rodrigues J-P., "Assessment of T-stub joint component at ambient and elevated temperatures". *Fire Safety Journal,* 70, pp. 1–13, 2014.

Ribeiro J., Santiago A., Rigueiro C. and Simões da Silva, L., "An analytical model for the response of t-stub component under impact loading". *Journal of Constructional Steel Research*, 106, pp. 23-34, 2015

Lopes F.C., Santiago A., Simões da Silva L., Iqbal I., Veljkovic, M. and da Silva J.G.S., "Sub-frames with reverse channel connections to CFT composite columns – experimental evaluation", *International Journal of Advanced Steel Construction,* 11 (1), pp. 110-125, 2015.

Santiago A., "Impacto em Estruturas Metálicas". *Revista Metálica*, CMM, year 15, 33, pp. 6-12, 2014.

Reports

Report Nº 1 - Final Report – Impactfire project. Authors: Santiago, A. et al., 2014.

Report Nº2 to Report Nº 6 – 6 Deliverables. Authors: Santiago, A. et al., 2014.

Conference proceedings

16 International conference proceedings: https://www.dropbox.com/s/sr29cqh29mfs8h6/CI-Comunicacoes_Conf_Internacional.rar?dl=0

10 National conference proceedings: https://www.dropbox.com/s/a0tv9sz5qrook91/CN-Comunicacoes_Conf_Nacional.rar?dl=0

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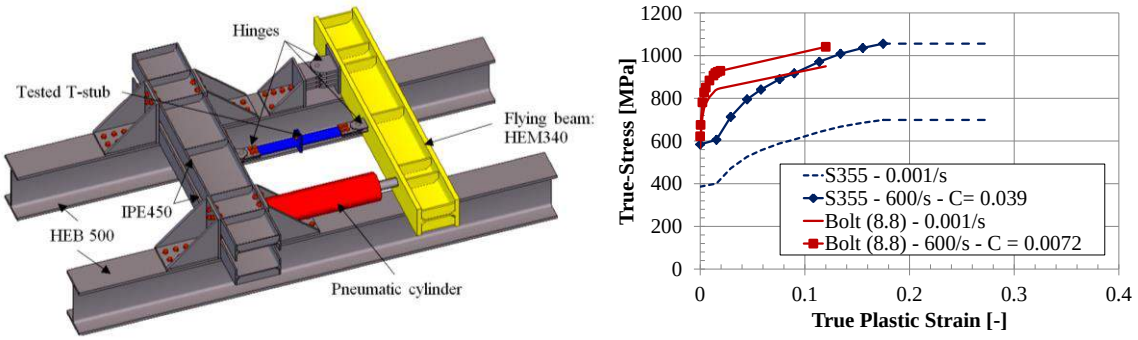

Fig. 1 a) Experimental layout; b) response of the steel (S355 and bolts 8.8) under high strain rates.

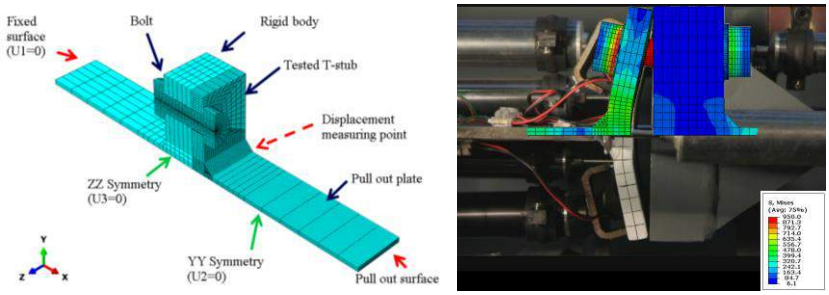

Fig. 2 a) numerical model of T-stub; b) numerical versus experimental results.

Seismic performance assessment of reinforced concrete buildings designed to Portuguese codes | SPARCS

Financing Institution: FCT

Promoting Institution: National Laboratory for Civil Engineering (LNEC)

Local Coordinator: Paulo B. Lourenço

Researchers and collaborators: Paulo B. Lourenço, Daniel Oliveira, Nuno Mendes, João Roque, Chrysl Aranha (only UMinho researchers listed)

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE/UMinho), Faculty of Engineering of University of Porto (FEUP), University of Aveiro (UA),

Period: March 2010 to August 2013

Relevant facilities: Laboratory equipment and facilities of National Laboratory for Civil Engineering, including 3D shaking table.

Objectives:

The main objective of the SPARCS project was to characterize the seismic performance of reinforced concrete buildings representative of the Portuguese housing stock, taking into account the buildings of the first generation (pre-code) and those that have been designed according to the different codes. As result, the project contributed to the calibration of capacity and fragility curves necessary for regional scale risk analysis and provided additional basis for the development of future codes.

Description:

The survey of the Portuguese housing stock based on National databases and the analysis of the inventoried data show that, from the middle of 20th century, reinforced concrete (RC) buildings have been rapidly increasing and they represent nowadays a major parcel of the existing housing stock.

The first Portuguese seismic regulation dates from the early sixties and its successive updating has led to a present seismic code reflecting the modern knowledge in earthquake engineering. Under these conditions, it is expected that reinforced concrete buildings evidence a growing adequacy of seismic performance, ranging from a likely significant vulnerability of the pre-code RC construction, designed essentially for gravity loads and which constitute a smaller but non negligible portion of the residential buildings stock, to a reasonably adequate performance of seismically designed buildings, depending essentially on the assurance of an effective application of the code dispositions. Moreover it is expected that buildings designed to seismic codes evidence a growing adequacy of performance along time in line with the evolution of design criteria that converged to the acceptance of damage of RC structures up to a certain extent provided that loss of life and collapse are prevented through adequate ductility detailing.

Thus, in a first glance it would seem that, besides other types of vulnerable construction (e.g. existing masonry buildings), only RC buildings of the first generation (pre-code) would be of concern as they have limited lateral resistance and are susceptible to story mechanisms during earthquake loading. However, several recent earthquakes have shown that even the RC buildings designed to the recent seismic codes may suffer severe damages and have in some cases been responsible for the major part of economic losses. This apparent inconsistency between modern design provisions and the actual seismic performance of buildings has raised a growing interest, within scientific and technical communities, for the development of procedures for more accurate and realistic estimates of performance, in the framework of the so-called performance-based engineering. Within this context, important advances have been achieved during the last decade resulting in a significant improvement of the methodologies for the seismic assessment of structures and of the criteria for seismic design. The next seismic codes will represent an important step towards providing to future construction a more adequate and risk consistent performance. Taking into account these aspects, there seems to be a critical need of developing research efforts for a better assessment of the seismic performance of reinforced concrete buildings, not only either the pre-code ones but also those that have been designed to the different codes, with the purpose of contributing to more accurate estimates of seismic risk and to the launch of decisions regarding the reduction of future losses due to earthquakes.

The achievement of the objectives of the project involved the following main steps: (a) Dynamic testing of different reduced RC prototypes in the shaking table; (b) Definition of the damage limit states through the numerical evaluation of the seismic non-linear response; (c) Derivation of fragility curves from predicted seismic demands and structural capacity.

The numerical works carried out at University of Minho included the validation of modelling approaches using complex and simplified model for reinforced concrete frame buildings with and without the presence of infill walls. Different numerical simulations of the reduced buildings were done using the following approaches: (a) Bar elements for the beams and columns with/without struts for the masonry infills, using two commercial structural analysis programs; (b) Continuum finite elements (Figure 1). The results obtained confirm that similar failure modes are found for all models, indicating that simplified models are adequate for the definition of damage limit states and derivation of fragility curves. The finite element simulations demonstrated that the width of the strut can be reasonably approximated by the proposals in

the literature (Figure 2). Furthermore, the fragility curves for a real case study were obtained. The selected case study correspond to a reinforced concrete building of medium rise (from three to five floors) located in Lisbon, were performed. Finally, the fragility curves for reinforced concrete buildings of small and high rise were also obtained (Figure 3).

Publications:

Conference proceedings

Leite, J., Lourenço, P.B., Pereira, P. M.F., Masonry infills and earthquakes, Proceedings of the Eleventh Canadian Masonry Symposium, May 31- June 3, Toronto, Ontario, Canada, CD-ROM (2009).

Leite, J., Lourenço, P.B., On the Influence of Masonry Infills in Concrete Buildings, Proceedings of the Tenth International Conference on Engineering Computational Technology, September 14-17, Valencia, Spain, CD-ROM, paper 102 (2010).

Lamego, P., Lourenço P.B., Sousa, M.L., Seismic vulnerability: from building evaluation to a typology generalization, Proceedings of the Fifteenth World Conference on Earthquake Engineering, September 24-28, Lisbon, Portugal, CD-ROM (2012).

Lamego, P., Lourenço P.B., *Caracterização e comportamento sísmico de edifícios de placa*, Proceedings of the *Congresso Construção*, December 18-20, Coimbra, Portugal, CD-ROM (2012).

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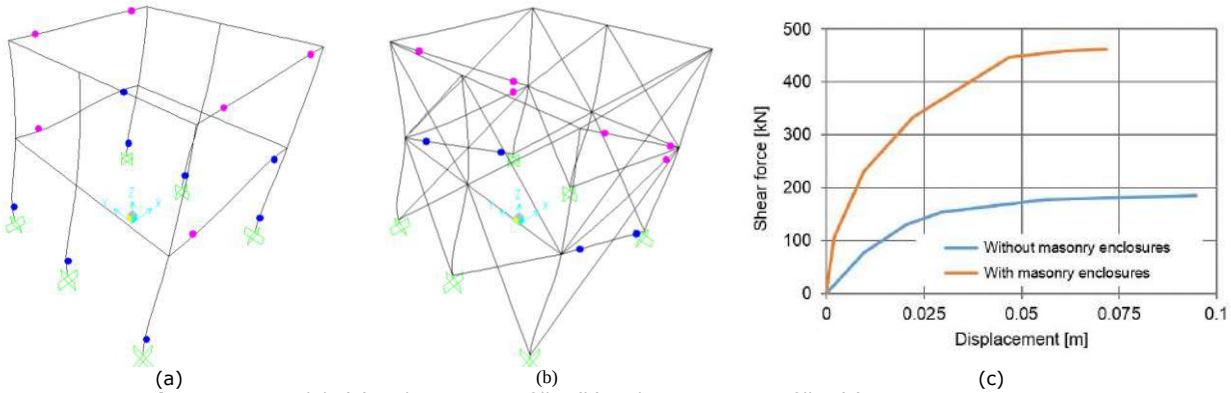
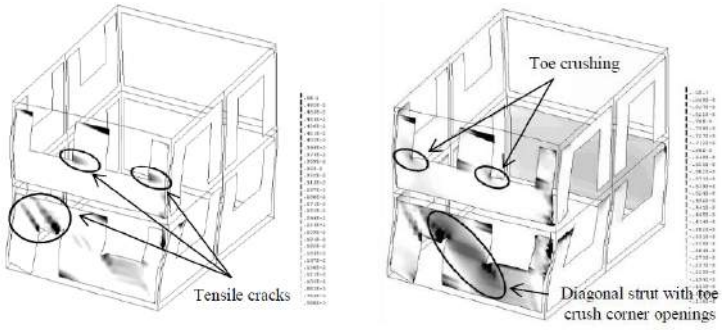


(a) (b) (c)

Fig. 1 Beam model: (a) with masonry infills; (b) without masonry infills; (c) capacity curves.



(a) (b)

Fig. 2 Finite element continuum model with infills: (a) tensile strains; (b) compression strains.

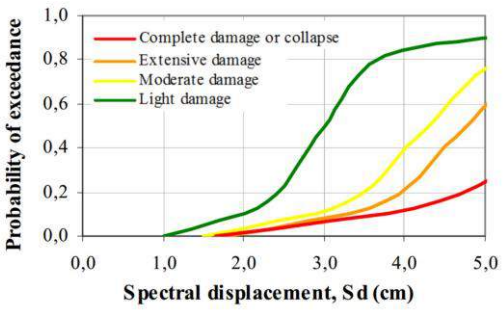


Fig. 3 Fragility curves for reinforced concrete buildings (high-rise) of *Alvalade* neighbourhood (Lisbon).

Service life behaviour of concrete structures: a multiphysics approach to self-induced stresses | SeLCo

Financing Institution(s): Supported under the Operational Program for the Science, Technology and Innovation (POCTI)

Promoting Institution(s): Faculty of Engineering from University of Porto (FEUP)

Coordinator(s): Rui Faria

Researchers and collaborators: Rui Faria; Miguel Azenha; Joaquim O. Barros, Joaquim Figueiras, Abel Henriques, António Ventura Gouveia (and two research scholarships)

Partner Institutions: Faculty of Engineering from University of Porto (FEUP)

Period: July 2010 to November 2013

Relevant facilities: New additions include: Humidity sensing systems (sensors and data loggers); Climatic chamber adaptations for moisture control in small chambers; Weight scales; Deformation measurement system (based on microscopy and laser); Bundle of transducers and actuators; system for testing shrinkage stresses of concrete under restrained conditions; Bundle of transducers (strain, temperature) and actuators; Sawing machine for concrete and stone; Diverse day-to-day laboratory equipment; Additional data acquisition and control equipment.

Objectives and Main achievements:

Concrete is a composite material whose stress history begins at its early ages. Soon after concrete casting important exothermic cement hydration reactions take place, ensuring the development of an internal porous structure responsible for the material strength growth. Simultaneously, chemical and physical processes driven by early cement hydration and by concrete interactions with the surrounding environment are responsible for load-independent volumetric changes, of thermal and autogenous/drying shrinkage origins. Under partial or total restraints these volumetric changes lead to an initial stress state build-up that may either limit concrete ability to carry further tensile stresses, or generate cracks, during service life operating conditions.
In spite of the growing attention devoted by recent design codes (like Eurocode 2) to service life behaviour of concrete structures, the know-how on this subject is still far from being consolidated in civil engineering practice. This is due to the enormous variations that may occur on the concrete compositions and on the in-situ environmental conditions, which makes rather difficult to predict the actual shrinkage deformations based on the simplified rules provided in codes. Furthermore, concrete performance as related to shrinkage is still insufficiently known in what concerns to stress relaxation under restrained conditions, and to the role of humidity on the development of local shrinkage deformations. Prediction of concrete actual stresses and cracking since casting and throughout service life, with due account for major influences such as shrinkage, early age thermal deformations and evolution of the mechanical properties, is therefore a crucial issue. The present project proposal aims to contribute to overcome this knowledge insufficiency, providing as a final output a more realistic numerical simulation framework to predict concrete stresses under service life conditions, allowing economical savings as far as malfunction avoidance is concerned.
Two of the main phenomena involved in the load-independent volumetric changes of concrete are: (i) expansion/contraction associated to temperature variations (heat of hydration included); (ii) expansion/contraction associated to changes in the moisture conditions within the pore structure of the cementitious concrete matrix (both due to internal water consumption in chemical reactions, and to evaporation towards the surrounding environment).
A recently concluded research project headed by the same Principal Investigator (POCI/ECM/56458/2004 – Early age concrete: Behavioural prediction) allowed the research team to get substantial know-how on volumetric changes (i), related to cement hydration heat release. It is considered that the experience of the research team, the thermo-mechanical framework developed so far and the lab equipments acquired within that project are cornerstones to the proposal of the present research project.
To cope for the concrete volumetric changes (ii), within the present proposal an extensive experimental research focused on the evolution of moisture distribution inside concrete, and its relation with shrinkage deformations, is considered strategic for fulfilment of the project objectives (Tasks 1, 2 and 3). Besides, a variable axial restraint testing device (to be developed within Task 4) will be used to characterize the tensile behaviour of concrete induced by shrinkage (autogenous or drying), using specimens with a dog-bone configuration (Task 5). Tensile stress relaxation due to concrete creep, as well as post-cracking behaviour, will be taken in due account on this testing device.
After this experimental campaign, a numerical framework will be implemented (Task 6), upgrading the existing thermo-mechanical numerical model developed by the research team during the concluded project referenced above. The intended upgraded numerical model, to be implemented on a Finite Element platform, has to solve a thermal problem (to predict the distribution of temperatures generated by the cement hydration heat release), and to evaluate the relative humidity distribution inside concrete by solving a moisture problem (an essential improvement of the present project). The output of these thermal and moisture models allows the evaluation of the corresponding concrete deformations. Then, a mechanical model takes these deformations into account to finally predict concrete stresses, with due allowance to phenomena like strength growth (aging), creep and cracking. Due to the explicit modelling of temperature, moisture and stress fields, this multiphysics approach renders a thermo-hygro-mechanical numerical framework, an essential outcome of the present project.

Finally, Task 7 will be focused on the numerical simulation of real structures, appropriately monitored, to provide an in-depth validation of the developed numerical tools, and a thorough discussion concerning service life concrete performance.

Fig. 1 Formwork with pre-placed tubes for humidity measurement.

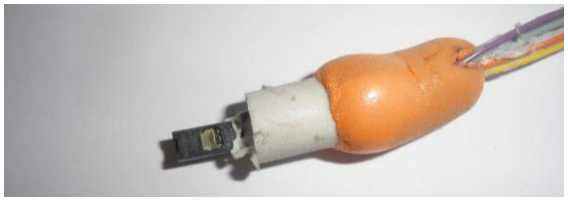


Fig. 2 Humidity sensors for embedment in concrete: mounting devised in the scope of the research project.

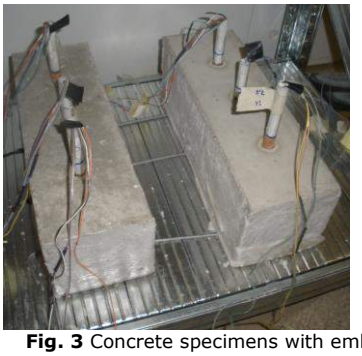


Fig. 3 Concrete specimens with embedded humidity sensors; embedded strain gages in formwork for shrinkage monitoring

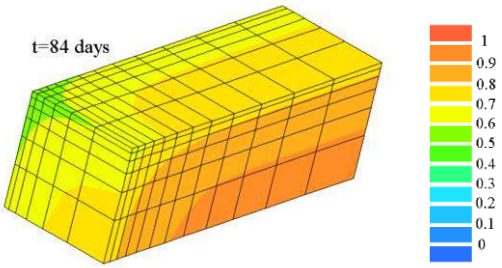


Fig. 4 Numerical simulation of internal humidity through the finite element method.

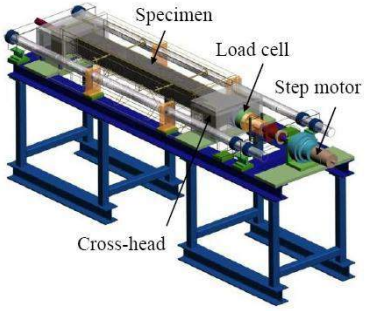


Fig. 5 Variable restraint frame for assessing shrinkage induced stresses (to be implemented).

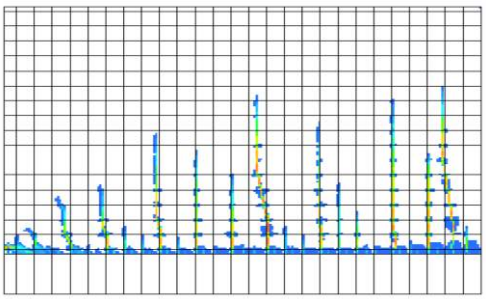


Fig. 6 Numerical simulation of shrinkage-induced cracking in a retaining wall through the finite element method.

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Short and long-term structural behavior of concrete elements flexurally strengthened with prestressed CFRP laminates | FRPreDur

Financing Institution: FEDER funds through the Operational Program for Competitiveness Factors - COMPETE and National Funds through FCT - Portuguese Foundation for Science and Technology

Promoting Institution: University of Minho (UMinho)

Coordinator: José Sena-Cruz

Researchers and collaborators: José Sena Cruz, Julien Michels, Paulo França, Paulo Costeira, Tiago Teixeira, Luís Correia, Gonçalo Escusa

Partner Institutions: Not applicable

Period: July 2013 to June 2015

Relevant facilities: Laboratory equipment and facilities from the structural lab of UMinho (LEST); servo close-loop equipment, data acquisition and control equipment for experimental programs; universal testing machine; climatic chamber; tanks; FEMIX software.

Objectives:

The main objective of the present research project is to contribute to the knowledge on short and long-term structural behaviour of RC elements strengthened in flexure with pre-stressed CFRP laminates under various specific application environments, load conditions and chemical degradation. The project involves the three following components: an experimental program, numerical simulations and design recommendations. The experimental program will be supported in reinforced concrete slabs flexurally strengthened with prestressed CFRP laminates. The influence of the prestressed system, prestressed level and the existing damage on the immediate and time-dependent losses under the effect of chlorides, sustained stress (creep), freeze-thaw, wet/dry and thermal cycles, will be the main variables to be studied. The test results obtained from the experimental programs will be used for predicting the service life behaviour of prestressed slabs, as well as the ultimate strength supported in some numerical models.

Description:

Over the last two decades, extensive research has been developed on the strengthening of reinforced concrete (RC) structures using the externally bonded reinforcement (EBR) technique with fibre reinforced polymer (FRP) materials. This technique yielded to several scientific publications, design guidelines and practical projects, worldwide. Among the commercially available FRP's, Carbon (CFRP) materials have been successfully applied to strengthen many structures due to their higher stiffness, strength and fatigue life, "no" creep rupture and less susceptibility of aggressive environments. More recently, the use of prestressed FRP materials for strengthening RC structures is emerging. This specialized application combines the benefits of passive EBR FRP systems with the advantages associated with external prestressing. Prestressed FRP applications have been showing several advantages, not only in terms of serviceability, but also in terms ultimate limit states, when compared with the passive ones. In attempt to develop this type of application, several systems have been developed to induce the prestress in the FRP. Nevertheless, the systems that tension the FRP against the RC element to be strengthened prevailed, with or without the use of additional anchors at the ends. The existing knowledge and literature concerning this technology, however, are limited compared with the conventional non-prestressed applications.

The evaluation of short and long-term structural behavior of RC elements flexurally strengthened with prestressed FRP materials is a critical key issue to be determined in order to facilitate the industry to take full advantage of this new technology. Literature treating this topic is extremely sparse. Since the prestressing with FRP materials is an emerging technique, short and long-term performance needs to be focused on.

The main objective of the present research project is to contribute to the knowledge on short and long-term structural behavior of RC elements flexurally strengthened with pre-stressed CFRP laminates under various specific application environments, load conditions and chemical degradation. The project involves the three following components: an experimental program, numerical simulations and design recommendations. The experimental program will be supported in reinforced concrete slabs flexurally strengthened with prestressed CFRP laminates. The influence of the prestressed system, prestressed level and the existing damage on the immediate and time-dependent losses under the effect of chlorides, sustained stress (creep), freeze-thaw, wet/dry and thermal cycles, will be the main variables to be studied. The test results obtained from the experimental programs will be used for predicting the service life behavior of prestressed slabs, as well as the ultimate strength supported in some numerical models. These numerical models will be implemented in the FEMIX program, which is a general purpose finite element software system. 2D and 3D models will be used in the simulation of the structural elements.

Design recommendations will be elaborated using the results obtained in the experimental programs and derived from parametric studies performed by numerical simulations.

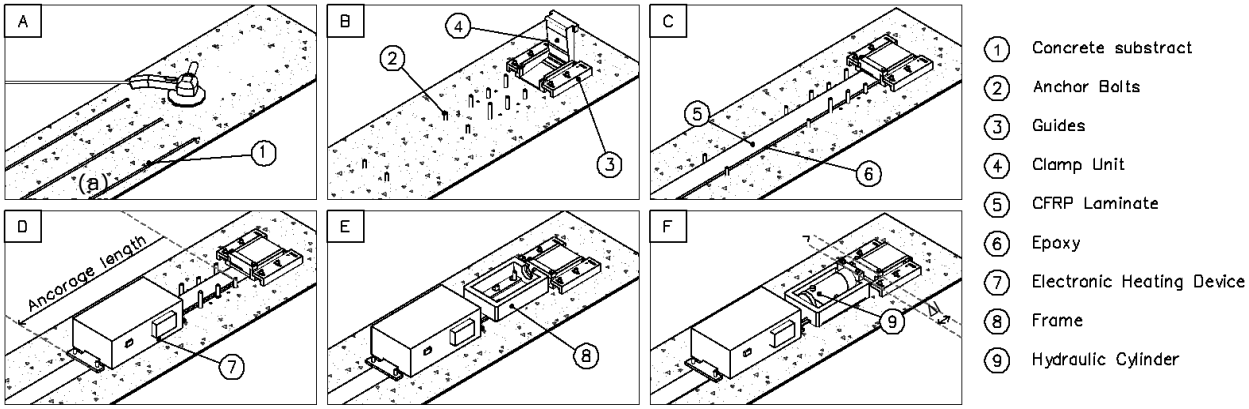

Fig. 1 Application procedures with the GA system.

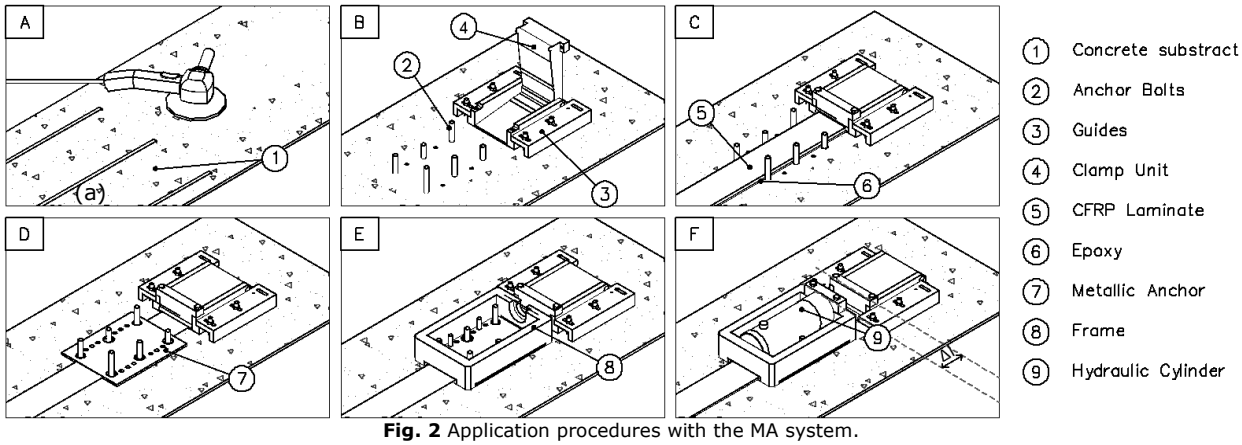

Fig. 2 Application procedures with the MA system.

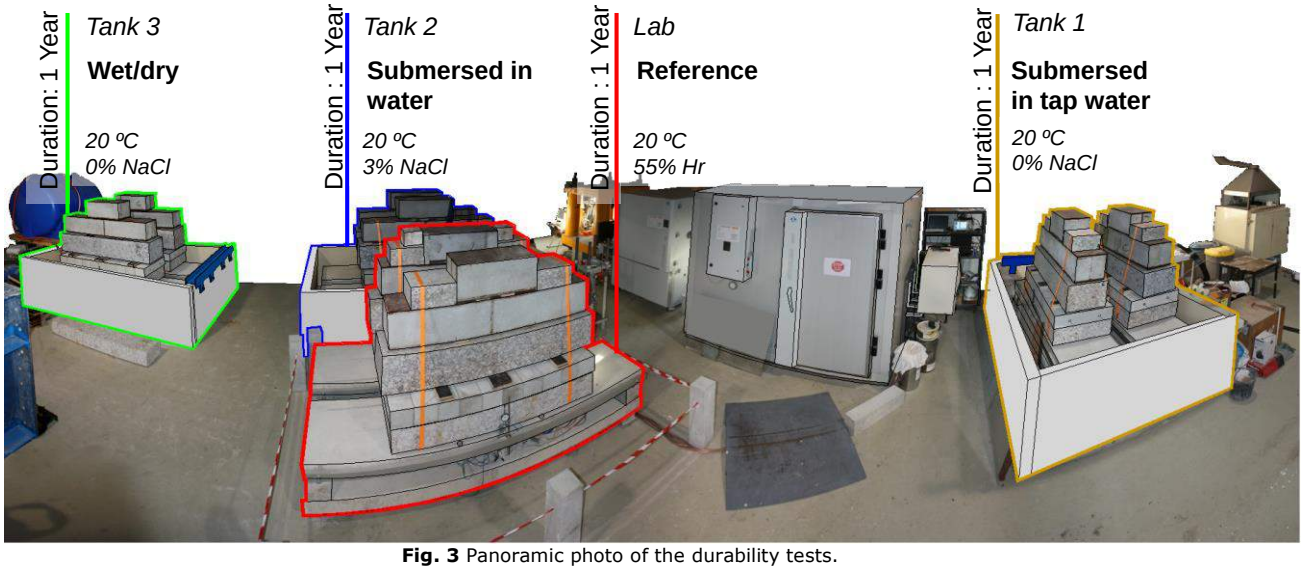

Fig. 3 Panoramic photo of the durability tests.

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Stability design of non-uniform steel members | TaperSteel

Financing Institution(s): FCT

Promoting Institution(s): University of Aveiro (UA)

Coordinator(s): Paulo Vila Real

Researchers and collaborators: Paulo Vila Real (UA); Luís Simões da Silva (ISISE-UC); Anísio Andrade (UC); Trayana Tankova (ISISE-UC); Liliana Marques (ISISE-UC); Carlos Couto (UA); Nuno Lopes (UA); João Ferreira (UA); João Pedro Martins (ISISE-UC)

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE).

Period: April 2013 to March 2015

Relevant facilities: Computational equipment and laboratory of Civil department of FCTUC.

Objectives:

Non-uniform steel members are commonly used over prismatic members because of their structural efficiency: by optimizing cross-section utilization, significant material can be saved. EC3 provides several methodologies for the stability verification of members and frames. Regarding non-uniform members in general, with tapered cross-section, irregular distribution of restraints, non-linear axis, castellated, etc., several difficulties are noted. Not only there are yet no guidelines to overcome any of these issues, but also existing rules for these types of members are mechanically inconsistent. As a result, safety verification is conservative, not accounting for the advantages non-uniform members provide. TaperSteel deals with the stability design of non-uniform members and structural systems subject to an arbitrary loading. The buckling phenomena are properly accounted for by mechanically consistent generalized imperfections and calibrated parameters to account for the member non-uniformity. Through further implementation of results in EC3, a more economic design will be achieved. The objectives of the project are:

•Application of the safety assessment procedure to the General Method in EC3-1-1 to a range of non-uniform isolated members and frames;

•Development of a mechanical generalized slenderness model for the any stability phenomena of non-uniform isolated members;

•Properly account for the interaction between local cross-section and member bucking phenomena;

•Safety assessment of the developed rules;

•Contribution towards the revision of EC3-1-1, by achieving transparent, simple and straight-forward unified stability check procedures.

Description and Methodology:

The main objectives of this project are firstly to develop rules for stability verification for a wide range of tapered columns and beams and with this to propose a new formulation of the General Method for frames and systems. At the same time, guidelines will be made for stability verification of other types of non-uniform members

These proposals are not only analytically backed up, but also there will be numerical as well as physical tests. With the results of the experiments and the technical experience gained by literature study and from other projects, the FE-Models will be validated, calibrated and verified. Afterwards parametrical studies of the typical application range will give deliverables for the development of design rules and guidelines. With this, the existing design rules in Eurocode can be checked and new rules can be proposed.

To achieve the goals in a first step existing rules are evaluated and its associated problems are documented based on numerical results. This is carried out both for uniform and non-uniform members in order to achieve consistency throughout the whole project. Also, decisions will be made and unnecessary parameters can be excluded for later consideration.

<u>Design rules for tapered members</u>

The main goal is to provide a design procedure for the verification of most commonly used tapered members. Beams and Columns are focused at this level, whereas beam-columns will be considered within the topic of the General Method. The main problems concerning the verification of a tapered member are: i) Choice of buckling curve and ii) Determination of the design position. If these two parameters are known, a similar procedure to current rules for uniform members can be considered. Experimental program will provide the necessary information for the definition of the initial imperfections. Geometrical imperfections and residual stresses will be measured as well as failure loads, from which numerical models are calibrated. An extensive numerical study will be carried out with GMNIA – Geometrically and Materially Non-linear Imperfect Analyses to provide enough data for input parameters fitting. Nevertheless, this will always be backed up by analytically derived expressions for the buckling. Parallelism to Ayrton-Perry format which is adopted in clause 6.3.1 for uniform columns is hoped to be kept both for columns and beams.

In the end, new imperfection factors are delivered in form of expressions (and not constants as it is done currently) which will most likely be dependent on tapering ratio parameters and slenderness. Regarding expressions for critical cross-section positions, two options are possible, based on further analysis of the numerical results: either an expression for that position is provided and verification will be based on that; or verification is based on the smallest cross-section properties (which is well known) and a factor is applied both to the slenderness and reduction factor as it is already done for the Special Case of beams, clause 6.3.2.2 in EC3-1-1.

Linearly web-tapered members, either symmetrically or by tapering only one half of the web, will be the starting point of this study. Then, linearly tapered flanges and also nonlinear tapered webs are also considered.
Finally, the application of the interaction formulae of clause 6.3.3 is directly applied considering the developed rules for analysed buckling modes. A validation of this procedure will be made in order to evaluate its safety.

General Method in EC3-1-1
The method (clause 6.3.4 of EC3-1-1) uses a Merchant-Rankine type of empirical interaction expression in which the the in-plane effects and the out-of-plane effects are analysed separately. However, no explicit derivation of this method is provided and reduction factors from clauses 6.3.1 for columns and 6.3.2 for beams are simply considered for the application of the method: at the moment, according to EC3-1-1, the reduction factor for the General Method may be taken either as a minimum or an interpolated value between the reduction factor for lateral buckling, according to clause 6.3.1 of EC3-1-1, or the reduction factor for lateral-torsional buckling, according to clause 6.3.2. One of the objectives in TaperSteel is to provide a theoretical formulation of the method in which at the end, a unique imperfection factor is chosen for the buckling mode of the member, i.e., the interpolation of the combined loading will be implicit in the provided formula. This will obviously include not only prismatic but also non-prismatic members for the calibration of such imperfection factor. Finally, within the analytical derivation procedure, the in-plane effect will be redefined, if necessary.
In the end, the proposal will be compared to the application of the interaction formulae already mentioned above.

Design Guidelines for other non-uniform members / systems
Although tapered members are the focus of this project, there are many other typologies of non-uniform members and systems which have the same design logic of non-prismatic members and are also not abridged by current rules of EC3, such as:

- Nonlinear members (e.g. curved – problem with definition of imperfections);
- Non-symmetrical restraints (e.g. torsional effects – definition of buckling curve);
- Irregularly distributed restraints (e.g. definition of global imperfections);
- Other support conditions (e.g. definition of sway imperfections);
- Frames.

These typologies will also be considered within TaperSteel. Through numerical and analytical derivations carried out for a wide range of non-uniform members, the main goal of this subject is to provide orientation for the designer to be able to easily generate adequate input parameters to apply proposed rules derived before; to model imperfections and boundary conditions in such cases where a numerical analysis is needed.
Finally, because framed systems are widely used, and many times present the characteristics that have been described (tapered columns / beams; irregular restraining systems…) a case study of an industrial hall will be carried out.

Publications:

Papers
Marques, L., Simões da Silva, L., Rebelo, C. and Santiago, A. "Extension of EC3-1-1 interaction formulae for the stability verification of tapered beam-columns", Journal of Constructional Steel Research 100 (2014) 122–135

Reports
Marques, L., Simões da Silva, L., and Rebelo, C. "Code proposal for rules for member buckling of non-uniform members", Technical Committee 8, ECCS, Document TC8-2013-11-23, Zurich, Switzerland, November 8th, 2013;

Conference proceedings
Marques, L., Simões da Silva, L., Rebelo, C., Santiago, A., Tankova, T., "Análise de posiveis abordagens para o dimensionamento de elementos não-uniformes em aço", in Simões da Silva, L., Silvestre, N., Santos, F. (eds.), IX Congresso de Construção Metálica e Mista / 1º Congresso Luso-Brasileiro de Construção Metálica Sustentavel, pp II.305-314, cmm Press, Coimbra (2013).

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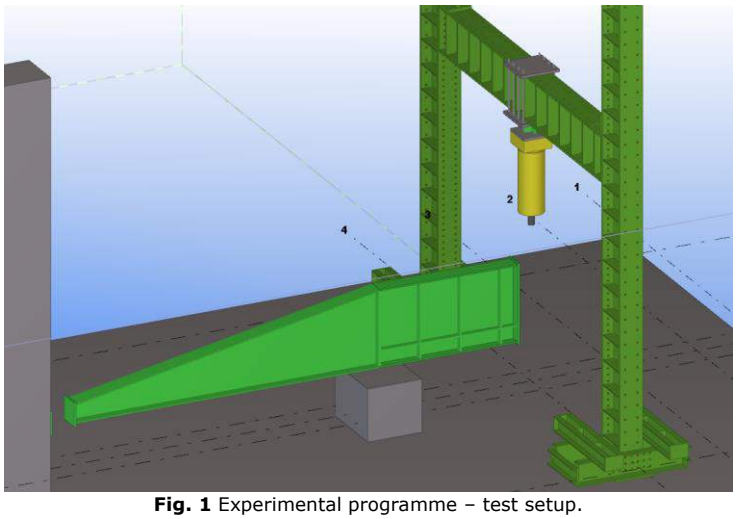

Fig. 1 Experimental programme – test setup.

Standardization of Safety Assessment Procedures across Brittle to Ductile Failure Modes | SafeBrictile

Financing Institution(s): EC-RFCS

Promoting Institution(s): University of Coimbra, Institute for Sustainability and Innovation in Structural Engineering (ISISE-UC)

Coordinator(s): Luís Simões da Silva (ISISE-UC)

Researchers and collaborators: Luís Simões da Silva (ISISE-UC); Anísio Andrade (UC); Trayana Tankova (ISISE-UC); Liliana Marques (ISISE-UC). Coordinators from partner institutions: Ulrike Kuhlmann (UStutt); Bert Snijder (TU/e); Véronique Dehan (ECCS); Louis-Gui Cajot (AMBD)

Partner Institutions: University of Stuttgart (UStutt) (Germany); Eindhoven University of Technology (TU/e) (the Netherlands); European Convention for Structural Steelwork (ECCS) (Belgium); ArcelorMittal (AMBD) (Luxembourg)

Period: July 2013 to June 2016

Relevant facilities: Computational equipment of Civil department of FCTUC; Computational and laboratory equipment of other partner institutions.

Objectives:

Currently, safety assessment is not consistently considered throughout the many parts of Eurocode 3, mainly due to a lack of guidance and lack of existing databanks containing information on the distribution of the relevant basic variables and steel properties.
Therefore, in SAFEBRICTILE an objective and consistent assessment procedure for the safety assessment of the various failure modes that are relevant for steel structures is developed. The unified procedure will result in codified procedures for inclusion in the structural Eurocodes and is able to cover ductile failure modes (driven by plasticity), semi-ductile failure modes (driven by stability) and brittle failure modes (driven by fracture).
A complementary and required task to accomplish this is also carried out within this project and consists of the conceptual development and further maintenance of an European database of steel properties resulting from experimental tests.
In addition, several rules in Eurocode 3 covering the failure modes treated in the project are reassessed in order to fulfil the developed safety assessment procedures.
The results of this project will lead to major competitiveness gains: (1) faster time-cycle in the development of new design procedures able to cope with innovation; (2) increased reliability in the accuracy of new design models; (3) major savings in R&D costs by avoidance of major duplication of work.

Description and Methodology:

In a first step, the safety assessment procedure is developed by considering the option of having or not having a previously established safety factor. This is carried out in accordance with Annex D of EN 1990 Basis of Design. In line with this task, a databank of test results and respective characterization of basic variables is developed. Then, considering the developed procedures, reliability assessment of design rules throughout Eurocode 3 is performed and new rules in line with the safety requirements are developed whenever necessary.

WP1 Development of safety assessment procedure
The objective of WP1 is to provide clear and objective guidance for the efficient safety assessment of design rules for steel structures and the establishment of the corresponding partial safety factor γM. This will be in line with the Eurocode – EN 1990 design philosophy and will cover two different viewpoints: (i) the evaluation of the safety of new design procedures; (ii) the assessment of the safety level of existing design procedures. By doing this, a consistent level of safety is established throughout Eurocode 3 which has to be ensured both by existing rules and new rules.

WP2 European Database of Steel Properties (S235 to HSS S460; S550; S690)
The safety assessment procedure developed in WP1 relies on the statistical distribution of certain basic input variables such as the mechanical properties of steel (yield stress; Young's modulus; etc.); cross section dimensions; geometrical and material imperfections.
The results of existing test measurements will be reported in a standard way. A comprehensive and up-dated database of sectional and material parameters for steel sections is here developed.
The European database will provide results of previous experimental work as well as a consistent statistical characterization of the relevant properties for calculation of resistance.

WP3 Ductile modes driven by plasticity
Based on the results of WP1 and WP2, a consistent level of safety throughout the many parts of Eurocode 3 will be ensured concerning failure modes governed by plasticity, by adjusting existing rules if needed. This failure mode is largely depending on the yield stress. The focus will be on the design rules present in EN 1993-1-1 related to cross-sectional resistance. The code rules were developed in the past for mild steels but there still is a need to verify if the rules are also applicable to high-strength steels. Limited effort will be put on the rules for single internal forces (tension, compression, bending moments, shear forces) since these rules are relatively simple. However, the focus will be on combinations of internal forces since these rules are more complex. Moreover, their scope is limited to double symmetric I-shaped, circular and rectangular sections. Therefore, also elliptical, mono-symmetric and asymmetric sections will be investigated and existing design rules will be assessed to achieve a consistent safety level. Also new design

rules recently developed for a gradual transformation from full plasticity in bending to outer fiber yielding only (semi-comp) will be considered and its safety level will be checked.

WP4 Semi-ductile modes driven by stability
Considering the achievements of WP1 and WP2, a consistent level of safety throughout the many parts of Eurocode 3 will be ensured in what concerns stability aspects, either by adjusting existing rules or by developing more mechanical and consistent design rules. For this, generalized slenderness straight forward procedures correctly adapted to a range of cross section shapes (uniform or not), boundary condition, buckling mode are developed. These procedures are limited to isolated members in which a combination of the above defined parameters is considered. A range of standard frame systems is also analysed. The interaction of local and buckling modes is also to be considered.

WP5 Brittle modes driven by fracture
Considering a similar approach as in WP3 and WP4, a method for statistical validation of design rules for typically brittle failure depending on material strength using as example weld design strength of mixed connections (MCS and HSS) is developed.
Within WP5 experimental program is conducted and focused on the load bearing capacity and safety against brittle fracture on welded dual-steel connections. The typical failure is a "fracture failure" where statistical evaluation plays the decisive role. One of the main objective is then to develop design recommendations drafted for statistical evaluation of brittle failure modes based on experimental testing for design and give more detailed rules of welded dual-steel connections composed of 2 different steel grades: mild carbon steel (MCS) and high strength steel (HSS) and range of different filler metals.

WP6 Design guidance, project management and dissemination
A project management WP will ensure effective communications between partners throughout the length of the project. A workshop will be held at the end of the project. In addition, a clear guideline for the assessment and development of design rules in steel structures is prepared as outcome of WP1 being applied and further developed by WP3,4,5.

Publications:

Papers
Tankova, T., Simões da Silva, L., Marques, L., Rebelo, C., and Taras, A. "Towards a standardized procedure for the safety assessment of stability design rules", Journal of Constructional Steel Research 103 (2014) 290–302

Dissertations
Tankova, T., Comparative review of possible alternatives for performing safety assessment of design rules for steel structures, Master Thesis, January 2014

Reports
Marques, L., Simões da Silva, L., and Rebelo, C. "Code proposal for rules for member buckling of non-uniform members", Technical Committee 8, ECCS, Document TC8-2013-11-23, Zurich, Switzerland, November 8th, 2013;

Conference proceedings
Tankova, T., Marques, L., Taras, A., Simões da Silva, L., Rebelo, C., "Development of a simplified probabilistic methodology for safety assessment of stability of steel structures", EUROSTEEL 2014, 7th European Conference on Steel and Composite Structures, Italy (2014).

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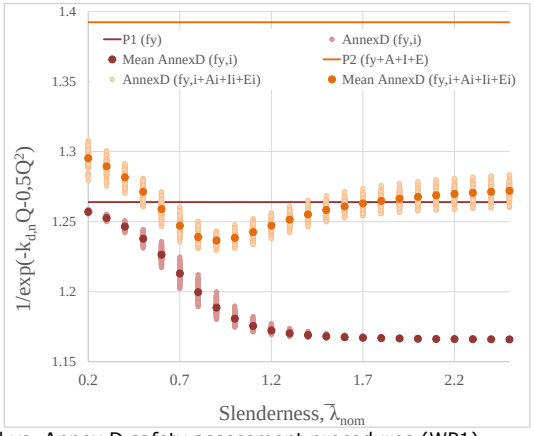

Fig. 1 simplified vs. Annex D safety assessment procedures (WP1).

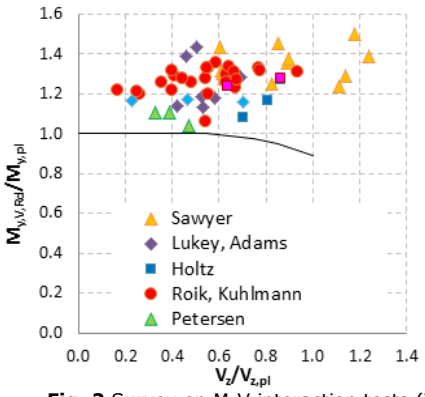

Fig. 2 Survey on M-V interaction tests (WP3).

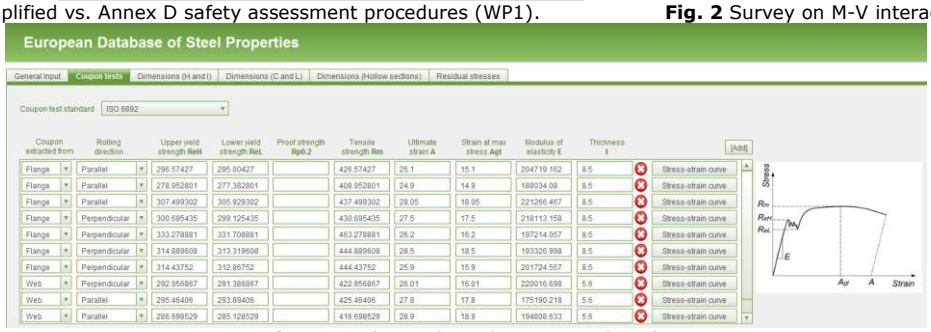

Fig. 3 Database of Steel Properties (WP2).

Steel Prost DEMO

Financing Institution(s): European Comission

Promoting Institution(s): European Comission

Coordinator(s): Roberto Ruiz

Researchers and collaborators: Alessandra Marmondi, Carlos del Castillo, Edoardo Lucini, Filipa Santiago, Gustav Notander, Iñigo Olaetxea, Luís Simões da Silva, Luís Figueiredo Silva, Lucio Carlucci, Pedro Sanz, Roberto Ruiz, Steffen Lutz, Vladimir Gumilar

Partner Institutions: AIN - Associacion de la Industria Navarra, Bersch & Fratscher GmbH, CMM - Portuguese Steelwork Association, Construction Cluster of Slovenia, Talleres Ruiz, Tecnologias Avanzadas Inspiralia.

Period: September 2013 – August 2015

Relevant facilities: Laboratory equipment of Alcea and other.

Objectives:

In sequence of SteelProst, Steelprost DEMO aims to continue with the route to market by achieving the IC certifications and to industrially validate the spraying/drying system. Moreover, in order to provide legal security to newly developed technology users, SP Demo project addresses the CE marking integration of the SP Project outcomes so that documented and demonstrated legal support is provided for claimed FR values in Europe.

Description:

During the previously EU funded FP7-SME-2008-2-STEELPROST R4A Project, and with the assistance of three RTD performers – i.e. INSP, ITRI and ACCIONA – it has successfully achieved all its defined technical objectives for developing a functional and technical solution of STEELPROST. Nevertheless, before commercialization of SP's technical solution, the Demo consortium must achieve further objectives to continue with the results of the R4Associations Project to be able to use the SP technical solution in the market, and these are described below:

1-Certification of the ICs according EN 13381-8 and CE marking **-** of their manufacturing process Pre industrial and lab formulations resulting from SP R4A need to be scaled up to Industrial batches manufactured under controlled conditions. These industrial batches will be certified under EN 13381-8 for I, H, L profiles in arrange from 60 to 400 m-1 section factor values. Graphical and tabulated temperature profiles will be obtained for Standard fire conditions so that a wide range of temperature profiles up to 800 ºC will be available for FR resistance assessment for utilization factors as low as 0.15 according to EuroCodes defined steel structural design criteria. Moreover EN 13381-8 test will provide l (thermal insulation of intumescent coatings) that will allow the evaluation of intumescent coating protected steel profiles under natural and localized fire definition. Costs are related to paint testing,scale up and optimization of dispersion procedures from pre-industrial to industrial scale, manufacturing of samples for other Consortium members and also the follow up/ control of tested samples and production quality management.

2-Validate our new spraying/Drying system to reduce cost & ensure best quality - advantageous optimized spraying and drying conditions were evaluated and identified in SP R4A at pre-industrial and lab scale. Flat samples were advantageously coated and dried resulting in a set of industrial conditions that led to reduced drying times. IR technology exhibited shorter drying times for moderate wet layer applications, up to 500 wet microns were dried in time as short as 90 seconds, while thinner layers could be dried in times as short as 30 seconds. Automatic spraying is able to coat at 5.5 m/ minute speed. SP Demo will integrate both results in an automatic spraying and drying system demonstrator for 1 m "L" or "I" beams in a 200-300 m-1 section factor. IR Drying times from 1-120 seconds will be targeted for infrared and spraying speeds up to 5.5 m/minute for high pressure airless and air assisted airless spray guns. Adjustable devices for automatic spraying and infrared drying technologies will be designed built and integrated in a single prototype.

3-Integration of developed foreground in CE Marking for the overall steelwork construction - SP R4A included evaluation of pre-industrial according to EuroCodes Steel Structural design criteria. Calculations were based on lab and pre-industrial samples evaluations results. Obtained results showed important savings related to the use of the new developed technology, specifically when localized and natural fires were evaluated. Now it is necessary to integrate the FR evaluation procedures (including standard fire and l based approach natural and localized fires) in CE marking procedures so that the obtained FR obtained values are considered as valid and legislation compliant in Europe.

All issues related to FR evaluation including failure criteria, fire definition, FR evaluation for standard, natural and localized fires, steel properties, mechanical loads, coating drying and transport issues and will be set, traced, documented and defined to ensure that cost efficient and legislation compliant Fire Resistance results. This task involves important efforts on testing, documentation, calculation and manufacturing processes and requires external validation by a notified body. Tests/documentations for EU certifications executed and delivered – CE Marking obtained and certified CE Marking is achieved for the overall steelwork construction. A fully validated, legislation compliant, industrialized and commercialized SP solution must be available to sell in Europe.

4-Demostrator Design guidelines, manuals and training materials will be produced for the final SP technical solution - Construct structured guidelines including real design representative examples and providing calculation tools and example descriptions including: Failure Criteria definition, Critical Temperature assessment, Fire situation definitions, FR assessment (tabulated and numerical), cost estimation and comparison versus standard procedures for

ensuring the technology absorption by the overall Steel Constructors community. Paper and electronic supported guidelines will be produced as result. A final Business strategy and Dissemination plan must be written. An (IR) prototype will be developed & completed with all demonstrator designs having the necessary EU/CE certifications. In the Research for SME Associations Project, a lab-tested solution for SP was developed and tested. However, such a solution cannot be used directly in the steel industry since more stringent and complete validations, plus quality tests are formally required. Furthermore, the integration of the components of STEELPROST is necessary, optimizing the technology and conducting a formal review of the enhanced ICs, spraying/drying research studies and FR design/calculation procedures from the very outset "post-project". SP Demo – includes technical refinements & quality/performance assessment of SP components required to allow integration of a fully functional solution. Workflow description for the SP Demo illustrated in Every step included in SP Demo's defined chain is subjected to legislative issues, so an important effort on standardization needs to be invested. Raw materials, paint manufacturing processes, structural design, calculations and the construction of structural steel needs to be executed according to standards and certified by external certification bodies. Protective systems are subjected to exhaustive validation and certification procedures which focus on: Controlling raw materials and manufacturing processes. Evaluating the reactive coating properties. Ensuring that the reactive coating is efficiently applied. Ensuring the FR of steel structures that are erected in real-life scenarios. FR (Fire Resistance) is a complex issue in which the design of structural elements and fire conditions' definition need to be considered, in addition to reactive protection of steel itself. Overcoming limitations of current intumescent technologies makes it necessary to provide strong, documented and legislation compliant evidences of obtained Fire Resistance values. EN 13381-8 results (Standard fire temperature profiles and l values) will be efficiently transformed into Fire Resistance values according to EuroCodes content under CE marking validated procedures. Certification according to the normative EN-13381-8 will be carried out during WP2 of the project. Generated foreground CE marking integration will be carried out during WP4.

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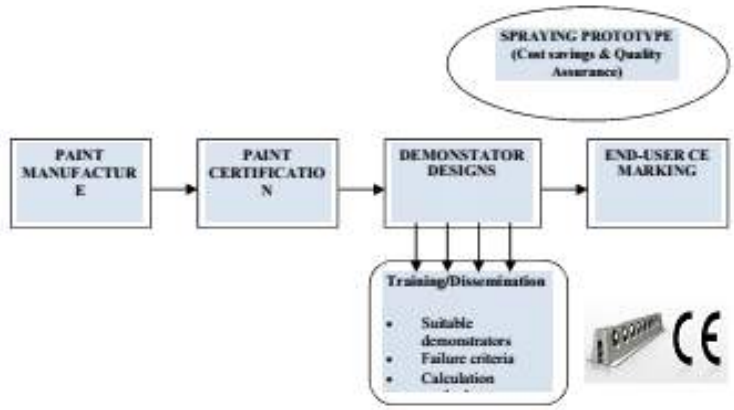

Fig. 1 Workflow in Stellprost DEMO.

Structural rehabilitation of masonry walls in old buildings | REABEPA

Financing Institution: FCT

Promoting Institution: Technical University of Lisbon (IST)

Local Coordinator: Fernando Branco (IST) and Daniel V. Oliveira (UMinho)

Researchers and collaborators: Daniel Oliveira, Paulo Lourenço, Graça Vasconcelos, João Roque (only UMinho researchers listed)

Partner Institutions: Technical University of Lisbon, University of Minho, LNEC

Period: April 2010 to October 2013

Relevant facilities: Laboratory facilities: strong floors and reaction walls; several universal hydraulic load frames, closed-loop servo-controlled actuators and data acquisition and control equipment; diverse day-to-day laboratory equipment / Computational facilities: advanced FE numerical tools.

Objectives:

After the devastating earthquake in 1755 which destroyed Downtown Lisbon, the city was rebuilt adopting an innovative construction, Pombalino buildings. These buildings consist of outer load bearing masonry walls and internal half-timbered shear walls. Since little information is available on the effectiveness of these constructions and many rehabilitation projects are currently under way, it is important to assess the seismic capacity of these structures. The aim of this project is to study these traditional shear walls in order to assess their seismic behaviour and propose retrofitting techniques for rehabilitation purposes.

Description:

Masonry buildings are part of the historical heritage of many countries. A particular type of masonry building is constituted by half-timbered construction, which has been adopted in Europe, Asia and America as a seismic resistant solution. In half-timbered buildings, the structure is composed of a timber frame filled with different materials, such as brick masonry, rubble masonry, hay and mud.

After the devastating earthquake in 1755 which destroyed Downtown Lisbon, the city was rebuilt adopting an innovative construction, Pombalino buildings, a particular type of half-timbered construction. These buildings consist of outer load bearing masonry walls and internal half-timbered shear walls, named frontal. The walls had a timber frame (frontal means cage) with vertical and horizontal elements, braced with X elements (the typical Saint Andrew's crosses) with an infill that could be either brick or rubble masonry. These timber elements were connected to the floors' structure, forming a three-dimensional timber frame with improved stiffness and deformation capacity under seismic actions. Most of these buildings presently need to undergo seismic rehabilitation due to the following reasons: (i) their natural degradation with time; (ii) the need for adaptation to the present serviceability conditions, generally involving structural changes; (iii) former interventions with elimination or damaging of structural elements, affecting seismic resistance; (iv) the noncompliance with the new generation of seismic codes.

Due to the lack of specific codes, seismic rehabilitation is usually carried out based on empiric rules, essentially depending on expertise and experience of designers and contractors. The main objective of this project is to contribute to the development of knowledge in the area of seismic rehabilitation and strengthening of old buildings, as a base for a better supported and more efficient design and construction practices.

The achievement of the referred objective will involve, on UMinho's part:

- Experimental tests to assess the in-plane seismic behaviour of "frontal" walls and to evaluate the effect of its components (timber frame, type of infill), allowing for more thorough rehabilitation projects, based on realistic parameters for the existing structure.
- Experimental evaluation of the adequacy and efficacy of compatible seismic rehabilitation methods, namely bolts, steel plates (with different configurations) and steel flat bars.
- Development of numerical models, calibrated with the experimental results, to be used in the seismic rehabilitation design of old buildings.

The experimental campaign consists of in-plane static cyclic tests on real scale walls with a geometry in accordance with what encountered in existing buildings both in terms of dimensions and of connection type.

The numerical simulation consists of modeling and calibrating a model of a single wall, both unreinforced and retrofitted, in order to perform parametric analyses taking into account different materials and vertical load levels. Subsequently, a simplified model will be prepared with the adoption of a hysteretic model that reproduces the behaviour of the connections, as observed in the experimental tests performed.

The main results to be expected in this research project are:

- Development of appropriate seismic strengthening techniques for old buildings;
- Numerical models to simulate the behaviour of half-timbered walls;
- Design manual for dimensioning of proposed seismic strengthening solutions.

Publications:

PhD theses:

Poletti E. (2013) Characterization of the seismic behaviour of traditional timber frame walls, PhD Thesis, University of Minho, hdl.handle.net/1822/28845

ISI papers:

Vasconcelos G., Poletti G., Salavessa E., Jesus A., Lourenço P.B., Pilaon P. (2013) In-plane shear behaviour of traditional timber walls, Engineering Structures, 56, pp. 1028-1048, 10.1016/j.engstruct.2013.05.017

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Conference proceedings

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Poletti E., Vasconcelos G. (2012) Seismic behaviour of traditional half-timbered walls: cyclic tests and strengthening solutions. Structural Analysis of Historical Constructions, Wroclaw, Poland.

Poletti E., Vasconcelos G., Oliveira D.V. (2013) Influence of infill on the cyclic behaviour of traditional half-timbered walls. In International Conference on Rehabilitation and Restoration of Structures, Chennai, India.

Vasconcelos G., Lourenço P.B., Poletti E. (2013) An overview on the seismic behaviour of timber frame structures, 1st International Symposium on Historic Earthquake-Resistant Timber Frames in the Mediterranean Region, 10 pp, Calabria, Italy

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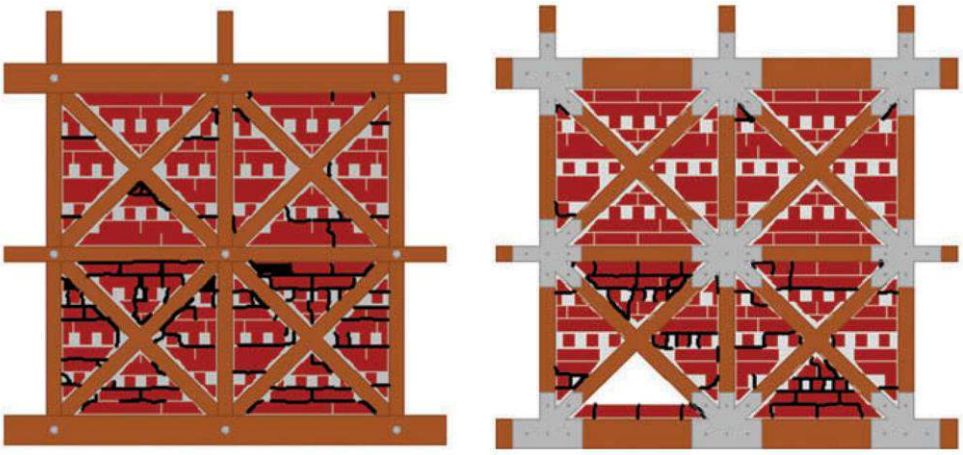

Fig. 1 Experimental testing of strengthened half-timbered walls.

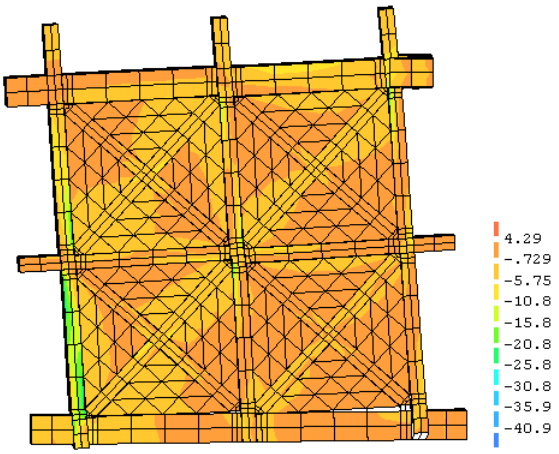

Fig. 2 FEM modelling of half-timbered walls.

Sustainable Infrastructure Management System | SustIMS

Financing Institution(s): ADI

Promoting Institution(s): ASCENDI; University of Minho (UMinho); New University of Lisbon (UNL)

Coordinator(s): Ugo Berardinelli (ASCENDI); José C. Matos (UMinho); Luis C. Neves (UNL)

Researchers and collaborators:

José C. Matos, Paulo B. Lourenço, Tiago Miranda, Antonio G. Correia, Joel Oliveira, Paulo Pereira, Jorge Cabral, Jose Mendes, Joao Monteiro, Ugo Berardinelli, Carlos Neves; Alvaro Soares; Vasco Corte-Real, Adriana Santos; Alexandra Ferreira; Luis C. Neves

Partner Institutions: Institute for Sustainability and Innovation in Structural Engineering (ISISE); Territory, Environment and Construction Research Centre (C-TAC); Centro ALGORITMI.

Period: September 2012 to June 2015

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho.

Objectives:

The main objective of this project is the development of a sustainable roadway infrastructure management system software. This platform will manage, within a coherent and sustainable way, all main elements of a concession, including bridges, pavements, embankments and walls. With this system it will be possible to improve the quality of available data in each moment about any infra-structure, improve the future performance forecasts, and take better decisions regarding the preservation and rehabilitation of each infra-structure element. By using advanced forecast performance models and optimization algorithms, it will be possible to define optimal preservation and rehabilitation strategies that: (a) reduce the economic and environmental impact on the infra-structure during the whole life-cycle; (b) reduce the risk of incidents and its impact on the users; (c) reduce the financial risk of the project, as they allow to preview with the highest accuracy the necessity of future investments. The project will be developed in three great lines: (a) Development of a management system, which includes forecasting performance models and optimization algorithms for the infra-structure performance; (b) Development and optional integration of a monitoring system, that allow to collect, on real time, important data for the efficient infra-structure management, namely, environmental conditions and incident detection on the roadway, due to landslides, or due to the vehicles flow or incidents, as also, the respective integration on developed management system; (c) Implementing developed frameworks and equipment's on an experimental road subsection for validation.

Description:

The project Sustainable Infrastructure Management System (SustIMS) arises from a pressing need to manage, in an efficient and sustainable manner, the Portuguese highway network, which has been subjected to huge investments in recent decades. It aims to develop a computational tool to support highway operators' decisions, improving not only their competitiveness but also users' satisfaction.

This instrument is an integrated infrastructure asset management system (Fig. 1a), which implements the core principles of asset management combined with sustainability considerations. The platform under development is a logical evolutionary step from traditional individual management systems to an integrated approach influenced by economic, environmental and geographical aspects. A singular monitoring system appears as one of the major contributions to the common asset management system framework (Fig. 2). This will allow to detect, on real time, collisions on safety guards, as well as imminent risk of landslides, so that proactive interventions can be addressed.

As a vital component of the entire system, the data warehouse will be able to store all collected data, as well as to support the adjacent models, i.e. forecast performance and maintenance models. Thus, its constant updating will improve the quality of the available data, resulting in better decisions on optimal allocation of resources. The performance models were developed according to Markov process. Based on expert judgment, operator's past experience and bibliographic references, maintenance models were developed and further integrated in adjacent models (Fig. 1b).

With the aim of improving and supporting the decision on strategic planning of maintenance actions, a multi-objective optimization problem was formulated. To numerically solve this problem, an approach based on a fast non-dominated sorting genetic algorithm was proposed. This first approach provides a timetable of maintenance actions to be performed for the entire infrastructure system considering the established objectives and restrictions.

The project's structure embraces so three main tasks: (a) development of a management system, which includes prediction models and performance optimization algorithms (Fig. 1); (b) development of a monitoring system, which allows to gather relevant information to ensure users safety and a more efficient infrastructure management (Fig. 2); (c) implementation on a case study - road subsection.

With this, as result of improvements in the quality of available data, as well as in future performance forecasts, a better decision support mechanism can be achieved. Thus, aiming to define optimal preservation and rehabilitation strategies several outcomes can be achieved, such as: (a) reduction of economic and environmental impact on the infrastructure during the whole life-cycle; (b) mitigation of risk incidents and their impact on users; (c) financial risk reduction, which results from a more accurate prediction of future investments needs.

The major milestones of this project are the following: (a) new infrastructure database; (b) advanced performance models, with integration of maintenance actions; (d) advanced optimization algorithm; (e) cutting-edge monitoring system; (f) integrated management platform, with an application in a case study.

Publications:

Reports

"SustIMS – Sustainable Infrastructure Management System" 1st Semester Technical Report. February 2013.
"SustIMS – Sustainable Infrastructure Management System" 2nd Semester Technical Report. September 2013.
"SustIMS – Sustainable Infrastructure Management System" 3rd Semester Technical Report. February 2014.
"SustIMS – Sustainable Infrastructure Management System" 4th Semester Technical Report. September 2014.

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Ferreira, C., Neves, L. C., Matos, J. C., Soares, J. M. S. (2014) "A degradation and maintenance model: Application to Portuguese Context" IABMAS 2014, 7th International Conference on Bridge Maintenance, Safety and Management, Shanghai - China, 7-11 July 2014, http://hdl.handle.net/1822/30842.
Gonçalves, B., Matos, J. C., Lourenço, P. B. (2014) "Streamlining field inspections for infrastructures life-cycle management" 37th IABSE Symposium, Engineering for Progress, Nature and People, Madrid - Spain, 3-5 September 2014, http://hdl.handle.net/1822/30845.
Pinheiro, R., Matos, J. C. (2014) "3D Nonlinear analysis of a composite steel/concrete viaduct" 37th IABSE Symposium, Engineering for Progress, Nature and People, Madrid - Spain, 3-5 September 2014, http://hdl.handle.net/1822/30843.
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Santos, A., Freitas, E., Faria, S., Oliveira, J.R.M., Rocha, A.M.A.C. (2014) "Degradation Prediction Model for Friction in Highways" 14th International Conference on Computational Science and Its Applications (ICCSA 2014), June 30 - July 3,Guimarães, Portugal.

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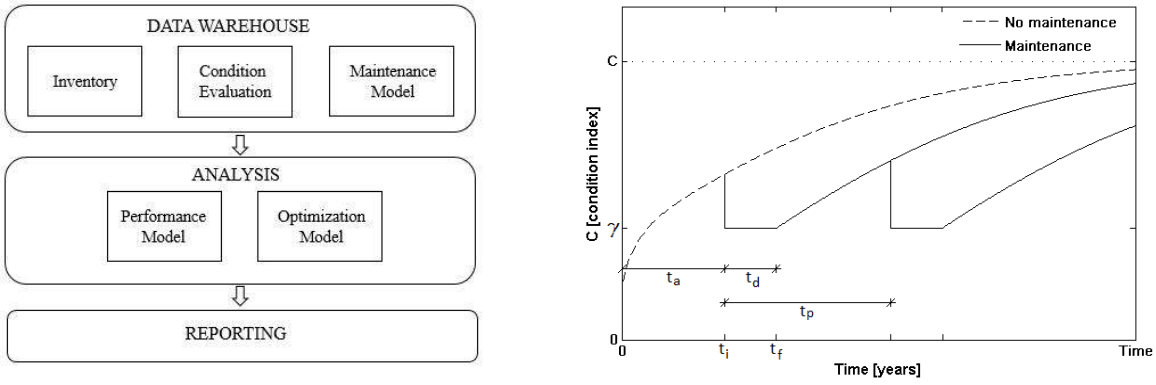
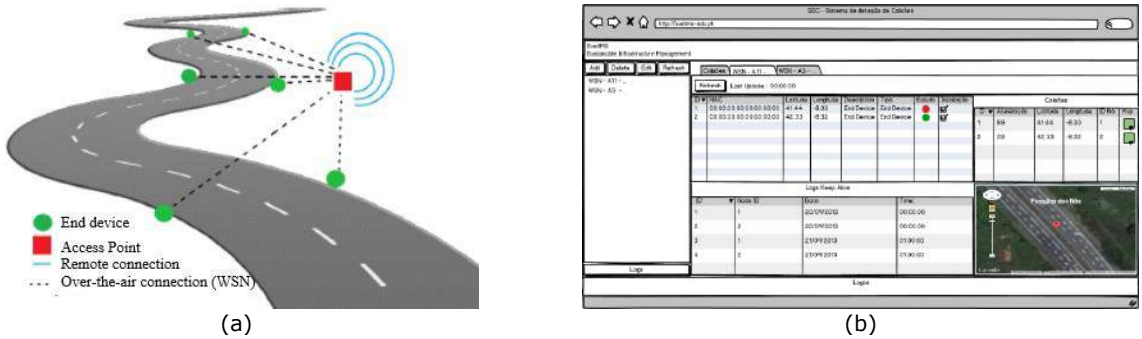


(a) (b)

Fig. 1 Asset Management Platform: (a) management system framework; (b) performance and maintenance models.



(a) (b)

Fig. 2 Integrated Monitoring System: (a) collision detection system scheme; (b) infrastructure monitoring system website.

Testing methods for E-modulus of concrete and mortar since very early ages: a round robin test series

Financing Institution(s): FCT / Egide

Promoting Institution(s): University of Minho and IFSTTAR

Coordinator(s): Miguel Azenha and Claude Boulay

Researchers and collaborators: Miguel Azenha, António Gomes Correia, Cristiana Ferreira, Jacinto Silva, José Granja, Claude Boulay, Jean Michel Torrenti, Florent Baby

Partner Institutions:

Period: March 2012 to March 2015

Relevant facilities: Equipment available at UMinho, IFSTTAR and Université Libre de Bruxelles (described below)

Objectives and Main achievements:

Concrete is a multiphase material that endures significant changes at micro structural level along cement hydration. In the instants after mixing it consists of aggregates suspended in the cement paste, behaving nearly as a Newtonian fluid, which gradually evolves to a solid state. Knowledge of how the mechanical properties of concrete evolve since casting is of importance for many fields of materials science, namely for the prediction of stress development at early ages. The importance of this knowledge is further extended if construction-related aspects are taken into account. In fact, many construction operations are conditioned by the evolution of concrete properties: pre-stressing operations, formwork removal, etc.
In view of the acknowledged importance of assessing the development of properties of cement-based materials since casting, the two teams to be involved in this cooperation have recently devised new methodologies for continuous (or almost continuous) measurement of E-modulus: (i) the method developed at IFFSTAR, known as BTJASPE (BéTon au Jeune Age : Suivi de la Prise et du module d'Elasticité); (ii) the method developed at the University of Minho, identified by the acronym EMM-ARM (Elasticity Modulus Measurement through Ambient Response Methodology). Both research teams have also recently dedicated themselves to stiffness measuring techniques such as ultra-sound wave velocity measurement, traditional cyclic loading and penetration resistance. Furthermore, the team at Minho Univ. is currently conducting research on applying bender-extender elements for quantification of E-modulus evolution of cement-based materials at early ages. The project also encompasses the informal collaboration of the Université Libre de Bruxelles through the use of a TSTM testing machine and smart aggregates.
The main objective of this research project is to conduct a round robin testing program involving the two teams, working on the same materials (concrete and mortar). This collaboration involves both established and the techniques recently developed, which have not been so far object of such kind of any inter-laboratory testing.

The whole experimental framework envisaged can contribute to the credibleness and establishment of BTJASPE and EMM-ARM as valid techniques for stiffness monitoring since very early ages, and perhaps act as a starting point for proposals of introduction of these techniques into currently existing normalization. It is actually expected that at the end of this 2 years collaboration, the joint work should predictably continue, namely through the establishing of a scientific committee (RILEM or FIB) for such purpose involving further research centers.
It is also expected that cross-validations of the traditional methods for stiffness measuring, together with BTJASPE and EMM-ARM can provide good grounds for comparison and interpretation of the results of the use of bender-extender elements to characterize concrete. In fact, this technology that has been mostly applied for soils, has not yet been applied in concrete, and the extents of such application are also envisaged in this collaboration.

Tasks:

Task 1 – Startup and planning. This task involves a personal visit of two members of the Portuguese team to IFFSTAR. This visit will allow better personal interaction about the main points of the project, and culminate with a formal videoconferencing meeting of all the members of the project. It is intended to establish the complete detailed plan and schedule for the project (shared materials, quantities, methods and updating of research targets).
Task 2 – Mortar testing. Mixes containing the same river sand will be tested, with variation on the type of cement (at least two types), and eventually water-to-cement ratio. The methodologies available to both teams for early stiffness testing are to be used, with particular emphasis to the recently developed methodologies (BTJASPE, EMM-ARM). Comparisons will be made between the results of the new methodologies, as well as with the traditional compressive cyclic testing and the Ultra-Sound based techniques.
Task 3 – Concrete testing. This is the most important material to test, when actual conclusions for application in construction are envisaged. Thus, after testing mortar and finding the main tendencies, the same kind of approach is applied to concrete in terms of experimental techniques. It should however be stressed that the concretes to be tested should contain the mortar tested in the scope of Task 2.

Task 4 – Integration of data. Further than mere performance comparison between the available methods, and bearing in mind the unprecedented amount of available data (particularly at early ages), it is intended to evaluate the possibility of upscaling results from mortar to concrete with homogenization techniques.
Task 5 – Closure of the project at the University of Minho, with visit of two members from the French team for final evaluation of the data and scientific results, and to establish the final project report. The complete closure of the project should again involve a videoconferencing meeting will all team members.

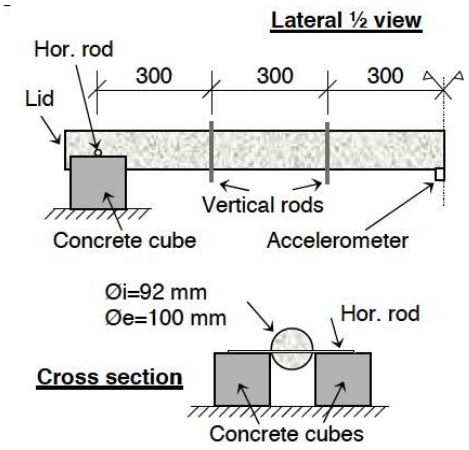


Fig. 1 EMM-ARM method.

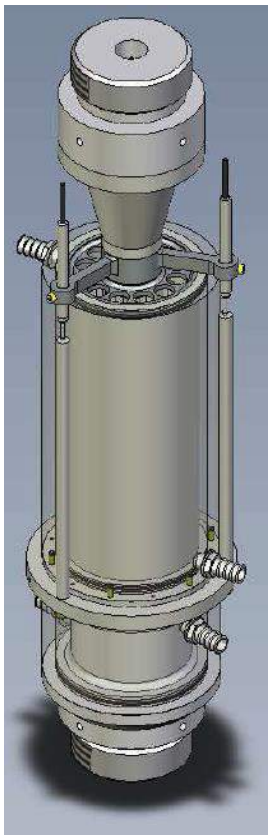
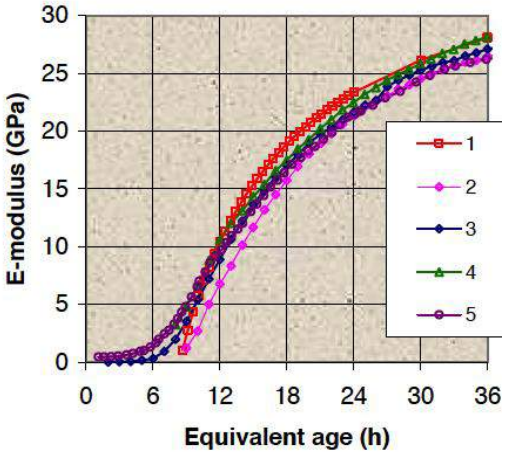


Fig. 2 Schematic representation of BTJASPE.

Fig. 4 TSTM at Université Libre de Bruxelles

Fig. 5 Smart aggregate patches



1. Model for static classical tests
2. Mean E-mod. of 4 validation tests for BTJASPE
3. Mean E-mod., 4 BTJASPE
4. TSTM
5. EMM-ARM, Acrylic beam

Fig. 6 Results obtained for static and quasi-static E-modulus testing.

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Three-dimensional behaviour of steel joints | 3DJOINTS

Financing Institution(s): Fundação para a Ciência e Tecnologia

Promoting Institution(s): Fundação para a Ciência e Tecnologia

Coordinator(s): Luís Simões da Silva

Researchers and collaborators: Luís Simões da Silva, Aldina Santiago, Juan Fonfria, Luís Borges, Rui Simões, Sandra Jordão, Fernanda Lopes, Liliana Marques, Filippo Gentili and Ricardo Costa

Period: January 2012 to April 2015

Relevant facilities: Computational equipment and laboratory of Civil Department of FCTUC.

Objectives:

The project aims the development of a consistent design approach for prediction of the three-dimensional behaviour of steel joints under arbitrary loading. Subsequently, the incorporation of the real joint behaviour in the 3D structural model is intended. Currently, steel joints are designed to perform adequately under wide range of loading conditions: standard static, fire and seismic loading. Recent concerns regarding robustness requirements impose that joints present a minimum level of resistance for any arbitrary loading. In such conditions, resistance around the minor axis or to torsion may also be required. Designers are therefore faced to a strong need to predict the 3-D behaviour of steel joints. The development of a design methodology based on the component method for the 3D behaviour of steel joints constitutes a major advance in this field.

Description and Methodology:

A practical yet consistent approach to predict the 3D behaviour of steel joints should consider: i) the adoption of the principles of the component method; ii) the integration within the global 3D structural models [1]. The incorporation of the real behaviour of the connections in the structural model can only be achieved in a practical way with implementation of a generalized joint element (GJ). The generalized joint element is then composed by several generalized connections (GC) and a generalized column web panel (GWCP). Each generalized connection element and generalized column web panel element contains the appropriate degrees-of-freedoms where each stiffness coefficient must correspond to the condensation of the appropriate component model. Some of these stiffness coefficients correspond to the assembly of the relevant components already available in the EN 1993-1.8 while others require new developed components e.g. T-stub in transverse bending.

The project starts with the development of a 3D design model for joint behaviour and the formulation of a FE generalized joint element. Experimental characterization of components, connections and joints are carried out. A software is developed to implement the joint models and the FE joint element is incorporated in a generic FE software. Finally, guidelines are given for other types of non-uniform members/systems.

In order to achieve the project goals, the first step is the development of design model for steel joints with 3D behaviour and subsequently, the formulation of the generalized joint element (GJ). From this work, new components are developed and interactions between components identified. Their characterization requires new developments. Thus, experimental tests will be carried out. Furthermore, numerical models are validated and parametric studies performed giving deliverables for the characterization of new components, generalized connections and generalized column web panel elements. The information produced in components, connection and joint behaviour characterization are then used for validation of the joint model implementation. Afterwards, the generalized joint element (GJ) is incorporated in general finite element software and benchmark studies are performed for validation. Finally, the knowledge gained performing all describe work allows the preparation of design guidance for consideration of 3D joint behaviour. In order to perform the describe work, seven tasks are foreseen.

DESIGN MODEL FOR 3D JOINT BEHAVIOUR AND FORMULATION OF GENERALIZED JOINT ELEMENT (GJ): The essence of the project is the development of design model for steel joints with 3D behaviour with the formulation of finite element generalized joint element (GJ) allowing the incorporation of the real joint behaviour in the structural analysis. Thus, all components and components interaction are identified. The conceptual model is built on their basis. Coupled to the model development is the formulation of finite element generalized joint element (GJ) that will permit the incorporation of the real joint behaviour in the structural analysis. The construction of the generalized will comprise the following sub-elements: generalized connections for major axis beam; generalized connection for minor axis beam; and column web panel. These sub-elements contain the relevant degrees-of-freedom to be considered according to the joint configuration. The formulation of the generalized joint element is performed for the different possible joint configurations.

CHARACTERIZATION OF COMPONENTS, GENERALIZED CONNECTIONS AND GENERALIZED COLUMN WEB PANEL AND GENERALIZED JOINT: Newly developed components require their behavioural characterization which is accomplished by means of experimental investigation on these components (components tests). The connections and column web panel 3D behaviour imply the consideration of interactions that are currently not approached by the existing models. Thus, experimental tests focusing only parts of the joints (generalized connections tests) will be executed. Further experimental work to assess the 3D joint behaviour is performed. In order to reasonable reduce the ambit of the project, the characterization of all these elements will be performed under static loading and the steel profiles to be used are H or I type. Experimental investigations are very time and cost

consuming therefore, the number of tests is always limited to fully assess the behaviour of all joint parts and of the joint. Thus, numerical simulations are used to complement the experimental investigations. The numerical work is divided in two parts: i) validation of models; ii) parametric studies. Simplified mechanical model composed of extensional springs and rigid links are formulated. Two macro-elements are described, covering nodes connecting beams with the same and with different beam depths. The developed FEM elements are implemented in OpenSees and are validated with some benchmark examples. Finally, from the experimental and numerical results, new analytical expressions/models are derived to characterize new components and components interaction. This work generates the input for the joint model and the generalized joint element application.

IMPLEMENTATION OF DESIGN MODEL AND INCORPORATION OF FINITE ELEMENT GENERALIZED JOINT ELEMENT (GJ): Nowadays, any engineering act can only achieve efficiency with the use of computational aids. The input for the structural analysis is automatically produced. One of the reasons of this project is the need to include the real joint behaviour in the structural analysis. This can only be achieved incorporating the general finite element software the real behaviour of joint. Thus, the formulated generalized joint element (GJ) is incorporate in general finite element software. As open source software, OpenSees is chosen to perform this task.

DESIGN GUIDANCE: The knowledge produce during the execution of the investigation is reflected defining guidelines for the prediction and design of 3D behaviour of steel joints. A handbook is produced describing the design model concept and the incorporation of the real joint behaviour on the structural analysis. The guide manual is completed including several worked examples. This is the final task.

Acknowledgements:

Financial support from the Portuguese Ministry of Science and Higher Education (Ministério da Ciência e Ensino Superior) under contract grant PTDC/ECM/116904/2010 is gratefully acknowledged.

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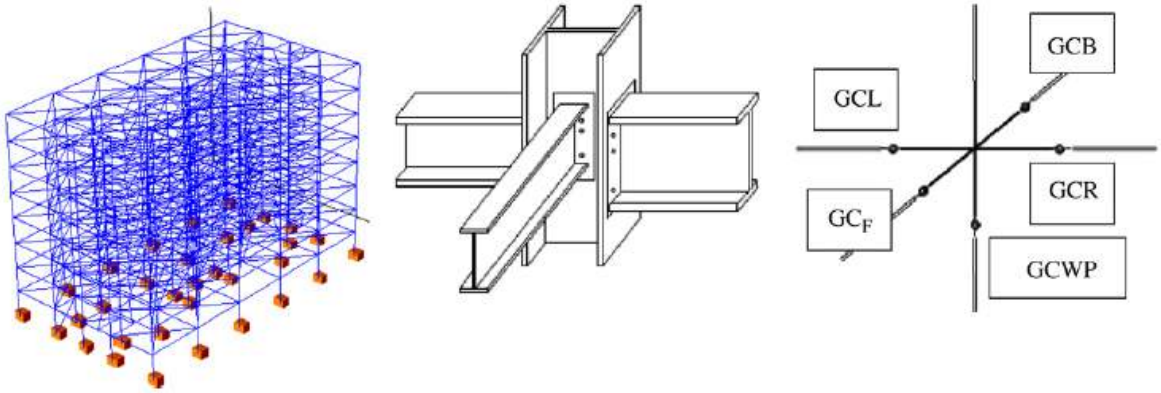

Fig. 1 (a) Structural model; (b) Detail of internal node; (c) generalized joint element.

$$GJ = \begin{bmatrix} GC_R^{MJ} & 0 & 0 & 0 & 0 \\ 0 & GC_L^{MJ} & 0 & 0 & 0 \\ 0 & 0 & GCWP & 0 & 0 \\ 0 & 0 & 0 & GC_F^{MI} & 0 \\ 0 & 0 & 0 & 0 & GC_B^{MI} \end{bmatrix}.$$

Fig. 2 Generalized joint element matrix and respective sub-element.

Towards the next generation of standards for service life of cement-based materials and structures | COST TU1404

Financing Institution(s): COST

Promoting Institution(s): University of Minho (UMinho)

Coordinator(s): Miguel Azenha

Researchers and collaborators: Network Action with more than 130 collaborators

Partner Institutions: Partner institutions in 28 countries (http://www.cost.eu/COST_Actions/tud/Actions/TU1404?)

Period: November 2014 to October 2018

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho and other partners.

Objectives:

Cement-based materials (CBM) are the foremost construction materials worldwide. Therefore, there are widely accepted standards for their structural applications. However, for service life designs, current approaches largely depend on CBM strength class and restrictions on CBM constituents. Consequently, the service life behaviour of CBM structures is still analysed with insufficiently rigorous approaches that are based on outdated scientific knowledge, particularly regarding the cumulative behaviour since early ages. This results in partial client satisfaction at the completion stage, increased maintenance/repair costs from early ages, and reduced service life of structures, with consequential economic/sustainability impacts. Despite significant research advances that have been achieved in the last decade in testing and simulation of CBM and thereby predicting their service life performance, there have been no generalized European-funded Actions to assure their incorporation in standards available to designers/contractors.

Therefore, the main purpose of this COST Action is to bring together relevant stakeholders (experimental and numerical researchers, standardization offices, manufacturers, designers, contractors, owners and authorities) in order to accelerate knowledge transfer in the form of new guidelines/recommendations, introduce new products and technologies to the market, and promote international and inter-speciality exchange of new information, creating avenues for new developments.

Description:

Cement based materials (CBM) for construction are produced by mixing water, cement and other raw materials. During the initial few hours, the material behaves as a solid suspension, but it changes from a quasi fluid state to a solid state at an instance called 'setting time' due to a set of exothermic chemical reactions of cement minerals, known as hydration. From then onwards, the hydration reactions continue and a set of targeted properties reach their high state of maturity after a certain period of time, varying from several hours to a few days or weeks depending on the composition of the cement and conditions that aid the hydration, known as curing. This early hydration period and reactions dictate many important properties of CBM, including their rheological, strength and durability characteristics.

Therefore, an adequate understanding of the behaviour of CBM at these early stages is crucial. Furthermore, CBM undergo significant volumetric changes since early ages due to exothermic reactions that cause increase in temperature and moisture movements in the CBM. These volumetric changes frequently cause cracks at early ages, even in cases where the existing EU regulations are strictly followed. These early cracks impair the material durability, resulting in costly repairs to restore their service performance. Even if cracks do not occur at early ages, a state of internal residual stress is induced that usually limits the capacity of CBM to resist tensile stresses, thus increasing the probability of crack occurrence. This in turn may limit the capability of reinforcement to control the width of cracks in structural members, or loss of prestressing force in the long-term, where applicable. These phenomena may critically compromise their performance in service loads and environments.

In view of the complexities and uncertainties regarding the viscoelastic behaviour and shrinkage effects of different CBM, adequate assurance of important service life parameters such as cracking and deflection of structural reinforced CBM (particularly reinforced concrete) remains challenging in many applications, with frequent deviations being observed in regard to design targets. These limitations are clearly linked to insufficient capacity of existing regulations to describe the real behaviour of CBM both at early ages and throughout the entire service life. Any undesirable CBM behaviour can lead to service lives being compromised for both conventional concrete structures, such as simple one-storey family house or car parks, and large infrastructure facilities, such as bridges, tunnels, water/gas reservoirs, and even critical structures such as concrete containments of nuclear power plants and nuclear storage facilities. Furthermore, frequent and regular maintenance and repair of these structures can increase the life cycle cost of the built infrastructure and negatively contribute to their sustainability.

New priorities are also arising for incorporation of by-products and waste materials in CBM to preserve the raw materials in Europe and to decrease the environmental impact of the production of cement. The development and application of new materials also carries further challenges as society demands undisputable proof of the safety and adequate performance of these new materials. Furthermore, the inclusion of new additional materials in CBM frequently

induces changes in performance that need to be taken into account by designers.

Recent scientific advances through experimental and numerical research have been addressing many of the issues raised above, with important opportunities being clearly identified towards more adequate integrated approaches to the evaluation and prediction of behaviour of cement-based materials and structures. These efforts were made by a wide range of research specialists worldwide, particularly in Europe. Even though millions of Euros have been spent on research on the subject (both by using national and EU funds), there are five fundamental levels of integration that are currently insufficient or even lacking in terms of Europe-wide research and application, which are thus relevant features of this COST Action: (i) mutual validation efforts between experimental techniques for CBM characterization and parallel development of CBM-related materials; (ii) mutual validation efforts between numerical simulation approaches to predict the service life of CBM materials and structures; (iii) mutual interaction between experimental and numerical research so as to establish integrated approaches that match adequate characterization techniques/strategies with the corresponding simulation/prediction tools; (iv) mutual interaction between developers of new products (either materials, experimental techniques or software) with companies at continental level to promote transition of new knowledge to the market; (v) effective joint efforts of the scientific community to produce guidelines and recommendations that accelerate the creation of new standards for construction. Consequently, the impact of this COST Action is relevant both at the scientific/technological levels through the unprecedented integration of knowledge, but also at the economic/societal level due to product development, drafting of guidelines/recommendations and interaction with standardization organisations, such as CEN. However, to achieve this, efforts need to focus on harnessing the research on CBM, not only at the level of countries involved, but also at the level of the numerous sub-specialties involved. The congregation of a large number of countries that a COST Action allows makes it the most adequate funding tool to promote this proposal's aims. Fundamental to this proposal is that research activities can solely rely on funds that each partner can deploy, and, hence, the main focus of the proposal is centred on activities that are mainly dependent on networking and joint research, which is precisely the purpose of COST Actions.

Apart from the acceleration of knowledge transfer to societal applications, there is a very strong potential for new innovations based on the exchange and sharing of knowledge that would otherwise be unfeasible. The new ideas and networking confidence provided by this COST Action will nurture the necessary conditions for new funding request applications that can further deepen the impact of the Action and contribute to the perpetuation of its effects. In fact, an interesting analogy can be made between the process of cement hydration and relationship of the researchers involved in this proposal with the COST Action funding. One may consider that each cement particle represents an isolated country with its own research teams, equipment and funds. Conversely, water (and mixing procedure) represents the opportunity in this COST Action. Once water and cement are together, the hydration reaction is spontaneous due to the potential energy within the cement particles themselves. This leads to strong interconnection between particles that end up constituting a macroscopic solid. That is what this COST Action is about. It is therefore important for Europe to grant a wide collaborative network that gathers partners from research, equipment manufacturing, software development and construction industry. This not only brings an integrated outcome to recent developments, but also has the potential to create new innovations.

The Action is divided in Three Workgroups

WG1 – Testing of cement-based materials (CBM's)
WG2 – Modelling of CBM's and the behaviour of structures
WG3 – Development of recommendations and products

For more details, visit www.tu1404.eu.

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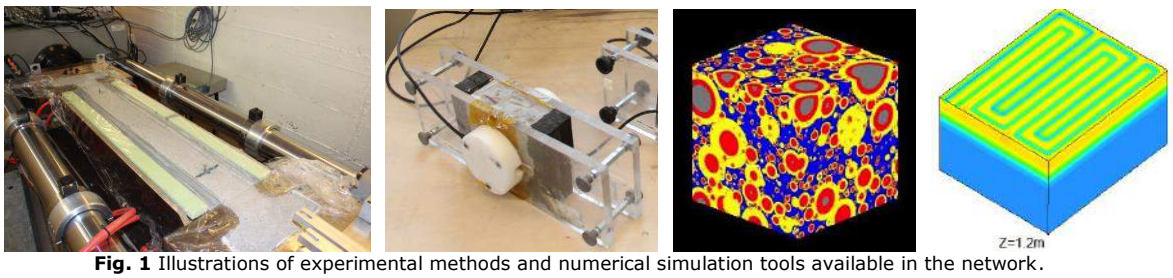


Fig. 1 Illustrations of experimental methods and numerical simulation tools available in the network.

Use of NSM FRP for strengthening of tubular and continuous RC structures | ENDURE

Financing Institution(s): European Commission

Promoting Institution(s): University of Minho

Coordinator(s): Maurizio Guadanini (Sheffield Univ.), Joaquim A. O. Barros (UMinho)

Researchers and collaborators: Joaquim Barros, Sena Cruz, Salvador Dias, Miguel Azenha, Isabel Valente, Chandan Gowda (only UMinho members)

Partner Institutions: University of Minho (ISISE), University of Sheffield, University of Ghent, University of Bath, University of Patras, Lulea University of Technology, Budapest University of Technology, Universitat de Girona, University of Padova, Politechnico Milano, University of Kaiserslautern, EMPA, University of Latvia

Period: 1/10/2014 – 30/9/2017

Relevant facilities: Laboratory equipment and computing facilities of UM.

Objectives:

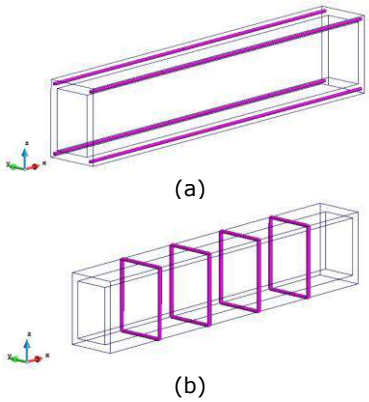
The objective of this project is to investigate the near surface mounted (NSM) fibre-reinforced polymer (FRP) strengthening technique for torsion on thin walled tubular RC structures and for flexure on continuous RC structures. In both cases, first the numerical analysis will be performed and then, based on the results obtained, the strengthening technique will be executed in the laboratory. Several configurations will be investigated for the torsion and shear strengthening by also considering the possibility of applying prestressed FRP reinforcements In regard to continuous structures, main focus will be on moment redistribution capacity and to prevent the early delamination failure in the hogging region. The effect of influence of longitudinal steel reinforcement, transverse steel reinforcement, spacing of the laminates, thickness of adhesive layers and its properties will also be investigated. The outcome of the project will aim at developing practical execution rules for on site strengthening of continuous and tubular structures, development of design guidelines.

Description:

The Endure project research activities will be carried out in two parts viz., torsional and flexural strengthening. Each part involves numerical analysis using FEM before executing experimental testing. The first part is concentrated on torsion (in progress) and the second part will focus on flexure. Presently numerical analysis is being performed on thin walled tubular elements for establishing a comprehensive experimental program. According to the bibliographic study it is noted that no research or experimental activity has been carried out on torsional strengthening using NSM technique.

Research methodologies

Torsion: The torsional strengthening is proposed to be carried out by two methods viz., longitudinal FRP strips/bars with pre-stress and FRP strips/bars in the transverse direction (shown in the Fig. 1).



(a)

(b)

Fig. 1 Research methodologies for torsion (a) Bars/strips with pre-stress (b) Transverse bars/strips.

Type B torsional strengthening provides both flexural and shear reinforcement for the RC beam. The horizontal bars at the top and bottom provide the flexural strength, while the vertical bars provide the shear strength.

Flexure: According to the bibliographic study and the previous experimental activities carried out in UMinho, delaminations of FRP strips are observed in the hogging region. To retain these bars/strips in the hogging region and to exploit the full utilisation of the FRP material, new innovative methods are proposed. The first method involves zigzag strengthening across the length of the slab through wet lay up system in one way, similarly zigzag strengthening in both the ways (top and bottom) and finally using bent FRP bars.

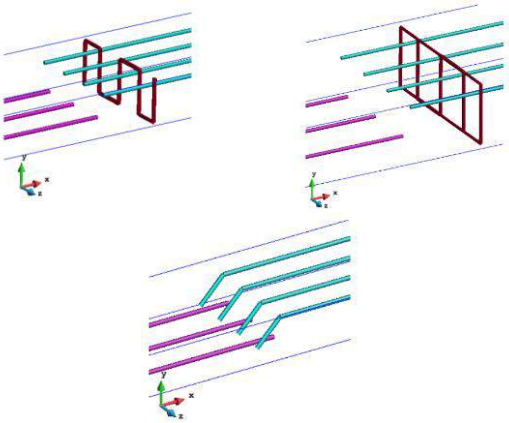


Fig. 2 Research methodologies for flexural strengthening (a) & (b) one way and two-way strengthening (c) Bent FRP bars.

The bending in FRP bars is achieved by using a machine, which provides the necessary angle of inclination along with additional FRP fibres in the bent region (not to have the stress concentration).

Structural concept

Torsional RC beam:

The dimensions of the tubular RC beam are: cross section of 400 mm x 400 mm, length of 3000 mm and thickness of 100 mm throughout the section. It consists of 3 x 12 mm longitudinal bars at top and at bottom of the beam with 25 mm cover. The stirrups are of 6 mm diameter bars with a spacing of 200 mm in the central 2000 mm length and 100 mm spacing at the beginning and the end of the beam so as the forces are transmitted to the central section. 4-legged stirrups are provided throughout the section. The cross sectional details are as shown in the figure.

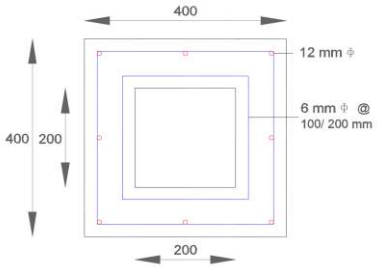


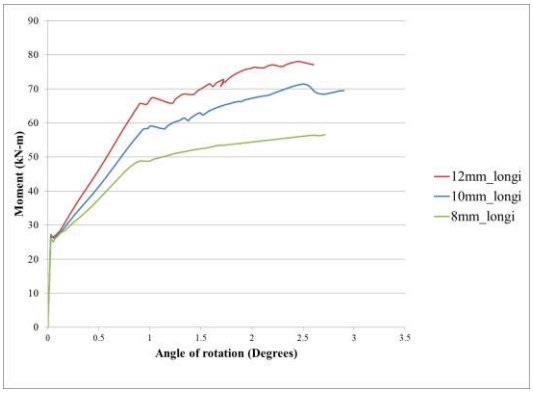
Fig. 3 Cross sectional details (in mm).

The beam is supported on a roller support to rotate freely at the point. In order to apply the torsional moment on the beam a steel section is designed, which will be inserted inside tubular region of the testing beam up to a length of 600 mm. The load is applied on this steel section which in turn applies the torsional moment for the tubular beam.

Work Progress

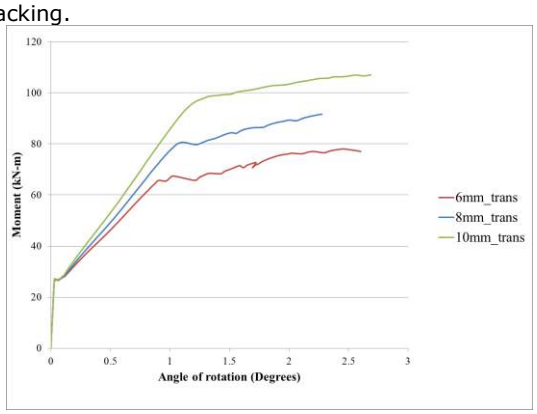
The study on torsion for tubular RC beams is being carried out using the finite element method. The details of the beam are as described in the previous section. The results of moment-angle of rotation for variation of longitudinal reinforcement bars (12 mm, 10 mm & 8 mm) and transverse reinforcement bars (6 mm, 8 mm & 10 mm) are shown in Fig. 4(a) & (b).

From the results it can be concluded that as the longitudinal reinforcement is decreased the stiffness of the beam decreases after concrete cracking, resulting in the yielding of the longitudinal steel reinforcement for a lower moment. The angle of rotation remains almost in the same range of variation in reinforcement bars.



(a)

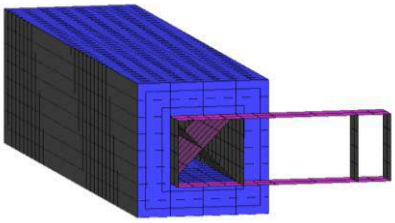
As the diameter of the transverse reinforcement is increased, the yielding of the reinforcement is delayed resulting in the increment of moment carrying capacity, increased angle of rotation at yielding and increase in the stiffness of the beam after concrete cracking.



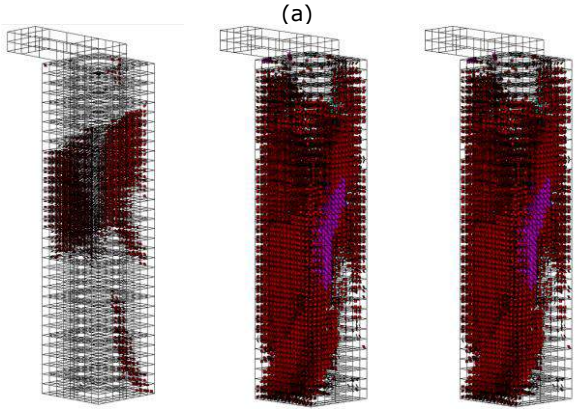
(b)

Fig. 4 Moment-curvature relationship (a) Longitudinal reinforcement variation & (b) Transverse reinforcement variation.

The mesh (a) and the results of the crack pattern (CP) at the point of concrete cracking (b), at yielding point of few longitudinal reinforcement (c) and right after yielding (d) for the model described in structural concept is shown in Fig. 5.



(a)



(b) (c) (d)

Red: Crack opening, Pink:Fully opened cracks

Fig. 5 (a) Model (b) CP at concrete cracking (c) CP at yielding of few longitudinal steel & (d) CP after yielding of longitudinal steel.

Publications

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Vernacular Seismic Culture in Portugal | Seismic V

Financing Institution(s): FCT

Promoting Institution(s): University of Minho (UMinho)

Coordinator(s): Paulo Lourenço (local coordinator)

Researchers and collaborators: Graça Vasconcelos, Paulo Lourenço, Javier Ortega

Partner Institutions: High School of Gallaecia (Coordinator); University of Aveiro

Period: July 2013 to October 2015

Relevant facilities: Laboratory equipment and facilities of Civil Department of UMinho.

Objectives:

This research addresses a critical gap in knowledge regarding vernacular architecture earthquake preparedness. The fact remains that Local Seismic Culture (LSC) research in vernacular architecture has had little attention by the Architecture and Engineering scientific communities. This research is based on the fact that vernacular architecture is an outstanding inheritance, from which remarkable solutions can be obtained and reinforced.

The long-term goal of SEISMIC-V is to contribute to the awareness of LSC, but also to propose recommendations to reinforce existing solutions and to avoid common errors. Thereby, it would be necessary to collect data concerning the efforts that were taken by the population in the past, and to contribute to the restoration and repair of the buildings that sustained damage from the earthquake.

The main goal of the research is to contribute to the awareness and protection of the vernacular heritage, as the need to protect this fragile heritage from natural hazards, particularly earthquakes, is evident. For that purpose and aiming at a better understanding of the seismic behavior of Portuguese vernacular constructions and traditional strengthening solutions, the proposed PhD research embraces specific and fundamental objectives:

1. Identification of materials and construction techniques on selected case studies in seismic prone Portuguese regions and its experimental *in-situ* characterization: 2. Development of a methodology for the seismic vulnerability assessment of vernacular architecture, calibrated with numerical parametric analyses: 3. Application of the proposed methodology on selected case studies and comparative analysis of the seismic performance of the distinct retrofitting techniques using numerical modeling; 4. Identification of common errors and proposal of strengthening solutions that reduce the seismic vulnerability of in-use vernacular architecture, so that guidelines can be accessible to main end-users and decision makers.

Description:

The workplan of the project Seismic V is divided in five technical tasks; (1) literature review; (2) definition of typical buildings representative of vernacular architectue existing in seismic prone regions in which signs of the local seismic culture can be identified based on the selection of region case studies; (3) development of a general methodology for the quantification of the seismic vulnerability of vernacular architecture; (4) numerical assessment of the addition of strengthening solutions to vernacular buildings and evaluation of the reduction of the vulnerability. Update the methodology for seismic vulnerability assessment based on the parameter corresponding to strengthening; (5) application of the vulnerability assessment methodology to real cases and purpose a systematization of the strengthening solutions for vernacular buildings.

A deep literature review was already carried out, namely with a deep insight of the seismic assessment vulnerability methodologies, the starting point of the practical research is the selection and analysis of typical vernacular buildings typical of seismic prone regions ana analysis of their geometry and existence of seismic resistant features. These buildings for study are defined according to the seismicity of the regions. Visual inspection, literature review and, if possible, additional experimental *in-situ* characterization will be used for the accomplishment of geometrical characterization of typical buildings.

A general methodology for the seismic vulnerability assessment of vernacular buildings is under development. This work is based on the methodologies used for masonry residential buildings and adjusted for the different building typologies defined in the case studies selected in the previous task. The base should be the general large scale methodologies based on earthquake damage observation and focusing on the most important parameters affecting the building seismic response that have been extensively applied in Italy and in several Portuguese historical city centers, obtaining useful and reliable results as a first level approach. The adopted methodology will be based on the calculation of a vulnerability index through the evaluation of the most important parameters affecting the seismic behavior of the building based on a hybrid approach. For this, in addition to the literature review on similar methodologies, this research will focus on the a series of numerical nonlinear parametric analyses to assess and calibrate the different weights of each parameter of the approach previously defined and this is considered to be relevant for the definition of the seismic vulnerability of vernacular buildings For this same purpose, some experimental analyses are also envisaged for the evaluation of the influence of the most relevant parameters detected, such as the connections between masonry walls, namely at the corners. Notice that this is a parameter that influences the out-of-plane performance of the masonry walls and, thus, this is intended to be investigated. This experimental analysis will also complement the numerical work carried out on the strengthening solution directed to enhance the intersection of walls.

The next work will be based on the assessment of the seismic performance of the distinct retrofitting techniques previously identified in the first task to evaluate its effectiveness in the enhancement of the seismic behavior of vernacular buildings. A detailed more complex numerical modeling of single buildings to assess their seismic vulnerability and to evaluate

the efficiency of different traditional strengthening techniques will be carried out. This will be needed to update he seismic vulnerability methodology including retrofitting techniques for seismic performance enhancement. Finally, the results of previous tasks will be essential for the fulfillment of the last main objective of the thesis, which consists of the proposal of strengthening solutions that reduce the seismic vulnerability of in-use vernacular architecture and the development of guidelines that could eventually be accessible to main end-users and decision makers. The identification and update of adequate retrofitting techniques for its eventual application for the preservation of the vernacular building stock is the main goal of this research work. Additionally, it is intended to apply the seismic vulnerability assessment methodology to real scale vernacular buildings to validate the approach.

Publications:

Conference proceedings

Ortega J., Vasconcelos, G., Correia M., An overview of seismic strengthening techniques traditionally applied in vernacular architecture, 07-09 July, University of Minho, 2014. (In CdRom).

Javier Ortega, Graça Vasconcelos, Mariana Correia, Hugo Rodrigues, Paulo Lourenço, Humberto Varum, Seismic vulnerability assessment parameters for Portuguese vernacular constructions through non-linear numerical analysis, 5th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering, 25-27 May, Greece, 2015.

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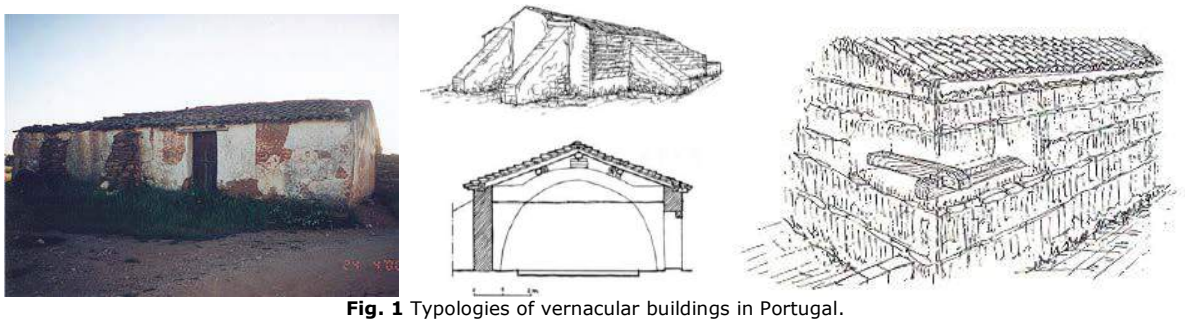
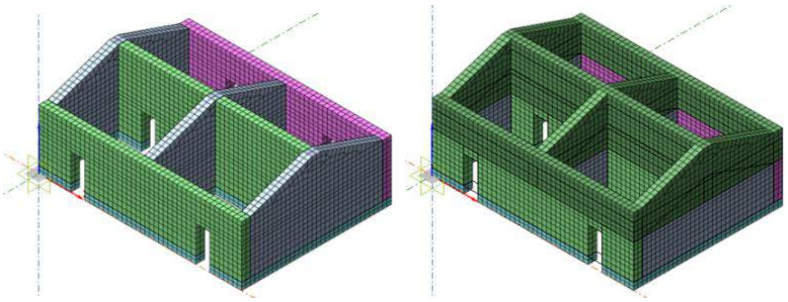


Fig. 1 Typologies of vernacular buildings in Portugal.



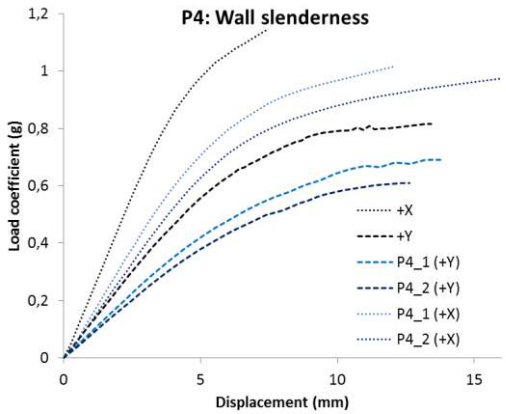


Fig. 2 Some results of the numerical parametric study.

PhD Theses

isise Institute for Sustainability and Innovation in Structural Engineering

Ali Edalat Behbahani

Supervisors: Joaquim Barros / Ventura-Gouveia

NUMERICAL APPROACHES FOR THE MATERIAL NONLINEAR ANALYSIS OF STRUCTURES MADE BY STRAIN SOFTENING AND STRAIN HARDENING CEMENT BASED MATERIAL

❑ MOTIVATION

- Develop a constitutive model appropriate for cement based composite materials capable of capturing diverse nonlinearities, e. g., cracking, crushing, thermal expansion.

❑ THE PROPOSED MODEL

- In order to simulate cracking in tension and crushing in compression for cementitious materials, a plastic-damage multidirectional fixed smeared crack model is proposed. According to this approach different domain of stress space is separately described by the plasticity theory, for compression, and fracture theory, for tension. So a composite criterion is formed by a fracture surface for cracking, and a yield surface to simulate the inelastic deformation of concrete between cracks.

❑ COMPONENTS OF THE PROPOSED MODEL

- The plasticity part of the model is based on the yield function, flow rule and evolution law for hardening variable. The yield function inspired from the work of Willam and Warnke, works based on a hardening process. It lies on the assumption that the plastic flow occurs on undamaged volume of the material; therefore micro-damages, due to compression, are not modeled using the plasticity approach. Softening is controlled by an explicit damage approach allowing decoupling plastic part from the damage part.
- The crack opening process is initiated based on the Rankine tensile criterion whereas a trilinear softening diagram is used to simulate the crack propagation. Two methods namely based on the concept of shear retention factor, and the shear softening diagram are adopted for modeling the sliding components of the crack constitutive law.

❑ VALIDATE THE PROPOSED MODEL

- The proposed model is validated for a variety of examples in literature: single IP examples; an experimental program composed of RC beams shear strengthened according NSM-CFRP technique; Shear wall panel tests; reinforced concrete deep beams; an experimental program composed of HPFRC short span beam, reinforced by hybrid system of steel and prestressed GFRP bars.

❑ SELECTIVE SIMULATIONS OF THE PROPOSED MODEL

- Predictive performance of the proposed model (called PDS model) is represented here for two structural applications such that:

➢ **Simulation of RC beam shear strengthened according to NSM-CFRP technique (beam number 3S-4LI-S2)**

Fig. 1a

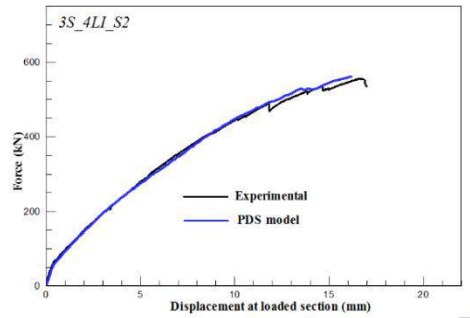


Fig. 1b

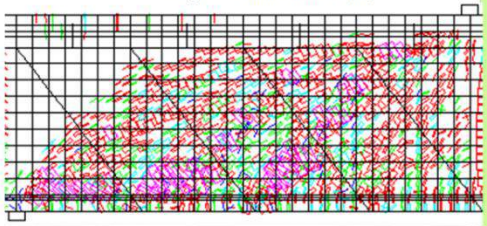


Fig. 1c

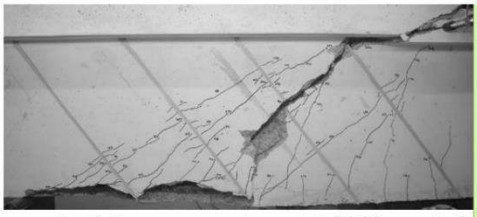


Fig. 1a-c : result of the proposed model (PDS model) Versus the test observations for the beam 3S-4LI-S2

➢ **Simulation of the shear wall panel test (panel number S1)**

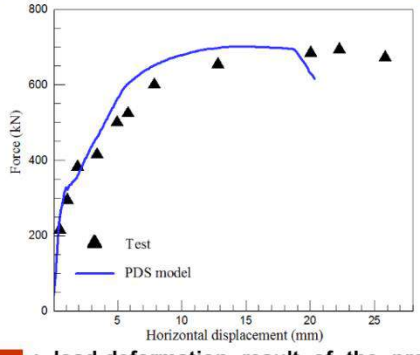


Fig. 2 : load-deformation result of the proposed model (PDS model) Versus test for the panel S1

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Amin Abrishambaf

Supervisors: Joaquim Barros / Vitor Cunha

AN INTEGRAL APPROACH TO SIMULATE THE CREEP BEHAVIOUR OF STEEL FIBRE REINFORCED SELF-COMPACTING CONCRETE LAMINAR STRUCTURES

❑ OBJECTIVES

- Determination of the fibre distribution/orientation parameters in the laminar structures,
- Evaluation of instantaneous nominal tensile stress – crack opening relationship,
- Execution of fibre pull-out creep tests with fibres preliminary subjected to distinct grades of slips,
- Performing flexural creep tests on the pre-cracked specimens extracted from a panel,
- Developing a model to predict instantaneous and long-term behaviours of the cracked SFRSCC laminar structures.

❑ EXPERIMENTAL RESEARCH

- In a panel, fibres tend to align perpendicular to the concrete flow direction:

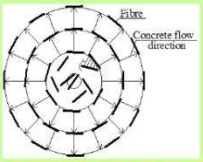

Fig. 1 Explanation for fibre alignment

- Instantaneous stress-crack opening width ($\sigma - w$) was assessed by both uniaxial, Fig.2, and splitting, Fig.3, tensile tests on cores extracted from a panel and notched either parallel or perpendicular to the concrete flow direction.

Fig. 2 Uniaxial tensile test

Fig. 3 Splitting tensile test

- The time-dependent fibre pull-out behaviour was assessed by the means of single fibre pull-out creep tests (Fig.4) on the pre-slip fibres. The influences of the fibre orientation (0, 30 and 60°) and pre-slip level (0.3 and 0.5 mm) were evaluated. Then, the assembled curves (Fig.5) were compared to the monotonic force-slip relationships.

Fig. 4 Fibre pull-out creep test

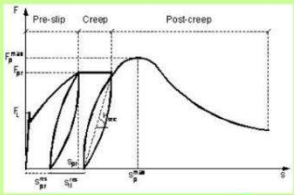

Fig. 5 Assembled curve

- A series of flexural four-point creep tests were performed on the beams extracted from a panel. The influences of following parameters were studied: initial crack opening level (0.3 and 0.5 mm), applied stress level (50 to 100%), fibre orientation/distribution and distance from the casting point. Finally, the assembled curves were compared to the monotonic force-CTOD relationships.

Fig. 6 Creep flexural test

Fig. 7 Monotonic flexural test

❑ NUMERICAL SIMULATION

- SFRSCC was assumed as a two phase material: plain concrete, Fig.8, and discrete steel fibres, Fig.9. The fibres were oriented using Gaussian distribution. Taking the results of fibre pull-out tests, the force-CTOD relationship and creep response of the beams were predicted.

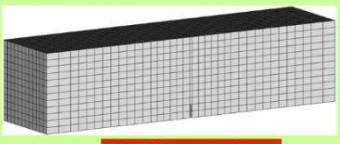

Fig. 8 Concrete phase

Fig. 9 Fibre phase

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University of Minho School of Engineering

Institute for Sustainability and Innovation in Structural Engineering
Ana S. Araújo
Supervisors: Paulo B. Lourenço / Daniel V. Oliveira / Guido Magenes

MODELLING OF THE SEISMIC PERFORMANCE OF CONNECTIONS AND WALLS IN ANCIENT MASONRY BUILDINGS

❑ IN-PLANE MASONRY WALLS BEHAVIUOR

- Numerical study was based on the experimental campaign performed at the University of Pavia on stone masonry piers with two distinct slenderness ratios and axial load levels:

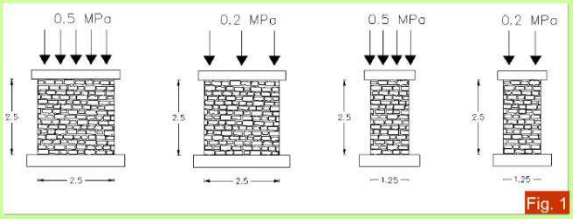

Fig. 1

- FEM were calibrated against experimental results and nonlinear analysis results show good agreement with the experimental behaviour of each wall. The validated models were used to carry parametrical analyses. Drift capacity and the application of analytical expressions to predict the in-plane strength were also studied.

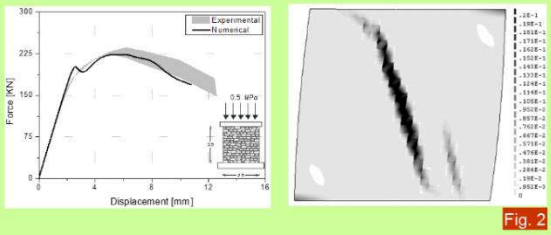

Fig. 2

❑ CONNECTIONS – INJECTED ANCHORS IN MASONRY

- This study was supported on the experimental campaign carried out at University of Minho for the characterization of a strengthening solution for connection between elements based on the use of injected anchors in masonry.

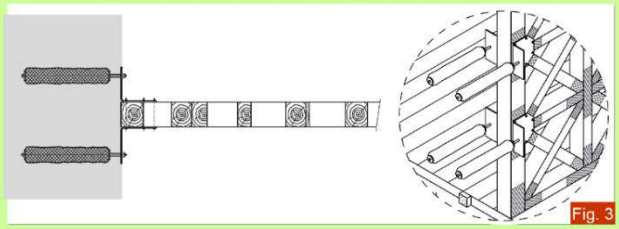
Fig. 3

The numerical study included:

- Construction of a detailed 3D FEM;
- Model validation against the experimental results;
- Parametric analyses in order to evaluate the influence of key parameters and analytical evaluation.

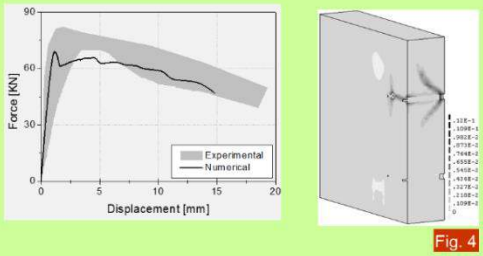

Fig. 4

❑ BEHAVIOUR OF A MASONRY BUILDING

- The seismic assessment of a typical masonry building is carried out through pushover analysis proportional to the mass. The influence of the connections between walls and floors and also the external and interior walls in the global behaviour of the structure is assessed numerically.

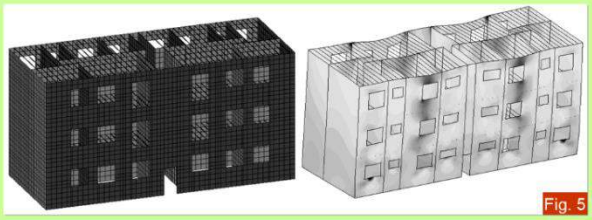
Fig. 5

❑ FINAL CONSIDERATIONS

- The study of the behaviour of walls and connections in masonry constructions have proven the potential of numerical analyses when used as a complementary tool for experimental campaigns, allowing for the deeper characterization of the behaviour and for parametrical analysis. The knowledge taken from these research works were the basis for the study of the masonry building considering the in-plane walls and connections behaviour.

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Andreia Martins

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SEISMIC BEHAVIOUR OF MASONRY VENEER WALLS

❑ BACKGROUND

The masonry veneer walls is a construction typology used in current practice and is increasingly used in Portugal and other countries due to aesthetic qualities, better thermal comfort and better moisture behavior.

Fig. 1 – Masonry veneer walls, England

A major concern on the use of this constructive element, which is not seen as structural, is the seismic performance, when it is applied in regions of important seismic hazards

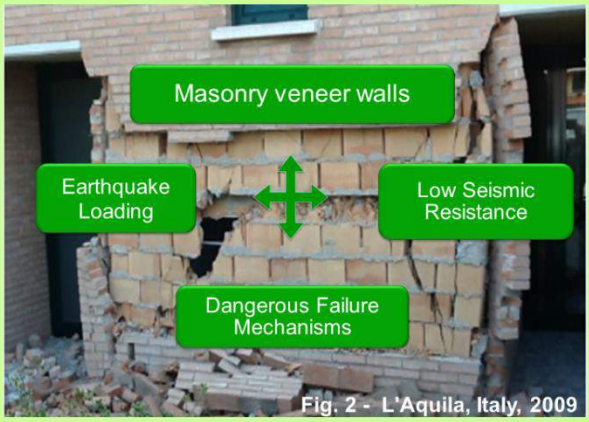

Fig. 2 - L'Aquila, Italy, 2009

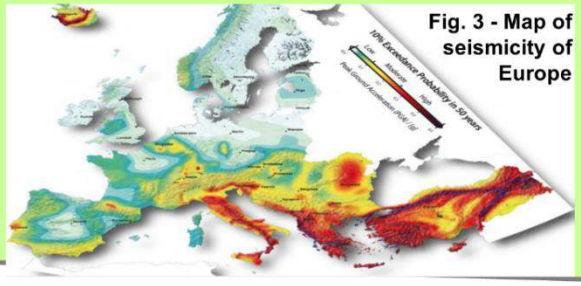

Fig. 3 - Map of seismicity of Europe

Taking into account the vulnerability of these walls to seismic actions, it is necessary to understand the behavior of this constructive system submitted to earthquakes

❑ RESEARCH STRATEGY

Task 1
- Definition and characterization of masonry veneer walls most common in Portugal and Europe

Task 2
- Mechanical characterization of materials:
  - Compression and flexural tests of masonry units and mortar and masonry specimens
  - Characterization of the mechanical behaviour of ties

Task 3
- Evaluation of the cyclic static behavior:
  - Behavior of the constructive system to in-plane and out-of-plane loading;
  - Interaction with structural support elements and behaviour of ties

Task 4
- Shaking table tests of masonry veneer walls
- Assessment of the dynamic behavior of the brick masonry veneer walls

Task 5
- Numerical analysis of masonry veneer walls
- Parametric study to evaluate the effect of the characteristics of the components of this constructive system.
- Design charts for veneer walls

❑ EXPECTED RESULTS

Static cyclic behavior of veneers and ties

Dynamic characterization and interaction with backing system

Developing strategies for numerical modelling

Developing guidelines for designing masonry veneer walls

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Angelo Gaetani

Supervisors: Paulo Lourenço / Giorgio Monti

SEISMIC CAPACITY OF ROUNDED MASONRY CROSS VAULTS: A HOLISTIC APPROACH FOR AN ANALYTICAL FORMULATION

❑ MOTIVATION AND OBJECTIVES

- The thesis focuses on the seismic behaviour of masonry rounded cross vaults, that is, one of the most diffused vaults within cultural heritage buildings in European seismic prone areas (Figure 1 and 2). The object of the thesis is to evaluate the *seismic capacity* and the *failure mechanism* of this element according to the main geometrical and mechanical parameters.
- This goal will be met via an integration of *shaking table tests* and *parametric analyses* based on data collected from historical manuals and treatises (*rules of thumb*). A *simplified analytical model*, aimed at supporting engineers and practitioners, will be then proposed and calibrated against the previous results.

Fig. 1

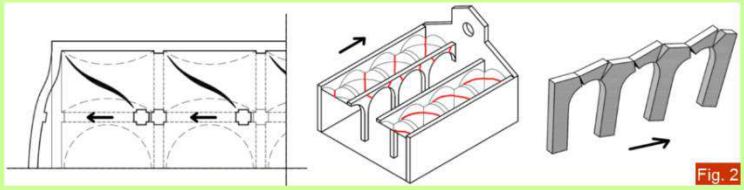

Fig. 2

❑ NUMERICAL ANALYSES

- The behaviour of the vaults is assessed through an *implemented limit analysis software*. This choice allows for quick analyses taking into account the following parameters: *span, thickness, infill, angle of embrace, tensile strength and seismic direction*. Moreover, in order to simulate the two main *boundary conditions*, either only two fixed corners or fully fixed supports are considered.
- Figure 3 shows the failure mechanisms and the horizontal load multiplier for the two aforementioned boundary conditions with increasing thickness.
- The results are validated by nonlinear FEM analyses with *DIANA software* (TNO - Delft)

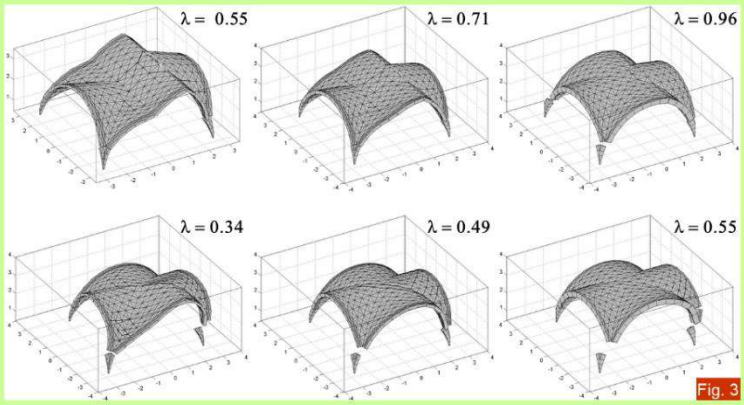

Fig. 3

❑ EXPERIMENTAL PROGRAM

- In order to validate the analyses and to shed light on further aspects, mono-directional shaking table tests on a scaled (dry joints) model will be performed. According to the *similitude law* and the facilities of the *laboratory in Sapienza University* (Rome), a scale factor equal to 3 will be adopted.
- The voussoirs will be *3d printed (ABS), coated by a mixture of polyester resin and "sugar-sized" sand, and with a steel insert* (Figure 4).
- With the aim of trying out the methodology, a small arch will be tested with the same scale factor and technology.

Fig. 4

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ANTÓNIO JOSÉ MOURA CORREIA
Supervisor: JOÃO PAULO C. RODRIGUES

FIRE RESISTANCE OF STEEL AND COMPOSITE STEEL-CONCRETE COLUMNS

❑ OBJECTIVES

- Study the influence of several parameters such as the contact with brick walls, the stiffness of the surrounding structure, the load level, and the slenderness of the columns, in the fire resistance of steel and composite steel-concrete columns.
- The purpose was to obtain valuable data for developing or improving the analytical fire design methods.

❑ EXPERIMENTAL TESTS

- Steel H Columns embedded on walls (14 experimental tests)
- Bare steel H columns with restrained thermal elongation (14 experimental tests)
- Partially encased steel H columns with restrained thermal elongation (12 experim. tests);

Fig.1

1. 3D restraining steel frame;
2. Hydraulic jack of 3MN;
3. Load cell (LC);
4. 2D reaction frame;
5. safety structure;
6. LVDT's;
7. Cable LVDT's;
8. Modular electric furnace;
9. Special device with LC;


Fig.2


Columns embedded on walls — Steel and Composite columns after test
Fig.3

❑ NUMERICAL SIMULATIONS

Modelling of the fire tests with the Finite Element code ABAQUS v6.7

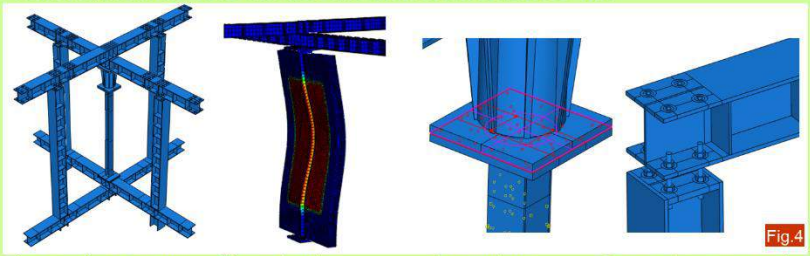
Fig.4

Surrounding structure — Thermal action — Interactions — Beam-column connection

❑ RESULTS

Restraining forces in composite columns

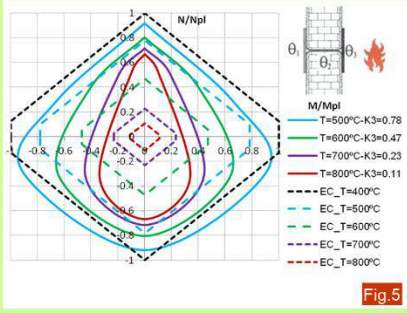

Fig.5

❑ ANALYTICAL PROPOSALS

- Simplified calculation method for the assessment of the temperature evolution in steel columns embedded on walls.
- Plastic Axial Force-Bending Moment interaction diagrams for steel beam-columns at elevated temperatures.
- Proposal of a simplified calculation method for fire design of steel columns.

❑ CONCLUSIONS

- Walls in contact with steel columns provide a great insulation and huge thermal gradients within the cross-section, under fire event.
- Steel columns embedded on walls, are submitted to thermal bowing, failing by bending instead of buckling.
- Steel columns inserted in building frames, are submitted to both axial and rotational restraint. These restraints play opposite roles, and the combined effect of both, makes a minor influence on the fire resistance of the columns.
- Partially encased steel columns present considerably higher fire resistance than steel columns.

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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Institute for Sustainability and Innovation in Structural Engineering

Ashkan Shahbazian

Supervisors: Luis Simoes da Silva / Carlos Rebelo

NONLINEAR NUMERICAL ANALYSIS OF STEEL CONNECTIONS UNDER CYCLIC LOAD

❑ INTRODUCTION

- The component-based model to predict moment-rotation behaviour of steel and composite joints was originally proposed by Tschemmernegg et al. (1987). Since then, component-based method has been adopted in Eurocode 3 part 1.8 (CEN, 2005). For the first time, this method has been extended to simulate steel joints under cyclic loading.
- Component-based method considers any type of joints as set of individual spring element (Fig. 1). To use this method in design, for each component the stiffness and yield force should be computed and assembled in appropriate position to assemble a form of spring elements which represents the behaviour of whole joint. This method has a potential to be used when components have nonlinear elongation-force behaviour. However, as we have nonlinear material, the FE method should be used to determine bending moment and rotation of the joint.

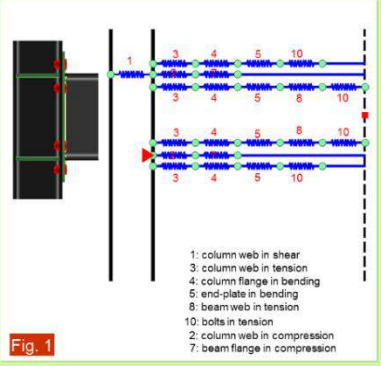

Fig. 1

❑ DEVELOPED FE PROGRAM

- A FE program has been developed for nonlinear numerical analysis of steel connections under both monotonic and cyclic loading.
- In order to simulate steel joint using component-based method, all equations are formulated following the principles of the finite element method. Therefore, the behaviour of the connection is represented by Eq. 1.
- This program uses an incremental iterative (path-follow) procedure with a displacement control in the rotational degree of freedom (DOF) of the joint.
- Developed program includes one core routine and eight subroutines.

$$\delta F = K_g \delta U$$

Where,

$$\delta F^T = [\delta M \quad \delta F \quad 0 \quad \dots \quad 0]$$

$$\delta U^T = [\delta \emptyset \quad \delta U \quad \delta U_3 \quad \dots \quad \delta U_{n_{DOF}}]$$

$$K_g = \begin{bmatrix} K_{1,1} & & & & & \\ K_{2,1} & K_{2,2} & & & & \\ K_{3,1} & K_{3,2} & K_{3,3} & & & \\ K_{4,1} & K_{4,2} & K_{4,3} & K_{4,4} & & \\ \vdots & \vdots & \vdots & \vdots & \ddots & \\ K_{n_{DOF},1} & K_{n_{DOF},2} & K_{n_{DOF},3} & K_{n_{DOF},4} & \dots & K_{n_{DOF},n_{DOF}} \end{bmatrix}$$

Eq. 1

❑ VALIDATION

- Modelling unstiffened extended end-plate steel joint which was tested by Nogueiro et al. (2007).
- Geometry/assembly (Fig. 1) and comparison between proposed cyclic component method and test results (Fig. 2).

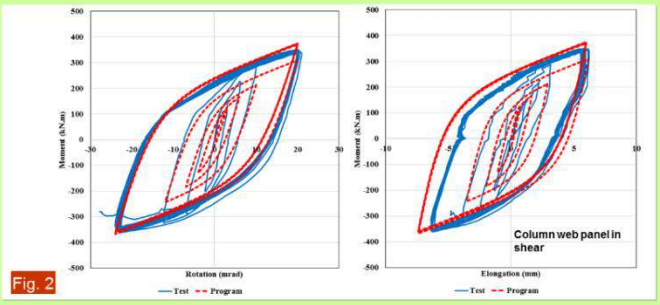

Fig. 2

❑ CONCLUSION AND FUTURE WORK

- The results show that the proposed cyclic component-based method appears to be a good predictor, but more simulations will be carried out to validate proposed method. In addition, a graphical user interface will be developed to have a user friendly design tool.

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CEN. (2005) Eurocode 3, Design of Steel Structures: Design of joints. Part 1-8.

Nogueiro, P., Silva, L. S. d., Bento, R. & Simões, R. (2007) Numerical implementation and calibration of a hysteretic model with pinching for the cycling response of steel joints. Advanced Steel Construction, 3(1), 459-484.

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Supervisors: Joaquim Barros / Guilherme Melo

PUNCHING RESISTANCE OF STEEL FIBRE REINFORCED CONCRETE (SFRC) SLABS CENTRICALLY LOADED

❑ RESEARCH SIGNIFICANCE

- The research deals with to the experimental assessment of the steel fibre reinforcement in terms of punching resistance of centrically loaded flat slabs, and to the development of an analytical model capable of predicting the punching behaviour of this type of structures.

❑ EXPERIMENTAL RESEARCH

- The experimental program assesses the steel fibre reinforcement in terms of punching resistance. Eight slabs (2550x2550x150 mm^3) were tested up to failure, having been investigated the content of steel fibres (0, 60, 75 and 90 kg/m^3) and concrete strength class (50 and 70 MPa). Two reference slabs and six SFRC slabs (one for each fibre content and strength class) compose the experimental program. The tensile reinforcement ratio (steel bars) were a percentage to assure punching failure mode for the reference slabs. The steel fibres were hooked ends (l_f=37 mm, d_f=0.55 mm, and f_y=1100 MPa).

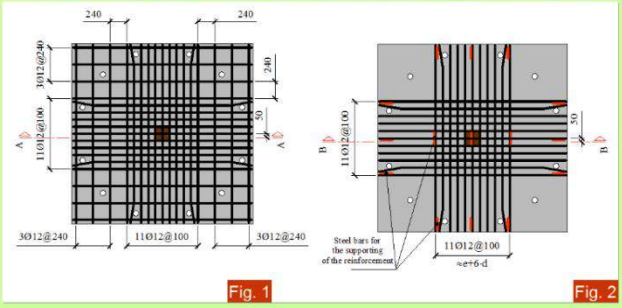

Fig. 1 Fig. 2

❑ THEORETICAL MODELS

- The proposals are based on the critical shear crack theory proposed by Muttoni (Fig. 3) and the recommendations of ModelCode 10 for modeling the post-cracking behaviour of SFRC. The models predicts (Eq.1=*Simple* and Eq. 2=*Refined*) the load versus rotation (*V-ψ*) of the slab (Fig.4), and attends to the punching failure criterion (Eq. 3).

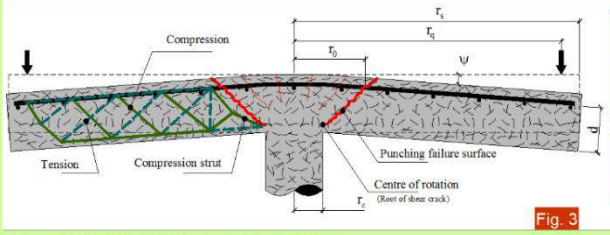

Fig. 3

$$V(\psi)=\frac{2\cdot\pi}{(r_q-r_c)}\cdot\left[\begin{array}{l} m_r(\psi)\cdot r_0+E\cdot I_0\cdot\psi\cdot\langle ln(r_s)-ln(r_{cr}(\psi))\rangle+m_{cr}\cdot\langle r_{cr}(\psi)-r_1(\psi)\rangle+\\ E\cdot I_1\cdot\psi\cdot\langle ln(r_1(\psi))-ln(r_y(\psi))\rangle+E\cdot I_1\cdot\chi_{ts}\cdot\langle r_1(\psi)-r_y(\psi)\rangle+\\ m_R\cdot\langle r_y(\psi)-r_0\rangle \end{array}\right] \quad \text{Eq. 1}$$

$$\psi=\bar{\Delta}\cdot\frac{m_R\cdot r_s}{E\cdot I_1}\cdot\left(\frac{V}{V_{flex}}\right)^{3/2} \quad \text{Eq. 2}$$

$$\frac{V}{b_0\cdot d\cdot\sqrt{f_c}\cdot\left[\lambda_f+k_f^{1/3}\right]}=\frac{1}{1.33+20\cdot\mu_f\cdot\psi\cdot d\cdot k_{dg}} \quad \text{Eq. 3}$$

❑ CONTRIBUTION OF FIBER

- The proposal (Eq. 4) is based on the concepts proposed by Muttoni and Ruiz (Fig. 5), where the *stress-crack width* law (*σ-w*) proposed by ModelCode 10 is conveniently integrated for simulation of the contribution of steel fibers for the punching resistance of SFRC slabs.

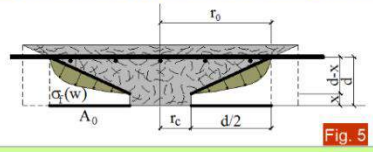

Fig. 5

$$V_{R,f}=\left[f_{Fts}-\frac{1.5}{2.5}\cdot\left(f_{Fts}-0.5\cdot f_{R3}+0.2\cdot f_{R1}\right)\right]\cdot A_0 \quad \text{Eq. 4}$$

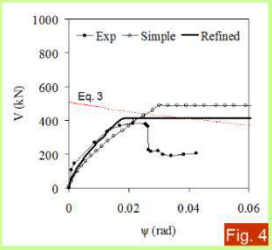

Fig. 4

❑ CONCLUSIONS

- Based on the results from the experimental program it can be concluded that a concrete strength class 50 and 70 MPa reinforced with a volume of about 1% of hooked ends steel fibres can assure a flexural failure mode and a very ductile behaviour;
- The proposed models (Eqs. 1, 2, 3 and 4) predicted with high accuracy the failure load of the 154 punching tests of the database, and assured better and safer predictions than another 7 models found in the literature for the evaluation of the punching failure load of SFRC slabs (Fig. 6).

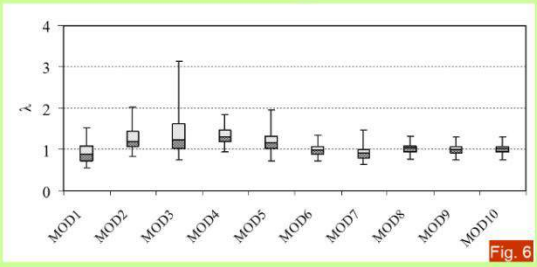

Fig. 6

MOD1=Narayanan and Darwish; MOD2=Shaaban and Gesund; MOD3=Harajli *et al.*; MOD4=Holanda; MOD5=Choi *et al.*; MOD6=Muttoni and Ruiz; MOD7=Higashiyama *et al.*; MOD8=Eq.1+Eq.3; MOD9=Eq.2+Eq.3; MOD10=Eq.4.

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THE USE OF ADVANCED TECHNOLOGIES ON LIFECYCLE ASSESSMENT OF INFRASTRUCTURES

Bruno Gonçalves

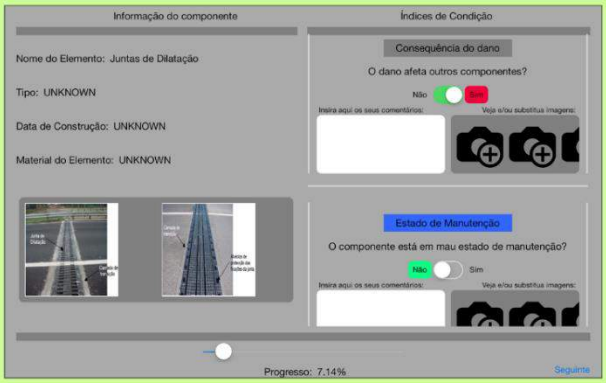
Supervisors: Paulo Lourenço / José Campos e Matos

❑ Framework

- This work program, in the scientific domain of the Lifecycle Infrastructures Management, consists in developing a tool for infrastructure lifecycle management integrating all stages of the management process, from the data collection in field inspections until decision-making.
- The work is divided in 3 main areas of development: 1st – Determining inspectors real needs in field inspections and development of a inspection platform for mobile devices; 2nd – Development of next condition state index models based on Markov Chains; Optimization and Decision-Making scenarios generation towards a predefined objective function.

❑MIP – Mobile Inspection Platform and Markov Chains

- Structured Information: the application presents a relational information scheme that correlates all the information gathered in field inspections;
- "one-step data handling":by gathering the information directly to the mobile device there is no need for posterior treatment and re-handling of the information because information is automatically stored;
- Support inspectors in the field: by supplying several types of information to the inspectors they will feel more confident and will produce more objective assessments;
- Normalized inspections forms: data gathered and outputs are normalized independent on the type of inspection.
- Multimedia items describing the component, technical information, and hints on how and what to inspect;
- "5-step" Condition State index assessment;
- Maintenance Condition state assessment;
- Possibility to take notes and to take photos and videos (multimedia items with GPS, altitude and orientation information);
- Presents a list of predefined damages for the component under inspection;
- Next condition index prediction based on Markov chains;
- Real-time assessment and Markov prediction feedback on several inspection parameters (in development).



❑ Overview and Scope

- The main objective consists in the development of a management tool that integrates inspections data collection (with the MIP), the prediction of next condition state indexes, and the optimization and scenarios generation. The tool will deliver useful information for the decision-making, task that will always be taken by managers and not the tool.

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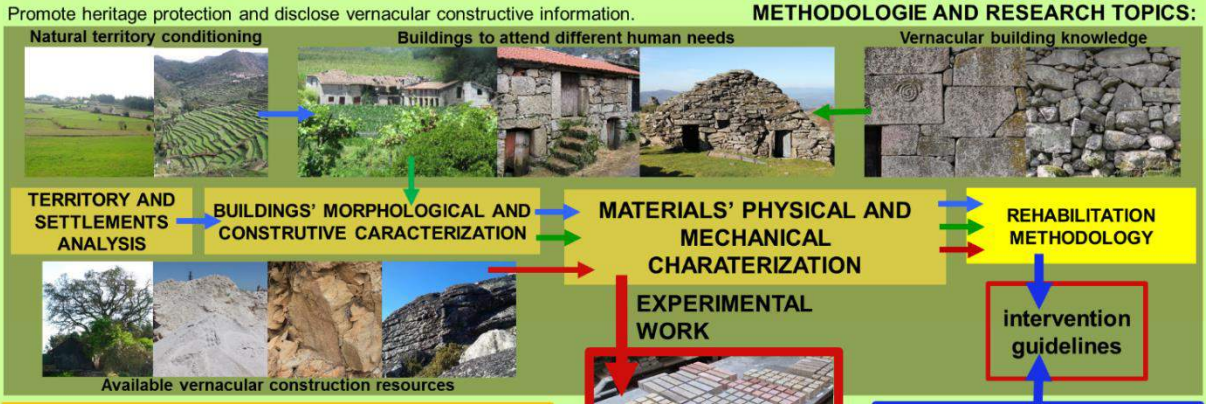
THE RURAL VERNACULAR CONSTRUCTION FROM ENTRE-DOURO-E-MINHO

Carlos Barroso

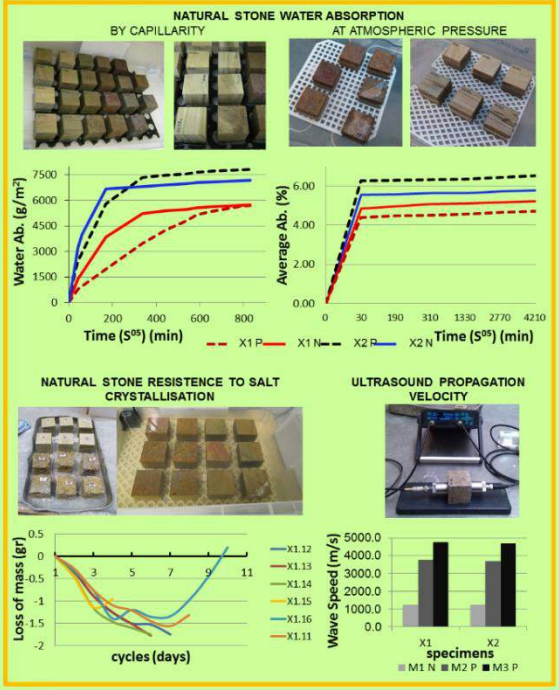
Supervisors: Daniel Oliveira / Luís Ramos

MOTIVATIONS: With acknowledged authenticity and cultural heritage values, rural vernacular construction from Entre-Douro-e-Minho region represents the results of the centuries-old relation between Mankind and available natural resources. In order to protect its cultural and key technical-constructive knowledge, its scientific study is required for an effective and non-damaging protection and to rehabilitate this fragile heritage. **OBJECTIVES:** 1. Vernacular materials' physical and mechanical characterization; 2. Rehabilitation methodology and guidelines; 3. Promote heritage protection and disclose vernacular constructive information.

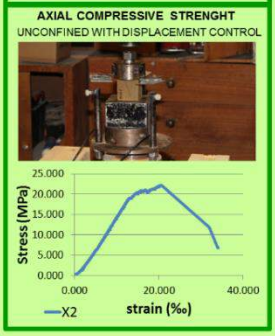
METHODOLOGIE AND RESEARCH TOPICS:

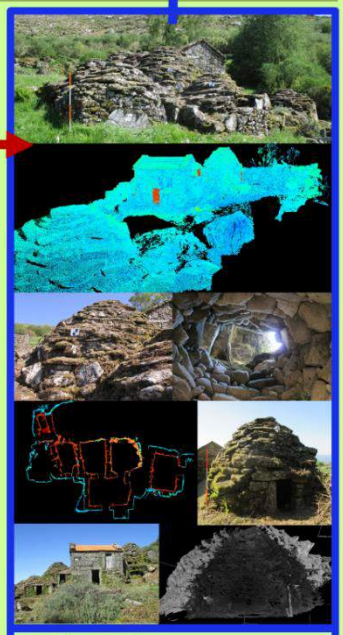


STONE PHYSICAL CHARACTERIZATION: This set of tests aim to the determination of natural stone's basic physical properties related to their natural resistances and this way assist in the determination of their compatibilities with other materials. **Other ongoing tests:** petrographic analysis; density and porosity analysis; Schmidt hammer; frost resistance.



STONE MECHANICAL CHARACTERIZATION: This set of tests aim to the determination of natural stone's mechanical behavior and, this way assist in the determination of the mechanical behavior of vernacular structural masonry. **Other ongoing tests:** flexural resistance.





STUDY CASE: The field survey was performed using a laser scanning equipment, with the objective of gathering detailed constructive and morpho-typological data to characterize the granite masonry corbelled domes buildings of the Serra da Peneda. For its complete structural analysis, using the data gather, an Discrete Element Method's model (DEM) will be built. **Other ongoing analysis:** statistic analysis of data

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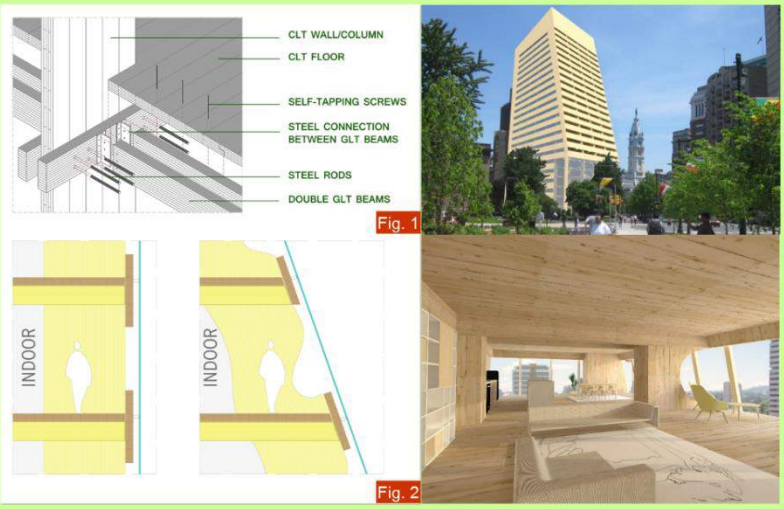
TALL BUILDINGS USING CLT. AN INTEGRATED DESIGN CONSIDERING MOISTURE INDUCED EFFECTS

Catarina Vilaça Silva

Supervisors: Jorge Branco / Paulo Lourenço

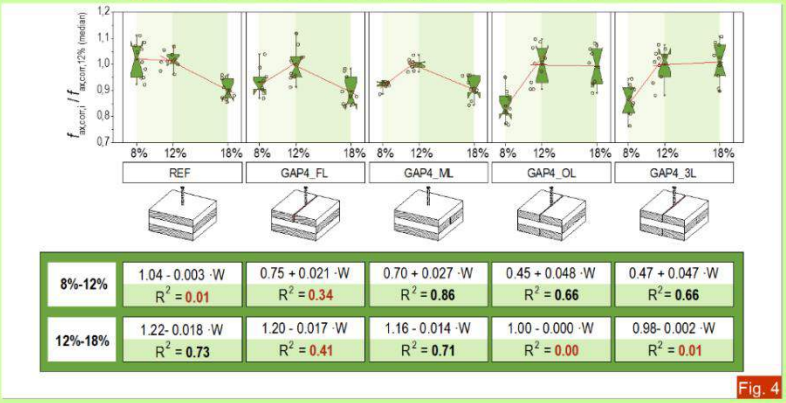
❑ URBAN TIMBER (UT) SYSTEM

- One of the goals of this work program is the conception of a new structural system (Fig.1), oriented for tall buildings, based essentially on cross laminated timber (CLT) elements. We developed the UT system which combines CLT and glulam elements and promises to overcome the limitations found on constructed CLT tall buildings.
- In terms of building shape and use, UT system allows to build oblique facades, deconstruct the box shape, rip wider openings and larger inner spaces (Fig.2).
- The system considers: timber shrinkage and swelling movements; high stiffness; easy construction and affordability.



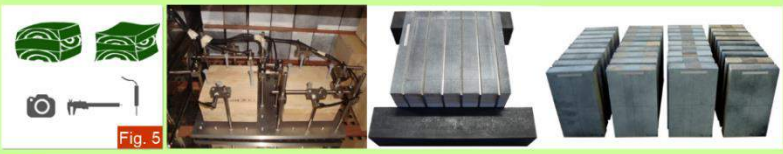
❑ EXPERIMENTAL CAMPAIGNS

- First experimental campaign (Fig.3) focus on the relation between withdrawal capacity of self-tapping screws and: moisture induced effects on cross laminated timber (CLT), the existence of gaps between glued boards, and the width of gaps.
- Results of first experimental campaign shown that the higher loses are related with moisture content increase, for close gaps, and with moisture content decrease, for open gaps (Fig.4).
- Second experimental campaign focus on hygroscopic behavior of CLT (Fig.5). Measurements with LVDT's were taken in order to quantify linear shrinkage and swelling on three directions of a CLT panel. DIC technique and manual measurements were used in order to obtain internal stresses on CLT elements. Both experiments were performed considering cyclic changes on relative humidity which varied from 30% to 90%.



	REF	GAP4_FL	GAP4_ML	GAP4_OL	GAP4_3L
8%-12%	1.04 - 0.003 ·W R^2 = 0.01	0.75 + 0.021 ·W R^2 = 0.34	0.70 + 0.027 ·W R^2 = 0.86	0.45 + 0.048 ·W R^2 = 0.66	0.47 + 0.047 ·W R^2 = 0.66
12%-18%	1.22- 0.018 ·W R^2 = 0.73	1.20 - 0.017 ·W R^2 = 0.41	1.16 - 0.014 ·W R^2 = 0.71	1.00 - 0.000 ·W R^2 = 0.00	0.98- 0.002 ·W R^2 = 0.01

Fig. 4



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ROBUSTNESS OF OPEN CAR PARKS UNDER LOCALISED FIRE

Cécile Haremza

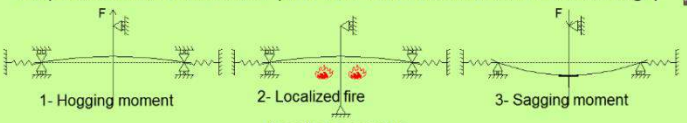
Supervisor: Aldina Santiago

1. OBJECTIVES

- Detailed study of the joint behaviour in a composite steel-concrete car park subject to the loss of a column under localised fire
- Evaluation of the influence of the beam axial restraint coming from the unaffected part of the building
- Evaluation of the M-N interaction behaviour of the composite steel-concrete joint

2. EXPERIMENTAL TESTS

- Seven tests: to observe the combined bending moment (M) and axial loads (N) in the composite joint;
- Loss of the column simulated in the composite frame subject to mechanical and thermal loadings;
- Influence of the beam axial restraint provided by the cold part of the building with: zero, total and realistic restraints
- Influence of the localised fire: the composite joint is heated and two temperatures are considered (500°C or 700°C in the beam bottom flange)



Loading sequence

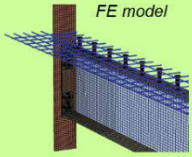
Final deformation of the tested structure (test 6)

Failures under sagging bending moment and elevated temperature:

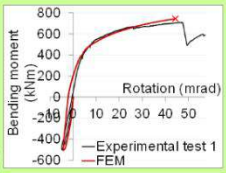
- Crushing of the concrete in compression
- Failure of bolts in tension in the bottom bolt row

3. NUMERICAL MODELS

- Commercial general finite element package Abaqus
- FE model of the composite steel-concrete joint
- Validation against the experimental tests results



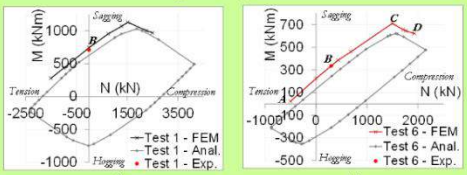
FE model



Validation (20°C)

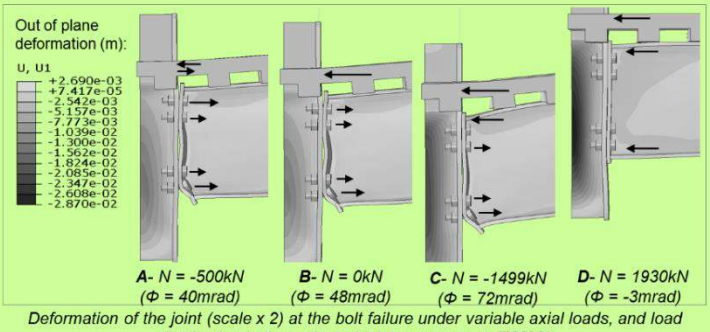
4. M-N BEHAVIOUR

- The numerical M-N curve of the joint is compared to the M-N curve predicted by the analytical method developed at the University of Liège:



a) b)

M-N curves at a) ambient temperature (test 1) and b) elevated temperature (test 6 – 700°C)



Deformation of the joint (scale x 2) at the bolt failure under variable axial loads, and load distribution in the activated joint components (700°C)

5. CONCLUSION

- Due to the low slenderness of the composite beam, high deformations of the joint are necessary to develop catenary action and reach an equilibrium deformed configuration. In these conditions, this topology of composite joint does not possess sufficient capacity of rotation to reach this equilibrium deformed configuration and to avoid progressive collapse of the building.

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César Javier Chácara Espinoza
Supervisor: Paulo B. Lourenço

AN INNOVATIVE APPROACH FOR THE NON-LINEAR DYNAMIC ANALYSIS OF MASONRY STRUCTURES

❑ INTRODUCTION

- The vulnerability of masonry constructions has been evidenced based on the severe effects of seismic solicitations. Due to the cultural and economic importance of existing masonry structures, the assessment of their dynamic behaviour constitutes an important issue in regions with seismic hazard.
- In the last decades, computational tools have been implemented in order to evaluate the dynamic response of masonry structures. However, the computational cost and the over simplifications limit their application of existing masonry constructions.

❑ OBJECTIVE

Implement a computational tool for the seismic evaluation of historical masonry structures

❑ METHODOLOGY

The research proposal consists on six tasks:

1. Review of the state of the art of numerical analysis on masonry constructions
2. Defining and implementing of cyclic constitutive laws for masonry
3. Development of a code for the nonlinear dynamic analysis
4. Validation of the code based on experimental results and literature
5. Application of extensive numerical analyses on cases studies
6. Assessment of retrofitting techniques

❑DISCRETE ELEMENT MODEL

This approach consists on the quadrilateral articulation of four rigid edges (panel). The shear behaviour is governed by two diagonal springs. The flexural and sliding shear behaviour is reproduced by means on orthogonal and longitudinal springs, respectively (Fig. 1).

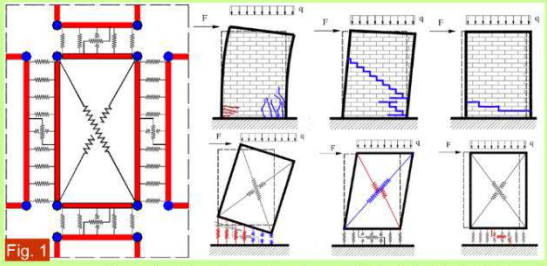

Fig. 1

I. Caliò, M. Marletta, and B. Pantò, "A new discrete element model for the evaluation of the seismic behaviour of unreinforced masonry buildings," Journal of Engineering Structures, vol. 40, pp. 237-338, 2012

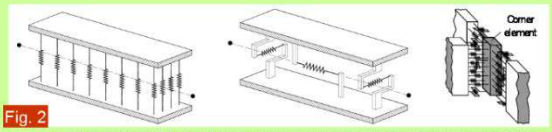

Fig. 2

I. Caliò, M. Marletta, and B. Pantò, "A Discrete Element Approach for the Evaluation of the Seismic Response of Masonry Buildings," in 14th World Conference on Earthquake Engineering, Beijing, China, 2008.

In addition, this modelling approach has been implemented in order to predict the out of plane behaviour of masonry structures by the introduction of additional springs (Fig. 2).

Finally, it has been adapted to simulate the complex behaviour of curved structural elements (Fig. 3).

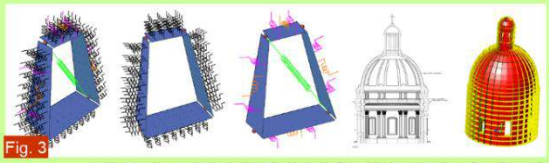

Fig. 3

I. Caliò, F. Cannizzaro, and M. Marletta, "A Discrete Element for Modeling Masonry Vaults," *Advanced Materials Research*, vol. 133-134, pp. 447-452, 2010.

❑ FINAL CONSIDERATIONS

- The assessment of the seismic behaviour of masonry structures is a complex task that need to be addressed.
- The shortened computational cost of this approach, due to the reduced number of degrees of freedom, will allow a more practical evaluation of masonry structures.

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Chandan C. Gowda
Supervisor: Joaquim Barros

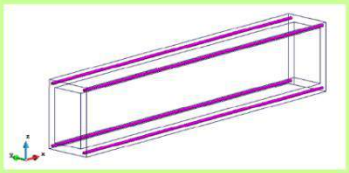
USE OF NSM FRP FOR STRENGTHENING OF TUBULAR AND CONTINUOUS RC STRUCTURE

❑ SCOPE & FOCUS OF THE RESEARCH

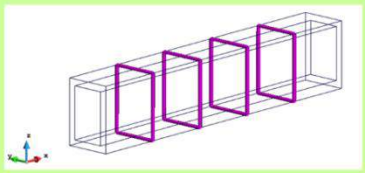
- The present study focuses on two parts (i) torsional strengthening of thin walled tubular RC structures and (ii) flexural strengthening of continuous RC structures.
- Innovative way of strengthening the hogging region in continuous structures will be performed. Main focus will be on moment redistribution capacity and to prevent the early delamination failure of FRP materials in the hogging region.
- Torsional strengthening will be carried out by two methods, use of pre-stress on longitudinal bars and use of bars/strips throughout the section.

❑RESEARCH METHODOLOGIES

- Torsional Strengthening

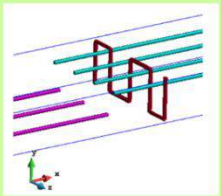


(A) PRE-STRESS NSM FRP BARS ALONG THE LONGITUDINAL DIRECTION OF THE BEAM



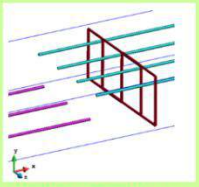
(B) NSM FRP BARS THROUGHOUT THE SECTION OF THE BEAM

- Provides flexural (horizontal: top & bottom bars) and shear strengthening (vertical bars)
- Flexural Strengthening

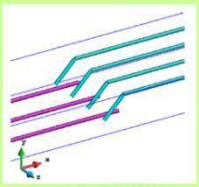


(A) ZIGZAG ONE WAY

- Zigzag strengthening of slab using wet lay up system.



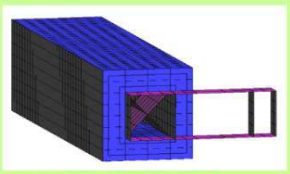
(B) ZIGZAG BOTH WAYS



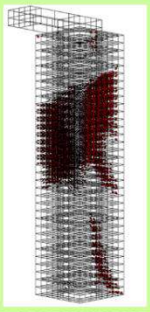
(C) BENT FRP BARS

❑ WORK PROGRESS (TORSION)

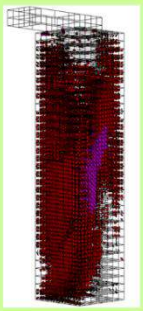
- Numerical analysis on non-strengthened tubular RC beam using FEMIX



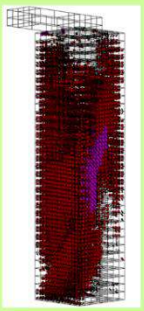
(A) MESH OF THE MODEL



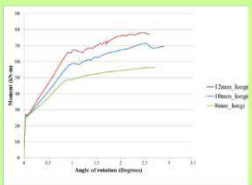
(B) CP AT CONCRETE CRACKING



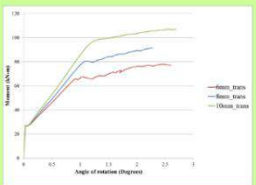
(C) CP AT YIELDING OF FEW LONGITUDINAL BARS



(D) CP AFTER YIELDING OF LONGITUDINAAL STEEL



(B) VARAITION OF LONGITUDINAL BARS



(C) VARAITION OF TRANSVERSE BARS

❑ NEXT STEPS

- Numerical analysis on strengthened tubular RC beam
- Analysis of different strengthening techniques
- Based on the results from numerical analysis, planning and execution of experimental activities.

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Cláudia Ferreira

Supervisors: Luís Neves / José C. Matos

BRIDGES MANAGEMENT SYSTEM: PERFORMANCE ASSESSMENT OF TRANSPORT NETWORKS

❑ RESEARCH OBJECTIVES

- **The scientific domain of this work program is bridge management system (BMS). The main goal is to develop a methodology for optimization of bridge maintenance strategies considering the information available on the degradation of these structures and the impact of maintenance actions in economic and network functionality loss.**
- **The work comprises four different phases: (i) deterioration models based on hidden Markov chains; (ii) fit of the models to existing inspection records; (iii) definition of the maintenance effects, including indirect costs; (iv) implementation of optimization algorithms that minimize maintenance costs over the life-cycle.**

❑ DETERIORATION MODEL

- **The Markov chains are a simple stochastic process, used extensively for modelling the deterioration of existing bridges.**
- **The intervals between inspections are not regular or similar for all structures. Kalbfleisch and Lawless (1985) proposed the definition of transition intensity matrix.**

$$P_{\Delta t} = e^{Q \cdot \Delta t}$$

- **The transition intensity matrix, *Q*, directly relates to any transition probability matrix, *P*. This matrix is unique. The matrix that gives the best expected results is considered the optimal intensity matrix, Q_o.**

$$Q = \begin{bmatrix} -\theta_1 & \theta_1 & 0 & 0 \\ \vdots & \ddots & \vdots & \vdots \\ 0 & \cdots & -\theta_i & \theta_i \\ 0 & \cdots & 0 & 0 \end{bmatrix}$$

Transition intensity matrix

$$P_{\Delta t} = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1j} \\ 0 & p_{22} & \cdots & p_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & p_{ij} \end{bmatrix}_{\Delta t}$$

Transition probability matrix

❑ MAINTENANCE ACTIONS (MA)

- **The impact of a MA in a structure can be modelled by one or more than one of the following effects: improvement in performance at time of application, delay and/or reduction of the deterioration rate for a period of time after application (Fig. 1).**

❑ MAINTENANCE MODEL

- **Bridges are designed for long periods of service life and must present an adequate safety level and serviceability. For this reason, maintenance must be applied during the structure's lifetime.**

Maintenance actions can be divided:

Preventive	Essential
- lower impact on the bridge safety; - lower cost.	- significant improvement in the performance at time of application; - higher direct and indirect cost.

- **The combination of both maintenance actions is necessary to achieve the most cost-effective life-cycle performance, due to budget limitations.**

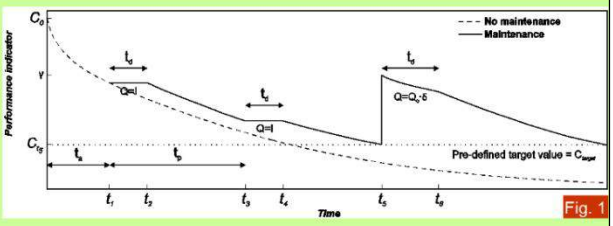

Fig. 1

Improvement

-Let's assume that a MA is applied at instant t_5 (Fig. 1), at this instant the performance indicator is within the range of applicability of the MA and just before the application of the MA is equal C_{t5}.

- Based on expert judgment, it is known that the MA improves the condition to γ, so after the application of the MA the new condition state at instant t_5 is defined by:

$$C_{t5} = \gamma$$

Delay

- If a MA causes suppresses the deterioration process for a period of time after the application, it is assumed the performance indicator remains unchanged.

$$Q = I$$

Reduction

- If a MA causes a reduction of the deterioration rate for a period of time after the application, the transition intensity matrix, *Q*, is affected by the deterioration factor, δ.

$$Q = Q_o \cdot \delta$$

Monte Carlo simulation

-There is significant uncertainty related to the assignment of a condition state of a bridge as well as definition of the effects of MA, therefore, the MA are usually better modelled using random variables.

- One way to consider the propagation of the uncertainties during the structure's lifetime is through the Monte Carlo simulation.

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CLÁUDIO PEREIRA

Supervisors: António Gomes Correia / Cristiana Ferreira

THE USE OF SEISMIC WAVE VELOCITIES IN THE EVALUATION OF STIFFNESS, DAMPING AND ANISOTROPY OF GEOMATERIALS IN ROUTINE LABORATORY AND FIELD TESTS

❑ SCOPE

The main objective of this work is to conceive, implement and provide a tool for the advanced geotechnical characterization of geomaterials, including stiffness, damping and anisotropy, based on the use of the seismic wave velocities, in particular measured with bender elements (BE), in routine laboratory and field tests. A significant part of this work, named the field tests and damping investigations will be conducted collaboratively in partnership with the University of Texas at El Paso (UTEP) and under supervision of Professor Soheil Nazarian.

❑ TASKS

- Task 1 - Bibliographic review concerning the implementation of BE and accelerometers (AC) on current laboratory and field testing devices;
- Task 2 - Parametric study related to the optimal geometry of specimens (height/diameter);
- Task 3 - Implementation of the new procedure based on the determination of wave velocities, for measurement of damping coefficient and anisotropy;
- Task 4 - Validation of the performance in terms of advanced geotechnical characterization, including stiffness and damping based on Resonant-Column (RC) tests on a reference material;
- Task 5 – Numerical Modeling in order to calibrate the setup procedure and assess its applicability;
- Task 6 - Applicability of advanced geotechnical characterization of a wide range of geomaterials; and,
- Task 7 - Application/adaptation of the BE procedure in-situ tests.

❑ EQUIPMENT AND BE PRINCIPLES

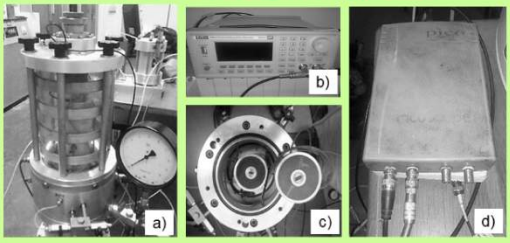

Figure 1 – Description of the equipment's used in bender element system: a) Stress-path chamber pressure; b) Function Generator; c) BE located in the chamber pressure; d) Digital Oscilloscope.

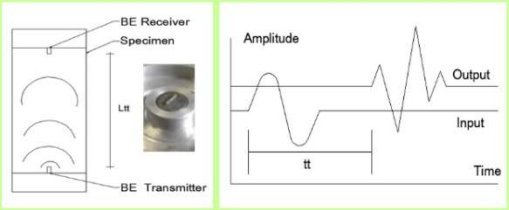

Figure 2 – Bender Elements principles.

$$V_S = \frac{L_{tt}}{tt} \qquad G_0 = \rho \times V_S^2$$

ρ – Soil mass density; Ltt – Distance between BE.

❑ PRELIMINARY RESULTS

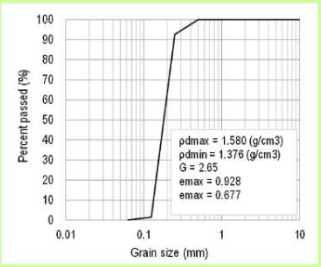

Figure 3 – Toyoura sand physical properties.

- For all isotropic stress stages (*p'*) specimens present similar trends.
- Facing the experimental results (G_0^{exp}) with empirical equations (G_0^{emp}), it is possible to observe a satisfactory agreement between these.

Table 1 – Specimens initial physical properties.

Specimen	D_r (%)	e	ρ_d (g/cm³)	G
PT1S1	74	0.716	1.544	2.65
PT1S2	58	0.771	1.496	2.65
SP38_P8	89	0.712	1.548	2.65
SP38_P9	87	0.719	1.541	2.65

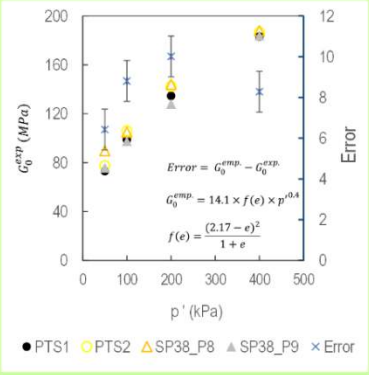

Figure 4 – Relation between experimental results and empirical equations.

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Escola de Engenharia

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CRISTINA CALMEIRO DOS SANTOS
Supervisor: João Paulo Correia Rodrigues

RESIDUAL MECHANICAL PROPERTIES OF ORDINARY CONCRETES AFTER FIRE

❑ OBJECTIVES

- The aim of this research work was to evaluate the influence of the fire extinguishing methods, the maximum temperature that the concrete was subjected to and the loading level on the residual mechanical properties of calcareous and granite aggregate concretes.

❑ RESEARCH PLAN

Materials

- Calcareous (CC) and Granite (GC) concretes were tested.

Cooling processes, maximum temperatures and load level

- Two cooling processes: cooling in the air (simulating a fire extinguished in a natural way) and the cooling by water jet (simulating the action of the firefighters) (Fig.1a, 1b and 1c).
- The temperature levels tested were 20, 300, 500 and 700°C.
- The load levels tested were $0.3f_{cd}$ or $0.7f_{cd}$.

Type of tests

- Residual compressive strength tests (Fig.1).
- Residual direct and splitting tensile strength tests (Fig.2 and 3).
- Residual flexural tensile strength tests (Fig.4).
- Residual modulus of elasticity and Poisson's ratio tests (Fig.5).

Fig.1 Residual compressive strength; a) test set-up; b) cooling in the air; c) cooling by water jet.

Fig.2 Test set-up for the residual direct tensile strength tests.

Fig.3 Test set-up for the residual splitting tensile strength tests.

Fig.4 Test set-up for the residual flexural tensile strength tests.

Fig.5 Test set-up for the residual modulus of elasticity and Poisson's ratio tests.

❑ SOME RESULTS

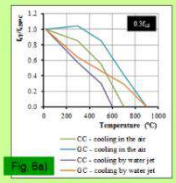

Fig.6 Residual compressive strength; a) $0.3f_{cd}$; b) $0.7f_{cd}$.

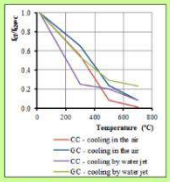

Fig.7 Residual direct tensile strength.

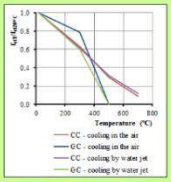

Fig.8 Residual splitting tensile strength.

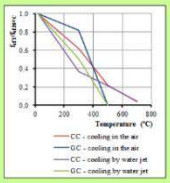

Fig.9 Residual flexural tensile strength.

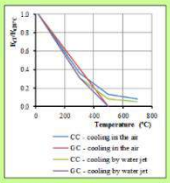

Fig.10 Residual modulus of elasticity.

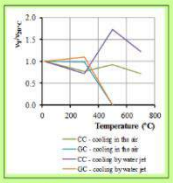

Fig.11 Residual Poisson's ratio.

❑ SOME CONCLUSIONS

- The high temperatures have had a negative influence on the residual compressive strength of the concrete being this most noticeable in calcareous than in the granite aggregate concrete.
- The loading level, if not too excessive, interferes positively on the residual compressive strength of concrete avoiding cracking.
- The cooling process influenced very much the residual compression strength of the concretes after heating and cooling.
- The residual tensile strength of concrete decreased also with the temperature.
- The residual flexural strength has reduced in function of the maximum temperature that the concrete was subjected to.
- Independently of the aggregate type of concrete and cooling process used, the residual modulus of elasticity and Poisson's ratio shows a sharply decrease with temperature.

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Escola Superior de Tecnologia

Institute for Sustainability and Innovation in Structural Engineering

David Cassiano

Supervisors: Carlos Rebelo / Raffaele Landolfo

POST SEISMIC STRUCTURAL ROBUSTNESS IN MOMENT RESISTING FRAME STEEL BUILDINGS

❑ NONLINEAR DYNAMIC ANALYSIS

- This work program is aimed at studying the structural robustness of moment steel frames for an existing damage level induced by an earthquake, which may render structures more prone to progressive collapse.
- A numerical parametric study is carried out on a set of 3D building configurations designed to be representative of realistic frames.
- The following parameters are analysed: number of storeys (4;8), interstorey height (3m;4m), span length (6m;10m), cladding type (facade; none), bay layout (5x3; 4x4; 5x4) and lateral force design scenario (wind action; wind and seismic actions).
- The frames are analysed using finite element nonlinear dynamic analysis under 4 different column loss scenarios.


Fig. 1

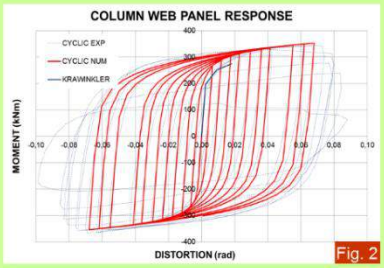

Fig. 2

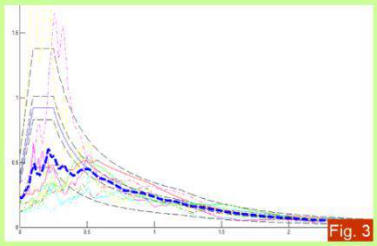
Fig. 3

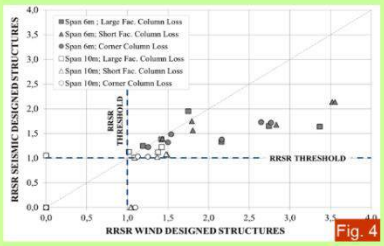

Fig. 4

❑ FLUSH ENDPLATE JOINTS AND CLADDINGS UNDER CYCLIC ACTION AND COLUMN LOSS SCENARIOS

- The robustness contribution from secondary frame beam-to-column joint is investigated for partial strength flush end plate joints through a parametric numerical study, in order to determine the moment-rotation curves to model the secondary frame nonlinear joint response.
- The joint behaviour is evaluated for cyclic loading followed by monotonic loading, to simulate the seismic and the column loss actions.
- The bolt assembly response in tension is modelled according to results from a conducted experimental parametric study on HV and HR bolt assemblies.
- Facade cladding response under cyclic and monotonic loading is modelled in order to quantify its contribution to structural robustness under column loss scenarios.

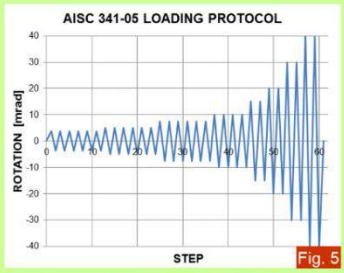

Fig. 5

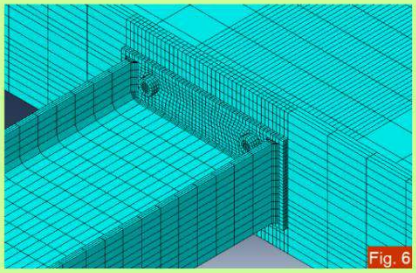
Fig. 6


Fig. 7

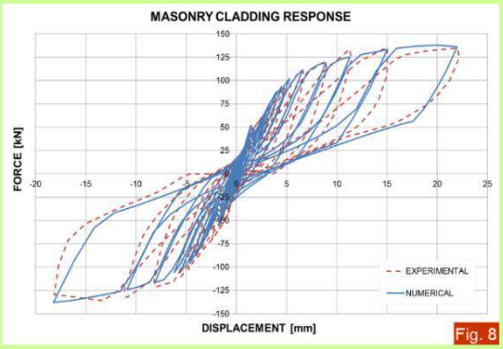

Fig. 8

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Elizabeth Manning

Supervisors: Luis Ramos/Francisco Fernandes

ENHANCEMENT OF THE TUBE-JACK AND SONIC NON-DESTRUCTIVE TEST METHODS FOR HISTORICAL STRUCTURAL MASONRY DIAGNOSIS

❑ EXPERIMENTAL RESEARCH

- The aim of this work program is to enhance two non-destructive test methods in order to obtain more accurate information about a historical masonry structure during the investigation phase.
- The tube-jack test method (similar to flat-jack testing) is being developed to more accurately determine the state of stress in the masonry and the masonry's deformability characteristics.
- The relationship between the state of stress in the masonry and the sonic velocity is being studied through experimental testing. Sonic tests are being performed in masonry wallets while they are loaded to different compressive stress levels.

❑ SONIC VELOCITY TESTING

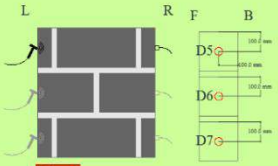

Fig. 1


Fig. 2

- Direct and indirect sonic tests were performed. The direct configurations are shown in Fig. 1 and testing in Fig. 2.

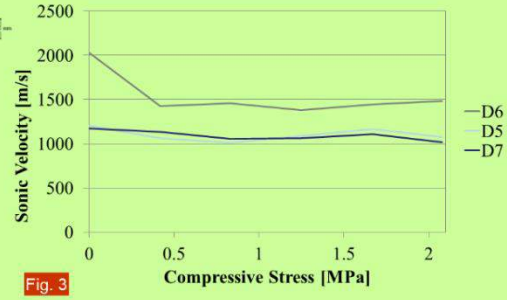

Fig. 3

- Direct test results show that when the specimens are initially loaded there is a drop in the sonic velocity as cracks in the mortar develop. Following the drop there is no significant change as stress increases.

❑ TUBE-JACK TESTING

- Tube-jack testing is similar to traditional flat-jack testing, except that a series of tubular jacks are used to pressurize holes in the masonry rather than using flat-jacks to pressurize slots in the masonry.
- Single and double tube-jack testing is being performed in masonry walls with three different typologies, loaded in compression. The single tube-jack test is used to determine the state of stress in the masonry and double tube-jack test is used to determine the deformability characteristics of the masonry.


Fig. 4


Fig. 5


Fig. 6

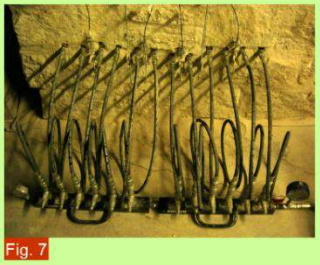
Fig. 7

- Fig. 4 shows a single tube-jack test in the regular typology wall. Fig. 5 shows the double tube-jack test in the same wall. Single tube-jack tests in the semi-irregular and irregular walls are shown in Fig. 6 and Fig. 7, respectively.

❑ CONTINUING ANALYSIS

- Single and double tube-jack tests performed in the masonry walls are being compared to traditional flat-jack tests performed in the same walls and under the same loading conditions.
- Numerical models are being created to compare with the experimental tube-jack and flat-jack results. The models will also allow for an examination of local stress concentrations.

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Esmaeel Esmaeeli

Supervisors: Joaquim Barros / Said Jalali

DEVELOPMENT OF HYBRID COMPOSITE PLATE FOR RETROFITTING OF RC ELEMENTS

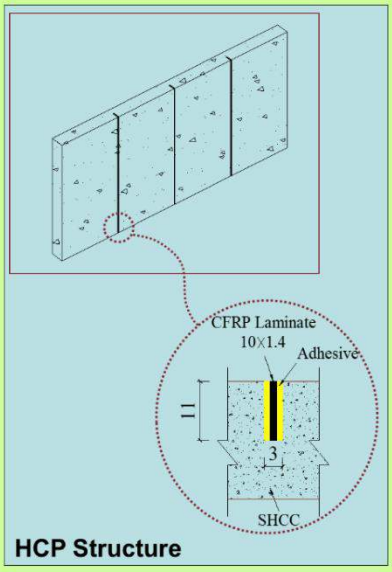
Hybrid Composite Plate (HCP)

A reliable retrofitting solution for concrete structures, which is composed of a strain hardening cementitious composite (SHCC) plate reinforced with Carbon Fibre Reinforced Polymer (CFRP).

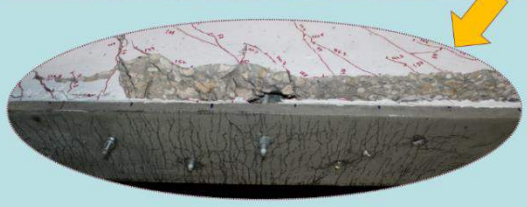
This system benefits from the **synergetic advantages** of these two composites, namely the **high ductility of SHCC** and **the high tensile strength of CFRPs**. In the material-structural of HCP, the ultra-ductile SHCC plate acts as a suitable medium for stress transfer between CFRP laminates (bonded into the pre-sawn grooves executed on the SHCC plate) and the concrete substrate by means of a connection system made by either chemical anchors (B), adhesive (G), or a combination thereof (BG). In comparison with traditional applications of FRP systems, **HCP is a retrofitting solution that**

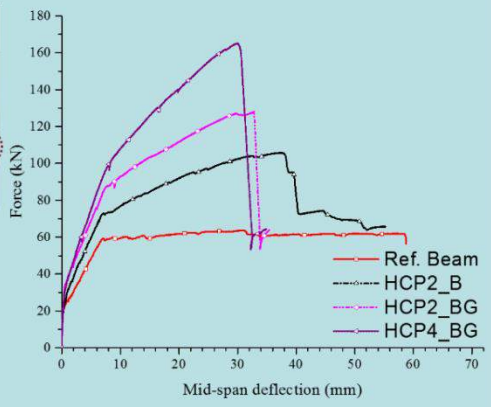
- Is less susceptible to the detrimental effect of the lack of strength and soundness of the concrete cover in the strengthening effectiveness;
- Assures higher durability for the strengthened elements and higher protection to the FRP component in terms of high temperatures and vandalism;
- Delays, or even, prevents detachment of concrete substrate.

Patent PT107111: "Painel compósito híbrido para o reforço de estruturas de betão existentes e respetivo método de produção e de aplicação"



HCP Structure





Flexural Strengthening of RC Beams By Attaching HCP to their Tension Face

HCP2 // HCP4: HCP composed of 2 // 4 CFRP laminates
B // BG : HCP-to-RC connection composed of "only anchors" // "combination of adhesive and anchors"

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HIGH PERFORMANCE FIBRE REINFORCED CONCRETE FOR THE REPLACEMENT OF SHEAR STIRRUPS

Fatemeh Soltanzadeh

Supervisor: Joaquim Barros

❑ MOTIVATION AND OBJECTIVES

- **This study presents** a methodology to develop a durable and sustainable prefabricated concrete beam with emphasis on eliminating the conventional stirrups, taking in to account the arrangements introduced in Fig.1.
- **These elements were produced by means of:**
- Development of a HPFRC aiming to suppress the steel stirrups without occurring shear failure, and
- Application of an effective system of reinforcement for pre-fabricating the HPFRC beams of larger life cycle, by combining the glass fiber reinforced polymer (GFRP) and steel bars, with the reinforcing ratio and the pre-stress level that assure the required load caring capacity and ductility of the elements.

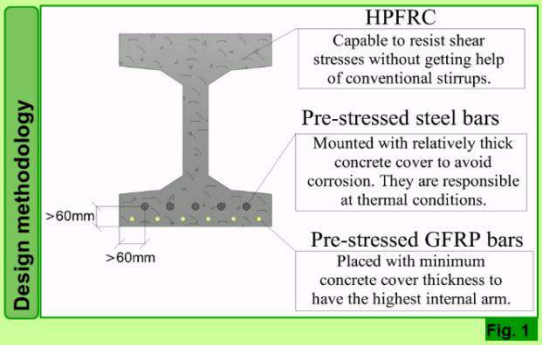


Fig. 1

- **The interest on using this system** is related to the structural efficiency, longer life cycle and lesser costs maintenance that can be obtained using this system.
- **The main purpose is** to develop a design guideline to predict the shear resistance of such beams without stirrups.

Fig.2 outlines the procedure of this research project.

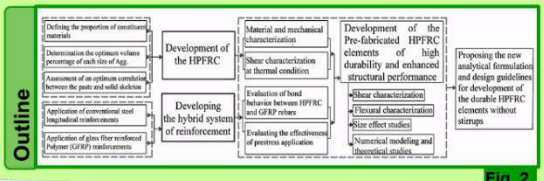


Fig. 2

❑ SUMMARY OF THE STUDIES & RESULTS

1. Characterizing the behavior HPFRC slender beams (with $a/d_{eff} > 2.5$)

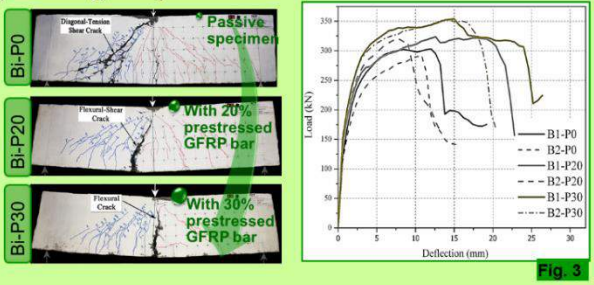


Fig. 3

2. Characterizing the behavior HPFRC slender beams (with $a/d_{eff} > 2.5$)

A. Evaluating the effectiveness of the prestressing on improvement the shear behavior of the elements

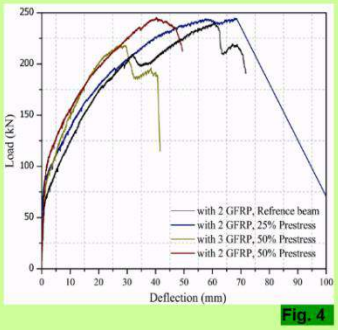


Fig. 4

B. Evaluating the effectiveness of the discrete steel fiber on improvement the shear behavior of the elements (Prestress: S70%&G30%)

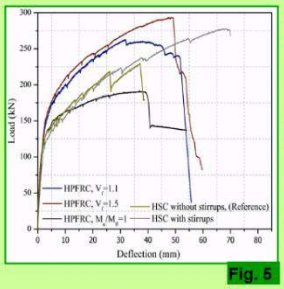
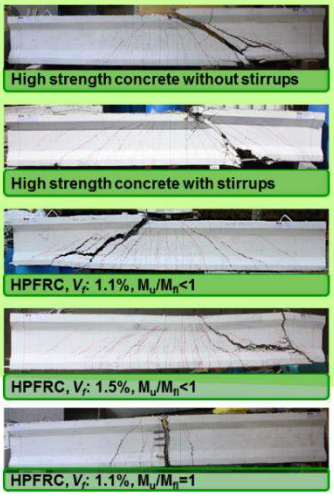


Fig. 5



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Acknowledgements:
Tensacciaci in the name of Eng. F. Pimenta for the assistance on the application of prestress reinforcements; Sireg and Schoeck (GFRP bars); Casais (moulds); Maccaferri and Exporplas (fibers); Secil (Cement), SIKA (superplasticizers); CiviTest (production of HPFRC specimens).

Institute for Sustainability and Innovation in Structural Engineering

Gilda Lucia Menezes

Supervisors: Miguel Azenha/Assunção Flores

INTEGRATION OF BIM METHODOLOGIES IN ENGINEERING TEACHING PROJECTS

❑ THE RESEARCH

- This work program, in the scientific domain of the Education and Engineering, consists in integrating Building Information Modeling methodologies into the Brazilian Federal Institutes mid-level technical courses teaching (students in the range of 14 and 18 years old).
- The schools have generally adopted two basic approaches to introduce BIM into their curriculum: using BIM in several courses across the curriculum (a facilitator to teach course content) or teaching BIM in just one or two courses such as a new autonomous course (BIM is the centerpiece of a pedagogical strategy). Figure 1 shows a scheme for the IFRN's proposal for using and teaching BIM.

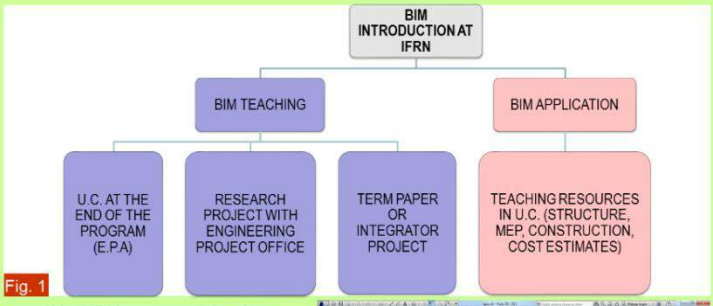

Fig. 1


Fig. 2

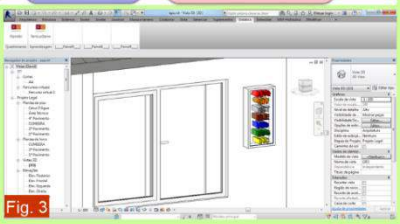
Fig. 3

- For the BIM teaching proposal, IFRN has created an engineering office, where students model real projects (Fig. 2). Furthermore, to accelerate learning there are plugins and a serious game being created (Fig. 3).

❑ DEPLOYMENT PARAMETERS

- The early deployment occurred with the dissemination of BIM through lectures and short courses at local events, in addition to involvement in research projects with funding of scholarships.
- In a second phase, the team of interested students and teachers had teaching materials at their disposal (for e-learning) such as printed bibliography, online courses and handouts produced especially for these group.
- In this sequence, there was classroom training, and the students themselves involved ministered BIM software short training at new local event (Fig. 4).


Fig. 4

IFRN BIM CURRICULUM

- The modeling of a complete project has been initiated at IFRN using worksharing. Support classes and an isolated course are being prepared for the effective implementation of the IFRN BIM curriculum. Figure 5 shows the first version of a biannual proposal for 4 years (course for 'Construction'): green are disciplines without BIM, blue are the general disciplines that only use BIM as a tool, and red corresponds to a BIM-oriented discipline.

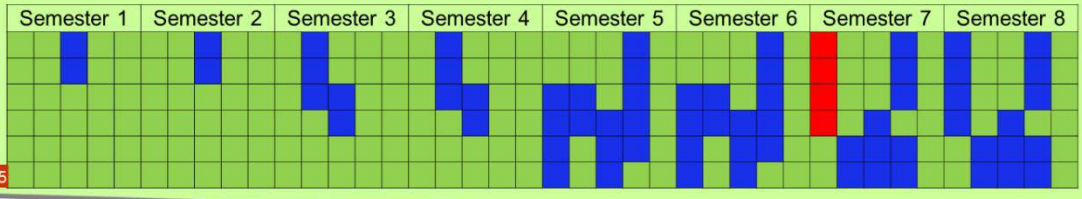

Fig. 5

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Campus Natal - Central

Institute for Sustainability and Innovation in Structural Engineering

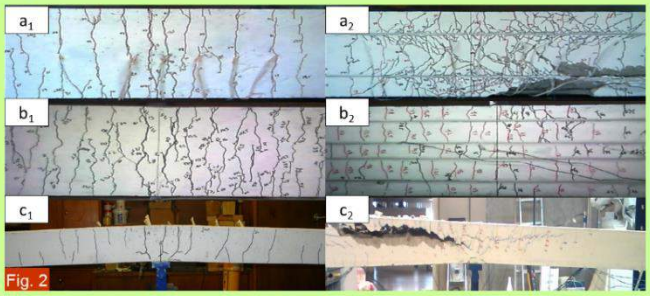
Gláucia Maria Dalfré

Supervisor: Joaquim Barros

FLEXURAL AND SHEAR STRENGTHENING OF RC ELEMENTS

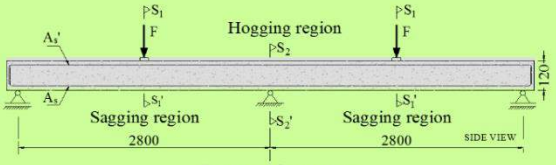
❑ Experimental and numerical analysis of RC two-span slabs strengthened with NSM CFRP laminates

An experimental and numerical program was carried out and it was verified the possibility of increasing the load carrying capacity in 25% and 50%, maintaining a relatively high level of moment redistribution, when correct NSM flexural strengthening arrangements are used. However, the load carrying capacity of the strengthened slabs was limited by the detachment of the strengthened concrete cover layer or due to the formation of a shear failure crack in the hogging region (Figures 1 to 3).

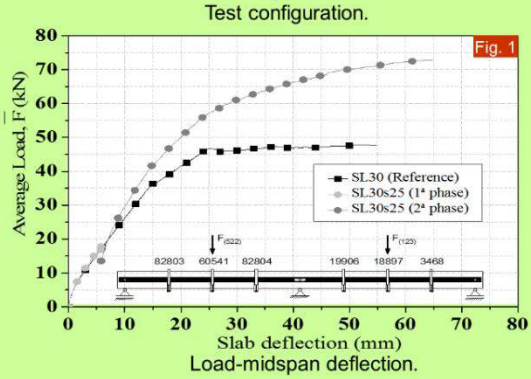


Reference slab strip NSM CFRP strengthened slab strip

Crack patterns: top view of hogging region (a_1-a_2) and bottom view of sagging regions (b_1-b_2); side view (c_1-c_2) of hogging region.



Test configuration.



Load-midspan deflection.

Failure of the strengthened slab strip by the detachment of the strengthened concrete cover layer or due to the formation of a shear failure – hogging region.

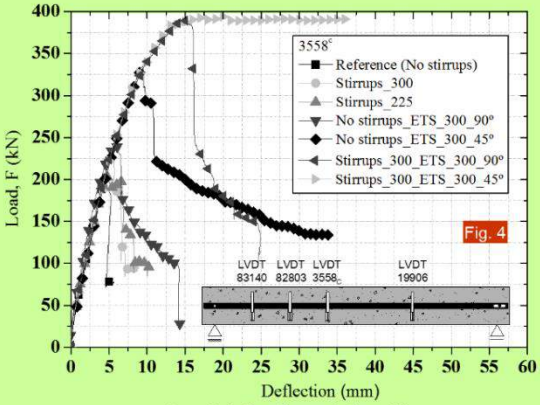
Additionally, to predict the load-deflection response of this type of structures up to its collapse, an analytical model was developed and its performance was appraised by using the data obtained from the experimental program. This model is based on the flexibility method and requires the knowledge of the flexural stiffness of the representative cross sections of the structure, which can be determined from the moment-curvature relationship of these sections. Finally, a strengthening strategy that avoids the occurrence of shear failure and provides extra resistance to the detachment of the NSM laminates was developed.

❑ Embedded Through-Section (ETS) shear strengthening technique

According to the strengthening strategy, holes are opened across the slab/beam thickness, with the desired inclinations, and steel bars are introduced into these holes and bonded to the concrete substrate with adhesive materials. From the preliminary results, it was verified the possibility of increasing the loading carrying capacity in 70%. It should be noted that the failure mode for the strengthened elements is more ductile (Figures 4 and 5).

Initial test configuration Failure mode

Crack patterns.



Load-deflection relationship.

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Institute for Sustainability and Innovation in Structural Engineering

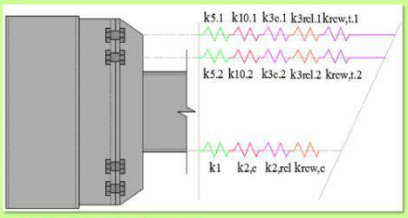
Guiomar da Silva Ferreira Vicente

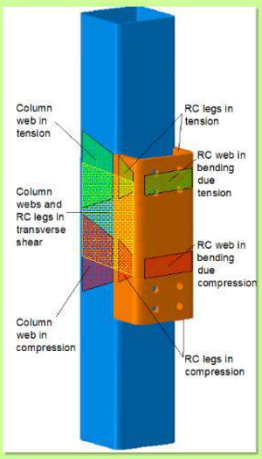
Supervisors: Rui Simões / Carlos Rebelo

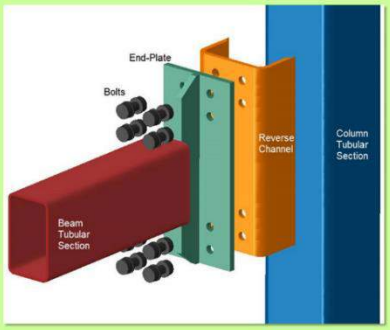
MOMENT RESISTING BOLTED JOINTS CONNECTING STEEL TUBULAR SECTION MEMBERS

❑ PURPOSE OF THE RESEARCH WORK

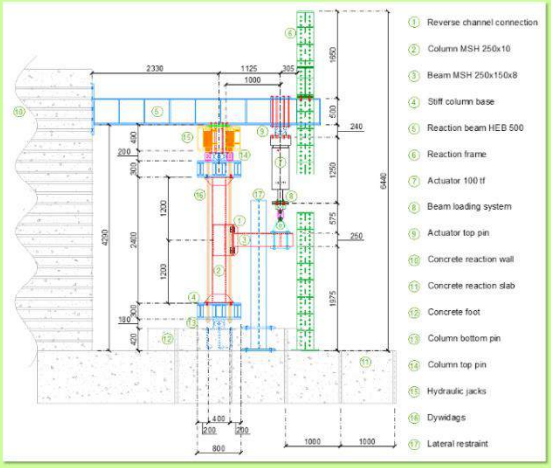
- **Assess the behaviour of the reverse channel joint**
- **Characterize the basic components of the reverse channel**
- **Propose analytical expressions for the components resistance and stiffness**
- **Enable the use of the component method, according to EN 1993-1-8, to design a reverse channel joint**



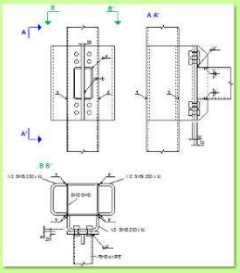




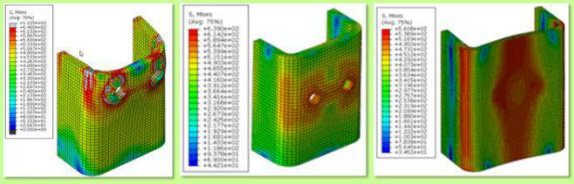
❑ EXPERIMENTAL WORK



- **Component tests – Individual characterization of the reverse channel components submitted to transverse tension ; shear or compression**
- **Tests on reverse channel joints – monotonic and cyclic tests to assess the joints behaviour**



❑ PARAMETRIC STUDY



- **Numerical analysis considering the reverse channel thickness, the bolts pitch and edge distance, and the compression flange edge as variable parameters;**
- **Proposal and validation of simplified equations to predict the resistance and stiffness of the reverse channel basic components**

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Hadi Baghi

Supervisor: Joaquim Barros

THE EFFECTIVENESS OF SHCC-FRP PANELS FOR THE SHEAR RESISTANCE OF RC BEAMS

❑ Motivation

- A new technique based on the use of Hybrid Composite Plates (HCPs) is used to increase the shear strength of RC beams. HCP is a thin plate of Strain Hardening Cementitious Composite (SHCC) reinforced with CFRP laminates. (Fig. 1 and Fig. 2)
- Due to the excellent bond conditions between SHCC and CFRP laminates, these reinforcements provide the necessary tensile strength capacity to the HCP, while the high post-cracking tensile deformability and resistance of SHCC avoids the occurrence of premature fracture failure of this cement composite in the stress transfer process between these two materials when the HCP is crossed by a shear crack.

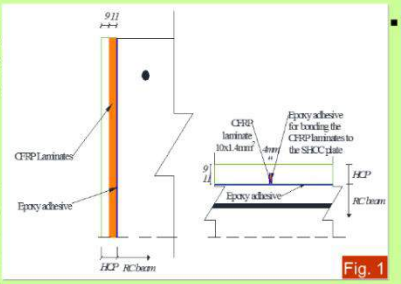


Fig. 1

- The shear strengthening contribution of the HCPs is limited by the tensile strength of the concrete of the strengthened beams. Mechanical anchors prevent a premature debonding of the HCPs and a certain concrete confinement is introduced in the zone of the beam to be strengthened, resulting favorable effects in terms of shear strengthening.

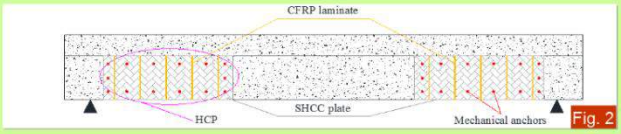


Fig. 2

❑ Experimental Research

- The behaviour of the RC beams strengthened with HCPs is assessed by three point bending test as shown in Fig. 3.

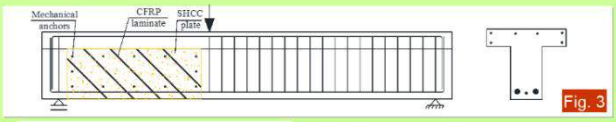
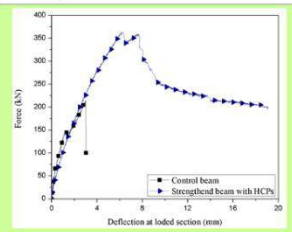


Fig. 3

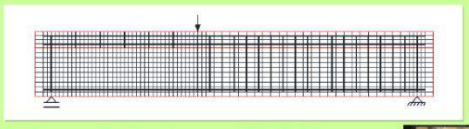
- The HCPs are capable of increasing not only the load carrying and deflection capacity, but also the post-peak resisting load, with favorable effects in terms of energy absorption capacity (Fig. 3).

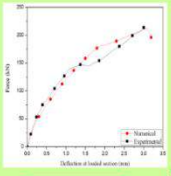


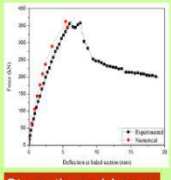
- Besides the contribution of the SHCC for the strengthening efficiency of HCPs, the SHCC also assures some protection to the CFRP laminates and adhesive in terms of vandalism, aggressive environmental conditions, and fire.

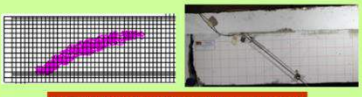
❑ Numerical Simulation

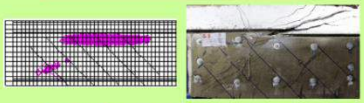
- In order to explore further the potentialities of HCPs for the shear strengthening, advanced numerical simulations were performed by using a FEM-based computer program.




Control beam

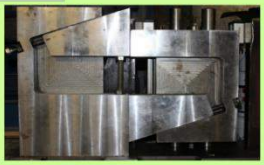

Strengthened beam with HCPs


Crack Pattern of the Control beam


Crack Pattern of the strengthened beam with HCPs

❑ Shear Behaviour of SHCC

- The shear characteristics of SHCC are determined by Iosipescu shear test developed at university of Minho.



- The main objective of these tests is to assess the effectiveness of Hybrid Composite Plates for shear strengthening of reinforced concrete beams.

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Hadi Mazaheripour

Supervisors: Joaquim Barros / Jose Sena Cruz

FLEXURAL BEHAVIOR OF HYBRID GFRP AND STEEL REINFORCED FRC PRESTRESSED BEAMS

❑ OBJECTIVES AND MOTIVATION

The present study intends to contribute for the development of a new generation of **high durable and sustainable** reinforced concrete (RC) structures, by combining the benefits that fiber reinforced polymers (FRP) and steel bars can provide. Combining GFRP and steel bars constitutes a high performance reinforcement strategy with **low probability of corrosion** occurrence. Additionally, the structure is made by **high performance fiber reinforced concrete (HPFRC)** in order to eliminate steel stirrups as the most susceptible to corrosion in this type of structural elements. The main structural parameters in terms of ultimate and serviceability conditions are being examined in the scope of this research project.

❑ ASSESSMENT OF BOND BEHAVIOUR BETWEEN GFRP BAR AND FRC

The bond behavior of GFRP bars have been studied under scope of an extensive experimental program. In addition, analytical and numerical simulations have been carried to simulate the results obtained from the test. **A sufficient bond strength of GFRP** bars was obtained from the test and the theoretical models showed good agreement with the experimental trends.

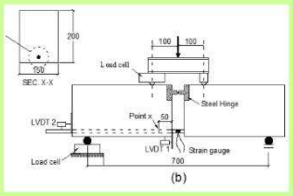

Figure 1 – Experimental campaign (Test setup and configuration)

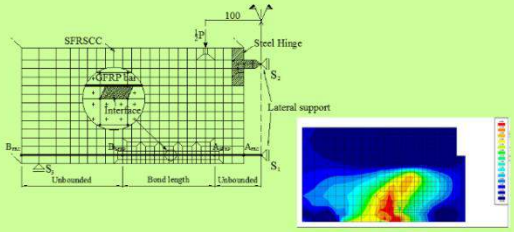

Figure 2 – Numerical Simulation (FE Model and stress field)

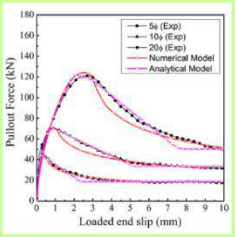

Figure 3 – Comparison between theoretical and experimental results

❑ EXPERIMENTAL RESEARCH ON PRE-FABRICATED HPFRC PRE-STRESSED BEAMS

The new reinforcing system for HPFRC beam has been fabricated and tested in the laboratory **under monotonic and fatigue loading condition**.

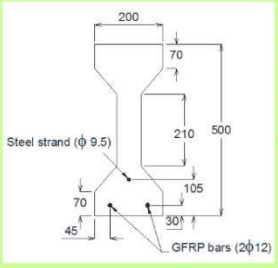

Fig. 4. Fabrication process of hybrid steel/GFRP pre-stressed beams

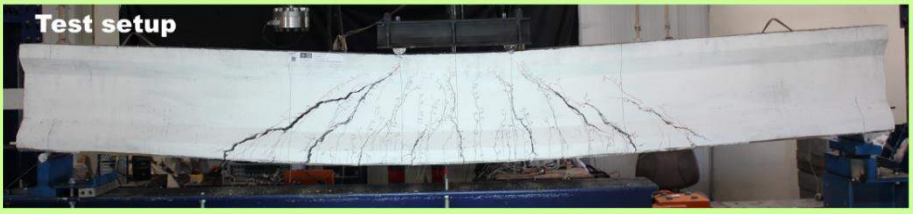

Figure 5. Test configuration and measurement devices of the beams

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SEISMIC ASSESSMENT OF UNREINFORCED MASONRY STRUCTURES

Hamed Azizi-Bondarabadi

Supervisor: Paulo B.Lourenço

❑ Objective

- The main objective of this PhD research work is to develop a new methodology for obtaining analytical fragility curves, which are continuous functions indicating the exceedance probabilities of a certain damage state as a function of the earthquake intensity (Fig. 1), for unreinforced masonry (URM) buildings in order to use them in seismic risk assessment studies. Concerning the uncertainties associated with the demand and the capacity, it should be clear hence that many nonlinear time history and pushover analyses should be performed in this study. For this purpose, the main component of this research work is related to develop accurate, reliable and simple tools for nonlinear analysis aiming at reducing their time and cost. The development is conducted in independent parts related to two main seismic behaviors of masonry structures: with and without box-behavior.

❑ Validation of numerical tools

- This part aims to confirm the validity of structural component models and discrete element method for numerical simulation of URM buildings with and without box behavior, respectively. The numerical models are verified with respect to the results of experimental works in terms of capacity curve and damage pattern.
- Numerical simulation of URM structures with box-behavior is carried out for a typical modern European URM building with regular geometry made of concrete block units and cement mortar with a rigid slab as roofing system. For validation purposes, shaking table tests on two-story buildings of this URM typology (Fig. 2) is selected. Structural component model implemented in TreMuri software, is adopted for performing non-linear dynamic analyses. For the buildings without box- behavior, Typical Peruvian adobe house, which is made using adobe bricks and mud mortar with a flexible wooden roof, is selected. Using relevant shaking table tests performed by Blondet, et al. on these adobe houses (Fig. 3), discrete element method implemented in 3DEC software is adopted for verification.

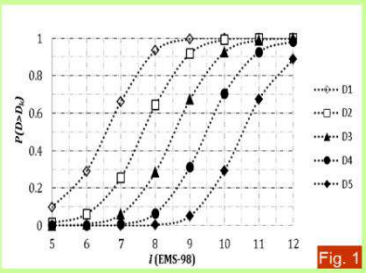

Fig. 1


Fig. 2


Fig. 3

❑ Generation of fragility curves

- This part aims to generate empirical and analytical fragility curves for typical Iranian masonry schools due to their vulnerability as well as the availability of a comprehensive database for them. The database was obtained from the field survey forms applied for each observed school to collect the features and damage of the structure. The database is appropriate for assessing damage using an index-based method. For this reason, a procedure is firstly proposed to generate empirical fragility curves correlating an available Iranian index-based method with two European observational method, namely as GNDT II level and Macroseismic.
- Next, based on the developed numerical tools, a fully analytical-based method for generating fragility curves that considers all sources of uncertainties associated with the demand (ground motion records) and capacity (material properties) is proposed. The validity of analytical fragility curves can be confirmed by the empirical curves.
- Finally, probabilistic performance based assessment, as a fully probabilistic framework for analyzing seismic risk, is performed on a typical school using obtained analytical fragility curves and appropriate numerical tool.

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Hamidreza Salehian

Supervisor: Joaquim Barros

EVALUATION OF THE POST-CRACKING RESPONSE OF SFRC IN SQUARE PANEL TEST

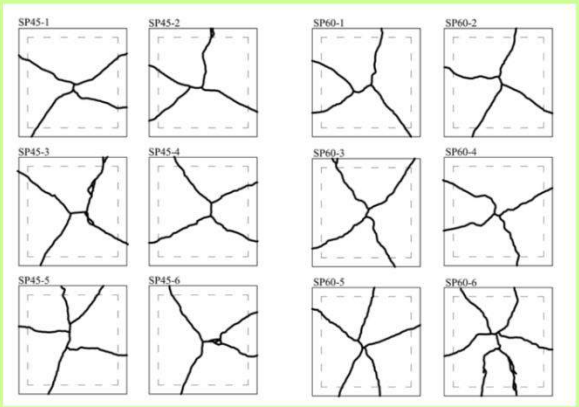
❑ MOTIVATION

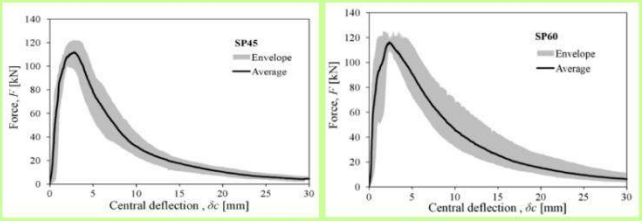
- **The post-cracking behaviour of SFRC is greatly affected by the fibre distribution and orientation, and the nature of cracking process.**
- **Therefore, a design methodology for SFRC slabs should be based on constitutive models that are representative of the behaviour of the SFRC in this type of structure.**

❑ EXPERIMENTAL RESEARCH

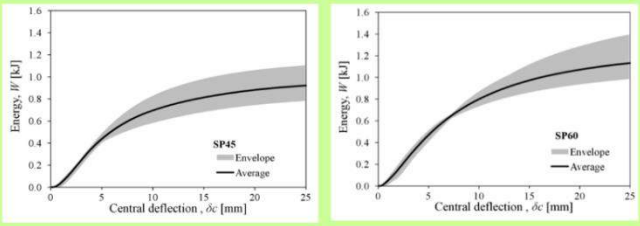
- **An experimental program conducted to evaluate the influence of the tensile post-cracking behaviour of SFRC on the load-deflection response of square panel (SP) test.**

- **The test was conducted on two series of square panels made with 45 and 60 kg/m3 steel fibres, designated SP45 and SP60, respectively.**





FORCE-CENTRAL DEFLECTION RELATIONSHIPS

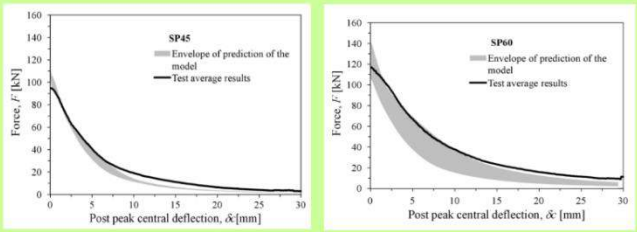


ENERGY ABSORPTION VS. CENTRAL DEFLECTION

❑ NUMERICAL MODEL:

- **To have an explicit representation of the influence of the tensile post-cracking behaviour of SFRC on the load carrying capacity of SFRC panels, a numerical model was developed based on moment-rotation approach.**

❑ MODEL ASSESSMENT:



- **The model is capable to be used for other type of conventional panel test such as round panel (RP) test with continuous support or RP test with three pivots.**

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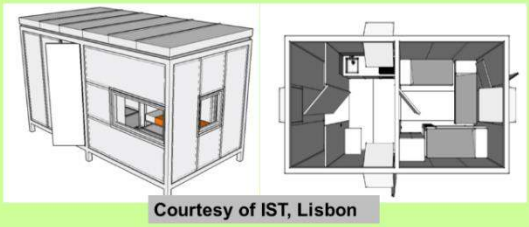
Hassan Abdolpour

Supervisors: Joaquim Barros / José Sena-Cruz

DEVELOPMENT OF COMPOSITE SANDWICH PANELS FOR PREFABRICATED BUILDING

❑ OBJECTIVE

The main objective of this thesis is developing composite sandwich panels for using in prefabricated building. The building could be used as an emergency house or temporary building in disaster areas.



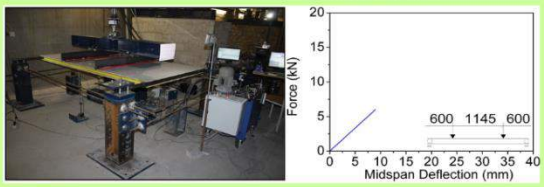
Courtesy of IST, Lisbon

❑ Development of sandwich panels

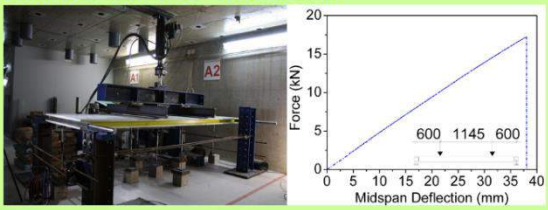
Composite sandwich panels was produced by using four main elements namely GFRP skins, polyurethane foam core, GFRP internal ribs and connectors.

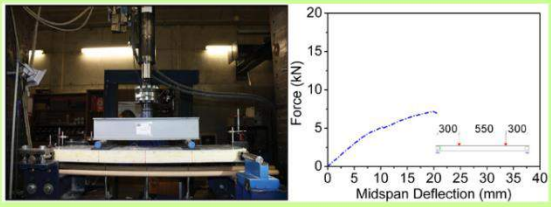
An experimental programme was conducted to evaluate response of floor composite sandwich panels in series of static tests.

FLEXURAL TESTS IN SERVICE LIMIT STATE

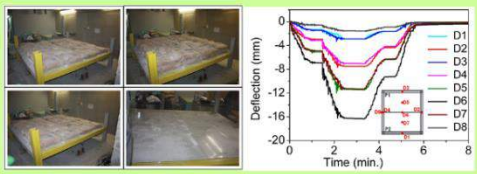


FLEXURAL TESTS UP TO FAILURE





A prototype of floor system was manufactured in order to study assembly process and responses of the structure in service limit state.



The results illustrated high potentiality of this system to be used as a prefabricated building and fulfilled the suggested requirement by different standards.

❑ONGOING RESEARCH

In the continuous floor panels will be studied in creep and low cyclic tests. Moreover other elements such as roof panels, wall panels subjected to study under flexural, creep and aging tests.

In the case of connections different tests such as direct tensile tests and shear tests will be performed to study responses of connections under corresponding loads.

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EXPERIMENTAL AND NUMERICAL ANALYSIS OF COLD-FORMED STEEL COLUMNS AT AMBIENT AND ELEVATED TEMPERATURES

Hélder D. Craveiro

Supervisors: João Paulo C. Rodrigues / Luís M. Laím

❑ OBJECTIVE

- Assess the load bearing capacity of CFS columns considering different cross-section shapes (single and built-up open and closed cross-section) and different end-support conditions (pinned-pinned and fixed-fixed);
- Study the effect of the instability phenomena on cold-formed steel columns with restrained thermal elongation under fire conditions. Influence of the cross-sections, the axial and rotational restraint to the thermal elongation of the column, end-support conditions and initially applied load level;
- Assess mechanical and thermal properties of CFS S280GD+Z;
- Development of simplified calculation methods for fire design of CFS columns, based on experimental and numerical results.

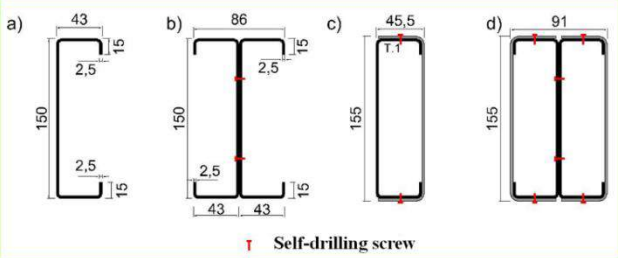

Fig. 1 – CFS cross-sections tested.

❑ RESEARCH PLAN

- 24 load bearing capacity tests – 4 cross-sections and 2 end-support conditions;
- 96 fire tests with restrained thermal elongation;
- Mechanical properties both at ambient and elevated temperatures;
- Thermal properties (thermal conductivity, specific heat and thermal diffusivity) using the Transient Plane Source equipment (TPS).
- Parametric study, using the finite element method and finite element software ABAQUS, based on the available experimental results.

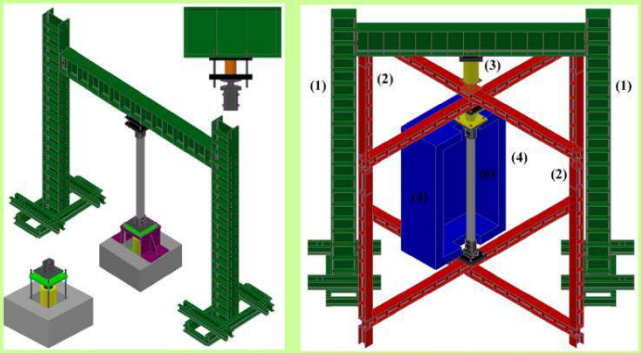

Fig. 2 – Experimental set-up for ambient and elevated temperature testing.

❑ RESULTS AND CONCLUSIONS

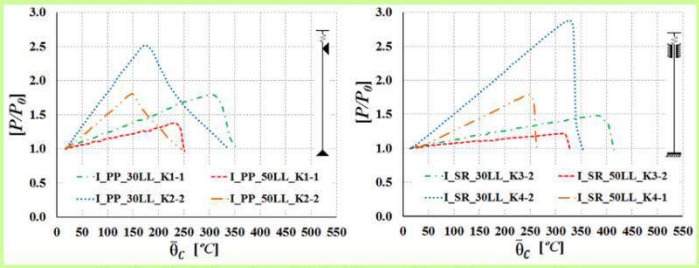

Fig. 3 – Evolution of restraining forces. C and I cross-sections.

- The higher the stiffness of the surrounding structure was the higher the maximum restraining forces generated during the heating phase;
- Increasing the level of restraint to thermal elongation may lead to the reduction of critical temperatures.

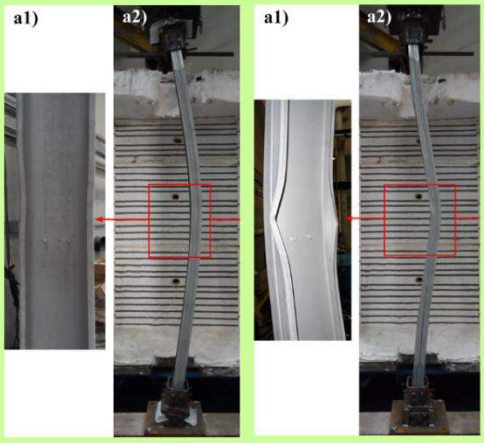

Fig. 4 – Final deformed shape observed in fire tests.

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Hugo Augusto

Supervisors: Carlos Rebelo / J. Miguel Castro

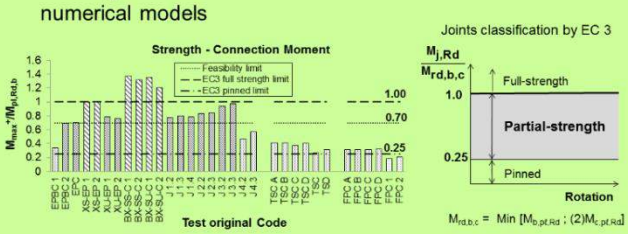
CONTRIBUTION TO THE SEISMIC ANALYSIS AND DESIGN OF STEEL FRAMES WITH PARTIAL-STRENGTH JOINTS

❑ SCOPE AND OBJECTIVES

- This doctoral thesis intends to contribute to an improved behaviour of steel frame structures, when subjected to earthquakes, through the inclusion of the real joints behaviour in the steel structures analysis and design process.
- The main objective of the research is to contribute to the extension of the components method to account for the cyclic behaviour of the various components, presenting a procedure to obtain some of the F-Δ components response, using detailed finite elements models, needed for the spring mechanical models, hence allowing its application in the characterization of partial-strength beam-to-column joints subjected to cyclic loading conditions
- In parallel it is intended to contribute to the development of practical guidelines for analysing steel moment-resisting frame structures that include performance criteria and a displacement-based design procedure capable of considering different beam-column joint typologies, particularly partial-strength bolted joints as defined in Eurocode 3.

❑ DATA COLLECTION AND TREATMENT

- Several existing experimental tests were catalogued and analysed.
- Allowing the selection of tests for the calibration of the numerical models



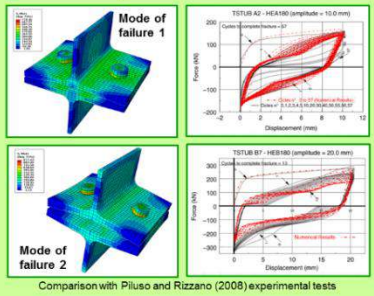
❑ CALIBRATION OF THE NUMERICAL MODELS

- Cyclic tests are used to calibrate the numerical models. Therefore, for each type of connection a series of experimental tests were chosen to calibrate the numerical models.

❑ **T-stub components**

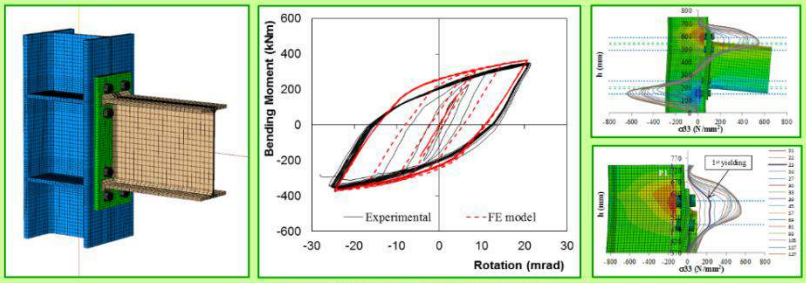
❑ **End-plate joints**

❑ **T-stub components**



Comparison with Piluso and Rizzano (2008) experimental tests

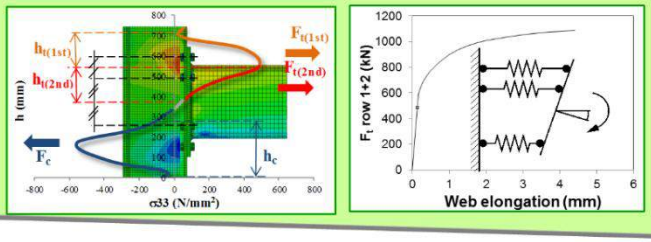
❑ **End- plate joints**



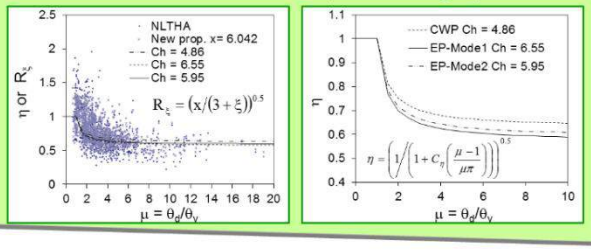
Comparison with Nogueiro *et al.* (2006) experimental tests

❑ ADVANCES AND CONTRIBUTIONS TO THE SCIENTIFIC COMMUNITY

- Contribution to cyclic components model



- Inelastic displacement spectra reduction factors for MRF structures with beam-to-column partial-strength joints



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SUSTAINABLE STEEL CONSTRUCTION

FCT Fundação para a Ciência e a Tecnologia

Institute for Sustainability and Innovation in Structural Engineering

Hugo Filipe Santos Caetano

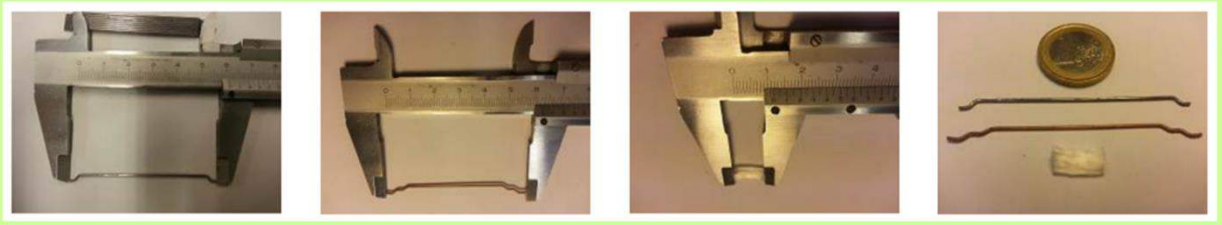
Supervisors: João P. C. Rodrigues / Pierre Pimienta

FIBER CONCRETES WITH IMPROVED FIRE BEHAVIOUR

❑ INTRODUCTION

One of the goals of civil engineering is to develop materials and structural solutions that will allow to improve the concrete structure`s behavior when subjected to the actions of different scenarios. One of the possible scenarios to which a concrete building may be subjected is one involving the fire action.

The proposed investigation aims to develop and characterize a fiber reinforced concrete (Fig. 1) with an improved fire behavior.



(a) (b) (c) (d)

Figure 1 - (a) Steel fibres 3D: (b) Steel fibres 5D; (c) Polypropylene fibres; (d) Fibres used.

❑ EXPERIMENTAL PROGRAM

To achieve this goal several concrete compositions including cocktails of steel and polypropylene fibers will be made as well as mechanical tests and numerical simulations.

RHEOLOGICAL PROPERTIES		THERMAL PROPERTIES	EXPERIMENTAL TEST SET-UP	NUMERICAL SIMULATIONS
Strength Parameters	Elastic Parameters			
Tensile strength	Modulus of Elasticity	Thermal Conductivity	Tensile/compressive/ bending tests on coupon specimens	Numerical Modeling of structural Behaviour of concrete slabs
Compressive strength	Poisson's Ratio	Specific Heat		
Bending strength			Flexural tests on slabs	

To sum up it is intended to present an optimized composition of a cocktail fiber reinforced concrete with improved mechanical and thermal properties in order to improve the fire performance of the considered fiber reinforced concrete structural elements.

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Hugo Guimarães

Supervisors: José Campos e Matos/ Dan M. Frangopol/ António Abel Henriques

RISK ANALYSIS OF BRIDGES USING A NEW RELIABILITY-BASED ROBUSTNESS ASSESSMENT METHODOLOGY

❑ MOTIVATION

- This research project is motivated by the infrastructure and bridge owners' need for risk-informed decision-making processes. The goal is to contribute to the next generation of risk-based bridge management systems by exploring advanced reliability methods and probabilistic nonlinear finite element models in robustness assessment.
- With this work, a holistic reliability-based methodology for evaluating robustness of highway bridges at two performance levels will be addressed: structural behavior under hazardous events and lifetime structural performance under uncertainty.

❑ RESEARCH FOCUS

- Aiming to link theory and practice in risk assessment methodologies and structural robustness quantification, the research (Fig.1) try to follow a natural path in the consideration of robustness criteria in risk assessment, from contextualization to the development and implementation of a new methodology to evaluate robustness at the two performance levels.
- Four main research question were formulated to guide our work:
  - Which are the most critical hazards affecting the system performance?
  - How to realistically model the system behavior under hazardous events while considering uncertainty?
  - How to achieved a time-dependent performance indicator?
  - How can the two levels of performance evaluation be integrated in a risk assessment methodology?

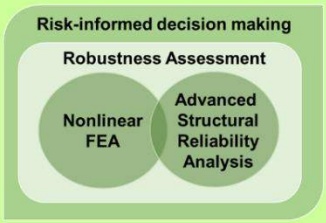


Fig. 1 Research scheme

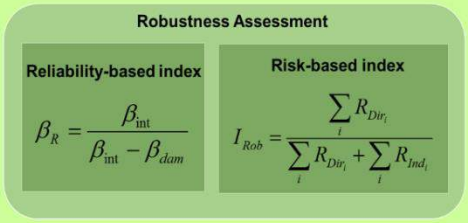


Fig. 2 Existing robustness assessment methodologies

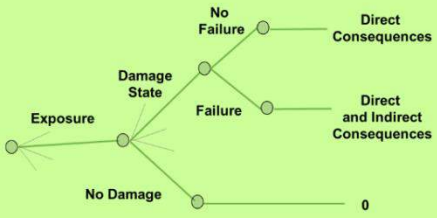
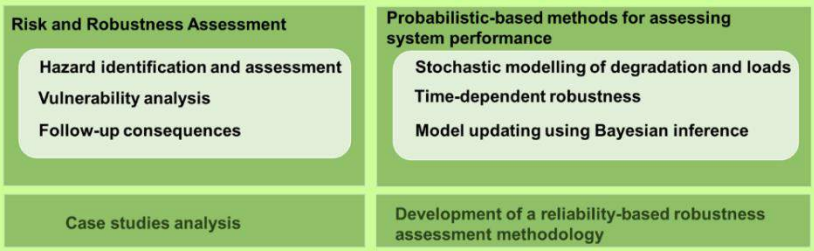


Fig. 3 Event tree for robustness quantification

❑ METHODOLOGY

- The research strategy to be followed intends to answer the aforementioned research questions and will cross-fertilize the areas of structural analysis and structural reliability theory within a risk assessment framework. The expected steps are shown in Fig. 4.



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Inês Gonçalves Costa

Supervisor: Joaquim Barros

PRESTRESSED CARBON FIBRE LAMINATES APPLIED ACCORDING TO NEAR SURFACE MOUNTED TECHNIQUE TO INCREASE THE FLEXURAL RESISTANCE OF REINFORCED CONCRETE BEAMS

❑ EXPERIMENTAL RESEARCH

- This research is dedicated to evaluate and quantify three of most relevant aspects associated to this strengthening system: the instantaneous prestress losses, the long term prestress losses, the effectiveness of the proposed technique.
- Three series of RC beams strengthened in flexure with NSM-CFRP laminates were produced, monitored, and tested up to failure, and the obtained results are presented and discussed. The numerical modelling of all the beams composing the experimental program is also presented

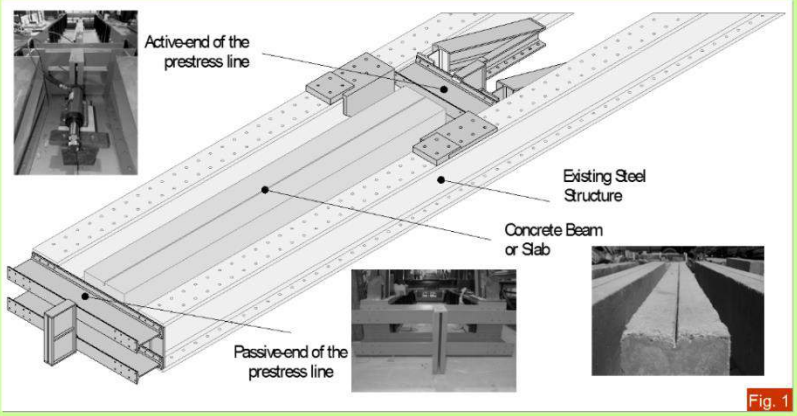
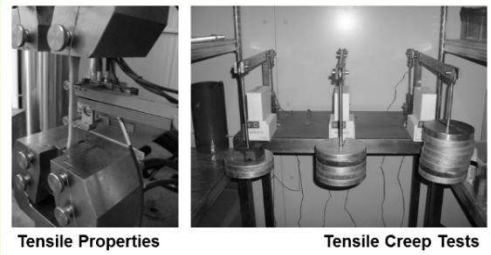


Fig. 1

❑ ADHESIVE CHARACTERIZATION


Tensile Properties Tensile Creep Tests

Pullout Bending Tests

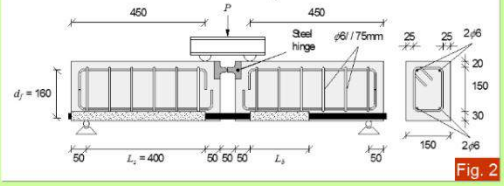


Fig. 2

❑ NUMERICAL MODELS OF FULL SCALE ELEMENTS

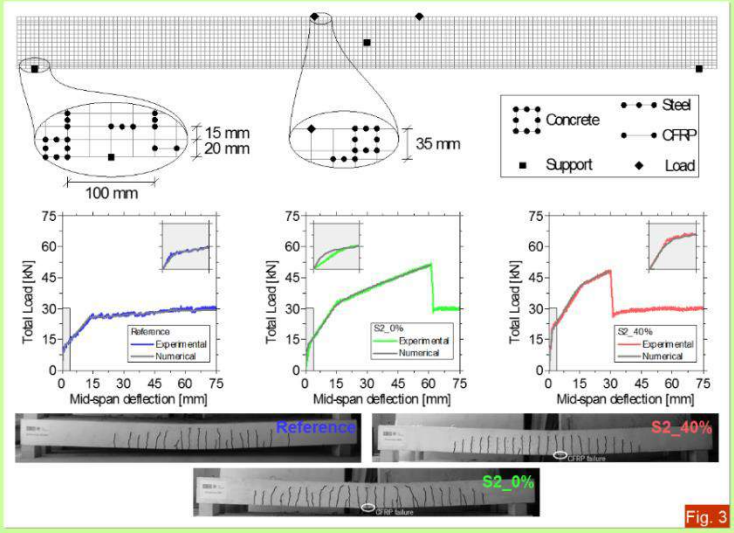


Fig. 3

❑ MAIN CONCLUSIONS

- Low levels of strain loss along the majority of the bonded length and reasonable initial deflection levels were obtained due to the prestress application.
- The load at crack and yield initiation increases significantly with the prestress level.
- A considerable decrease of ultimate deflection and total cracked length of the beam with the increase of the prestress level was observed.
- The load-deflection and load-strain curves, obtained by numerical simulations have fitted with good accuracy the corresponding curves registered experimentally.

CONTINUOUS MONITORING OF DEFORMABILITY OF STABILIZED SOILS BASED ON MODAL IDENTIFICATION

Institute for Sustainability and Innovation in Structural Engineering

JACINTO SILVA

Supervisors: Miguel Azenha / A. Gomes Correia

❑ SCOPE OF THE WORK

- Using EMM-ARM (Elasticity Modulus Measurement through Ambient Response Method) continuous monitoring of stiffness of stabilized soils with lime and /or cement.
- Technique based on the continuous monitoring of the first resonant frequency of a composite beam, which evolves as a consequence of the hardening of the tested material, which can be correlated with its E-modulus.

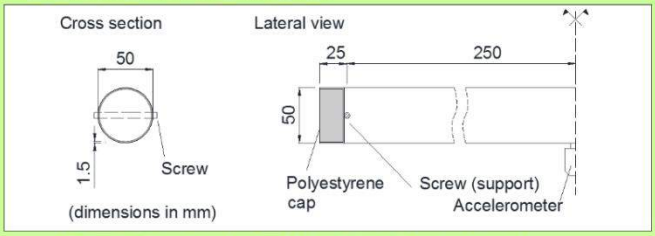


Figure 1: Cross-section and lateral view of testing mould

❑ MODAL IDENTIFICATION

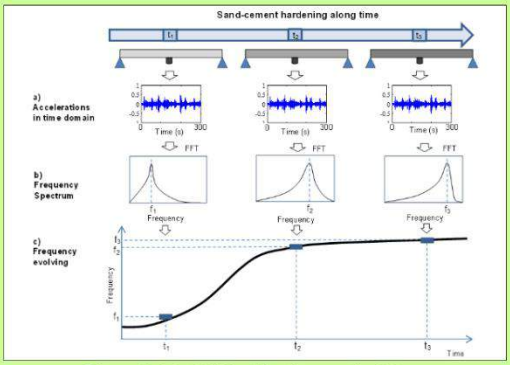


Figure 2: Modal identification methodology

❑ EVALUATION OF STABILIZED SOIL E-MODULUS

The first resonant frequency f of a simply supported beam with span L, homogenized E-modulus, homogenized moment of inertia and uniformly distributed mass is given by:

$$f = \frac{\pi}{2 \cdot L^2} \sqrt{\frac{\overline{EI}}{\overline{m}}}$$

It is possible to extract the E-modulus of the stabilized soil as all other variables are known.

$$\overline{EI} = E_{Support} I_{Support} + E_{Stab.Soil} I_{Stab.Soil}$$

❑EXPERIMENTAL PROGRAM

Study specimens sampled from a sand-cement layer stabilized with a Portland cement CEM II/B-L 32.5N.

The mix proportions for the stabilized soil, given in relation to the weight of dry sand, comprehended 7% of cement and 9% of water content.

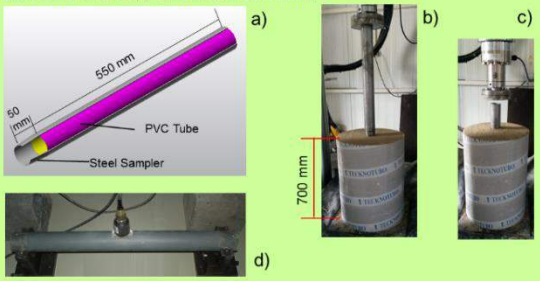


Figure 3: Sand-cement "layer": a) sampler; b, c) sampler introduction; d) EMM-ARM beam during testing

Table 1 - Specimens types and references

Type of test	Reference
EMM-ARM	S1;S2
Unconfined Cyclic Compression	UCC1 UCC2 UCC3

Figure 4: Evolution of stiffness for the first 30 days of curing

❑SOME ADDITIONAL TASKS

- Study of forced vibration solutions

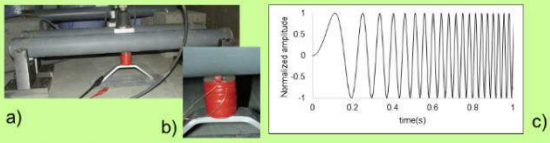


Figure 5: a) and b) bean with electromagnet to impose forced vibration; c) imposed sweep signal

- Propose a methodology to estimate the stiffness at reference ages (e.g. 28 days) with short duration tests.
- Study of different modal identification methods.
- Algorithm development and programming to automate the processing of data.
- Collection and testing of undisturbed samples of stabilized soils.

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Javier Ortega Heras

Supervisors: Graça Vasconcelos, Mariana Correia, Hugo Rodrigues

REDUCTION OF THE SEISMIC VULNERABILITY OF VERNACULAR ARCHITECTURE WITH TRADITIONAL STRENGTHENING SOLUTIONS

AWARENESS AND PROTECTION OF THE VERNACULAR HERITAGE

Reduction of its seismic vulnerability

Using traditional strengthening solutions

House in Algarve (CI-ESG, 2013)

Houses in Benavente

Hidden timber frame in Lagos

OBJECTIVES

(1) Identification of seismic resistant features on selected case studies

(2) Development of a seismic vulnerability assessment methodology

(3) Validation and assessment of the effectiveness of identified traditional strengthening solutions in the reduction of the seismic vulnerability of vernacular buildings

TASKS

T1.1. State of the art on vernacular architecture and Local Seismic Culture

T2. Analysis of case studies and identification of traditional strengthening techniques

T1. 2. State of the art on seismic vulnerability assessment methodologies

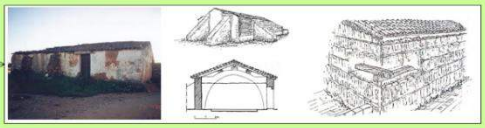
T3. Development and calibration of a seismic vulnerability assessment methodology

T4. Evaluation of the reduction of the seismic vulnerability by the addition of traditional strengthening solutions

T5. Study of real buildings and **final proposal of strengthening recommendations for main end-users and decision makers**

First Case Study

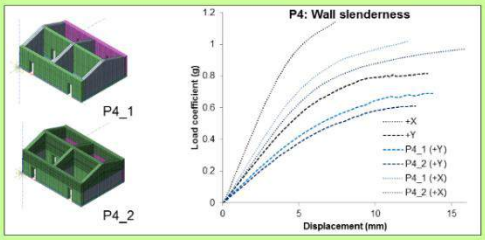
Rammed earth vernacular constructions in Alentejo



T3.1. Evaluation and selection of the parameters affecting the seismic vulnerability of specific vernacular building typologies

1. Location and position within urban fabric
P1: Location and soil condition
2. Geometry: Plan and elevation configuration
P2: Plan configuration
3. Construction solutions and materials: vertical resisting elements (load bearing rammed earth walls)
P3: Distribution of resisting elements
P4: Wall slenderness
P5: Maximum distance between walls
P6: Rammed earth quality
P7: Connection between perpendicular walls
4. Construction solutions and materials: horizontal elements (floors and roofs)
P8: Type of roofing system
5. Opening characteristics
P9: Number and area of wall openings
P10: Position and misalignment of wall openings
6. Maintenance, previous damage, alterations and traditional strengthening solutions
P11: Structural history of the building
P12: Non-structural elements
P13: Conservation state and previous damage
P14: Traditional strengthening solutions

T3.2. Numerical modeling for the calibration of the methodology



T3.3. Experimental study of wall-to-wall connections

a) **Reduction of the seismic vulnerability of the vernacular heritage**
b) **Preservation of old building traditions**
c) **Identification and update of adequate seismic retrofitting techniques**
d) **Application for the preservation of the vernacular building stock**

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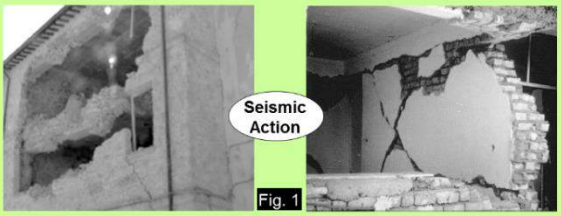
HIGH DUCTILITY STRENGTHENING SYSTEM FOR MASONRY STRUCTURAL REHABILITATION

João Almeida

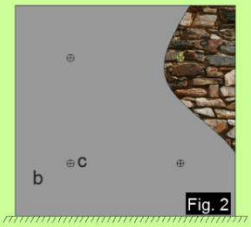
Supervisors: Eduardo Pereira / Joaquim Barros

❑ THE PROBLEM: Masonry deficient performance when subjected to cyclic and dynamic loads, essentially due to the brittle behaviour and low energy dissipation capacity, Fig 1

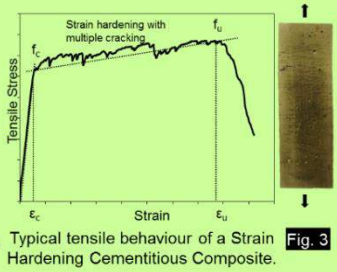


Out-of-plane colapse — In-plane damage

❑ SOLUTION UNDER INVESTIGATION: System composed of a high ductility fibre reinforced cementitious mortar, see Fig 2 and 3



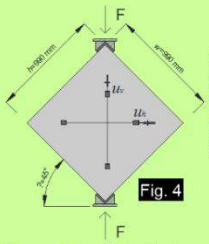
Strengthening system: a) masonry; b) SHCC mortar; c) connectors



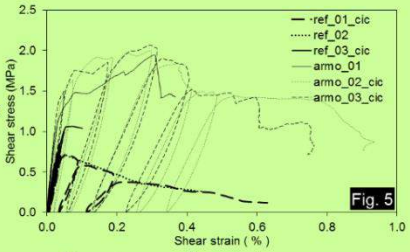
Typical tensile behaviour of a Strain Hardening Cementitious Composite.

❑ CHARACTERIZATION AND ANALYSIS OF THE PROPOSED SOLUTION

- **Assessment of the strengthening system contribution to the in-plane load carrying capacity through diagonal tensile tests: example of ceramic brick masonry, Fig 4 and 5.**



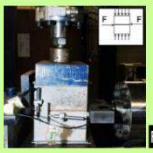
Diagonal tensile test set-up



Shear stress vs shear strain response

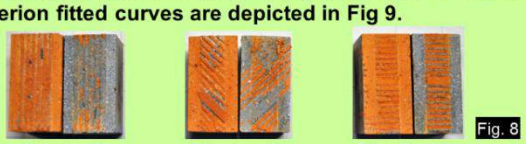
- **The *delamination* of the render and strengthening layer is the prevailing failure mode.**
- **The mechanical properties of the interface between masonry and the strengthening layer are critical for the strengthening system efficiency. These properties were analyzed by performing shear and pull-off tests (Fig. 6 and 7).**

Pull-off test

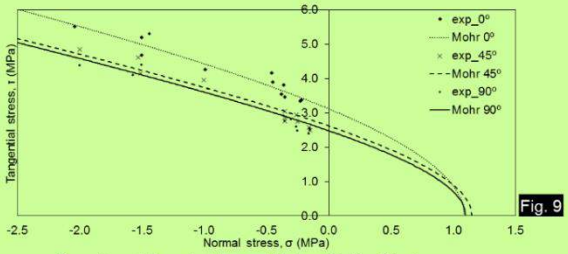


Direct shear tests

- **The Failure modes obtained for strengthening mortar/ ceramic brick interface after direct shear testing are presented in Fig 8.**
- **The experimental peak values of the tangential stress obtained for different normal stresses and the Mohr criterion fitted curves are depicted in Fig 9.**



Direction 0º — Direction 45º — Direction 90º



Experimental peak data and Mohr criterion fitted curves

FURTHER DEVELOPMENTS

- **Characterization of the interface SHCC/substrates and optimization of their performance (surface treatments, use of connectors).**
- **Assessment of the importance of other physical properties to the reinforcement system performance, such as surface roughness and composition.**
- **Development of analytical models to describe the typical failure modes, and of design rules to support the practitioner.**

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João Nuno Fernandes

Supervisors: José Campos e Matos / Daniel Oliveira / Joan Casas

PROBABILISTIC ANALYSIS OF EXISTING REINFORCED CONCRETE RAILWAY BRIDGES

❑ Numerical model and probabilistic–based analysis

- This research program aims at the modelling of a series of railway bridges. In order to model these bridges, a nonlinear structural analysis software will be employed. Thus, a probabilistic tool (to calculate the reliability index and the respective probability of failure) will be developed.
- The reliability index is obtained through a full probabilistic analysis that can give both load (S) and resistance (R) distributions (see Fig.1) and therefore a limit state function (G).
- Simulation techniques (e.g. Monte Carlo Method or Latin Hypercube Sample Method, see Fig.2) will be used.
- However, initially a semi-probabilistic approach will be tested:

$$\phi_R R_n \geq \gamma_{S1} S_{n1} + \gamma_{S2} S_{n2} + \cdots + \gamma_{Sn} S_{nn} \quad \textbf{(equation 1)}$$

- The DIANA software will be adopted to simulate the behavior of the materials and suitable non-linear constitutive laws will be used.

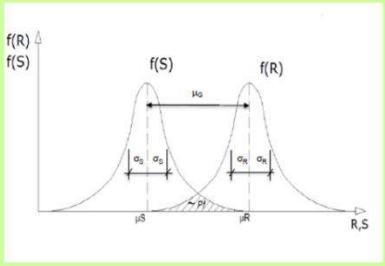

Fig.1 – R and S distributions

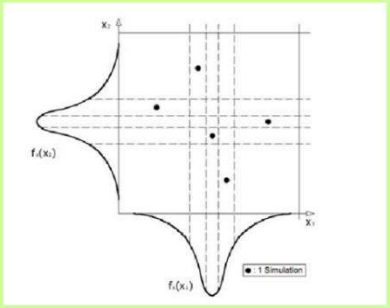

Fig.2 – Latin Hypercube Sampling (LHS) scheme

❑ Parametric study - sensitivity analysis

- Studies will start with the analysis of a simply supported beam to verify the most critical parameters of the model.
- The parameters that will be varied in the model are presented in table 1.

Concrete	Compressive strength, f_c
	Tensile strength, f_{ct}
	Young Modulus, E_c
Steel	Yield stress, f_{sy}
Geometry	Width, b
	Height, h
Loads	Pre-stress
	Dead loads
	Distributed overloads

Table 1 - Parameters

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João P. Gouveia

Supervisor: Paulo B. Lourenço

DEVELOPMENT OF AN INDUSTRIALIZED STRUCTURAL MASONRY SYSTEM

OBJECTIVE

The objective of this work is to develop a constructive solution for small and medium size buildings, using a system of confined and reinforced structural masonry, and aiming at more economical solutions, with better performance and more rational building technologies. The providing innovative solutions for confined structural masonry are to be assessed in terms of strength for seismic loading and of construction costs.

❑ WORKING JUSTIFICATION

i) Masonry walls in residential buildings represent around 12 to 17 % of the total cost. The walls exhibit often damage, being responsible for 25% of the total damage in construction.

ii) Recent studies demonstrate that a structural solution using masonry is 10 to 15% more economical than the competing reinforced concrete solution.

iii) The construction in Portugal presents a singular situation when compared another countries. The structures used a single execution technique: reinforced concrete.

❑ State-of-the-art and structures system in study

Review of the landmarks of masonry, materials, and examples of technological solutions.

Figure 1 – Historical landmarks, conception and materials used in structural masonry in other countries

Types of masonry to development of this work with a family of special blocks.

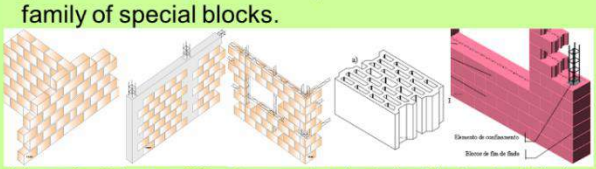

Figure 2 – Scheme of Structures system in study with structural blocks: Simple masonry, confined masonry and reinforced masonry with prefabricated bed joint reinforcement or reinforcing steel bars with concrete infill

❑ Conception and design

Development of simple application in Excel for the design

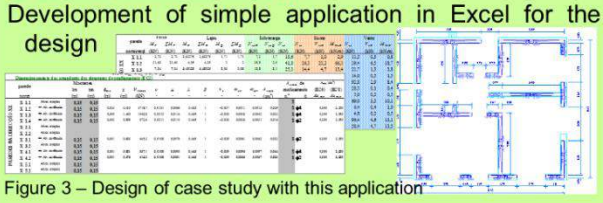

Figure 3 – Design of case study with this application

Basis definitions for the development of simple design software to structural analysis

❑ EXPERIMENTAL RESEARCH

The new system of masonry has been evaluated in laboratory, with different tests:

Figure 4 – Evaluation of mechanical properties of materials and of masonry

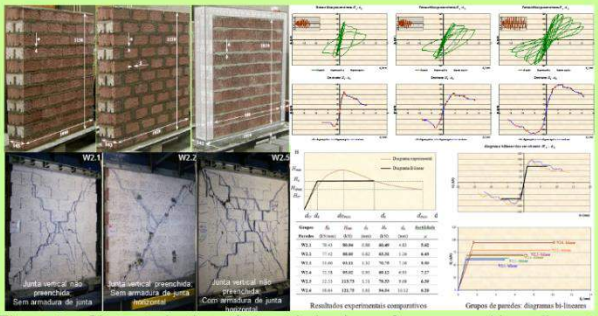

Figure 5 – Characterization of shear behaviour of masonry with cyclic tests

❑ Application in a Case Study

Case study in high seismicity zone with confined masonry system using light-weight concrete blocks

Figure 6 – Application in a Case study

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University of Minho School of Engineering

adi agência de inovação

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Projecto "SINALES – Desenvolvimento de um Sistema Industrializado para Alvenaria Estrutural"

isise Institute for Sustainability and Innovation in Structural Engineering

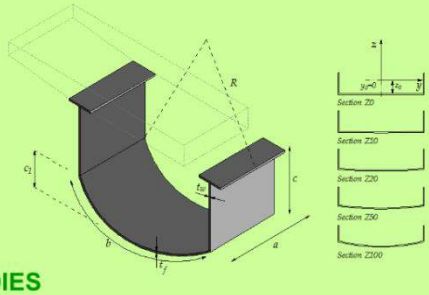
João Pedro Martins

Supervisors: Luís Simões da Silva / António Reis

BEHAVIOUR OF CYLINDRICALLY CURVED STEEL PANELS UNDER IN-PLANE STRESSES

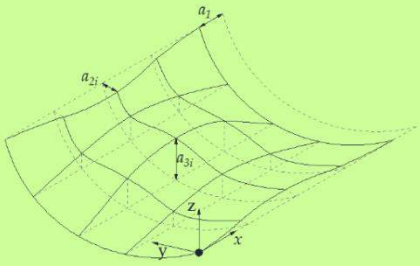
❑ SCOPE

- **The substantiation of this dissertation starts with a very simple statement: there are few design rules (in fact, there is no European standard in the framework of the Eurocodes), design recommendations/ guidelines or any other background document (at least relevant enough) allowing an accurate design of curved steel panels and sections built up with cylindrically curved steel panels in the civil & structural engineering field, namely transversally curved steel panels for structural application.**



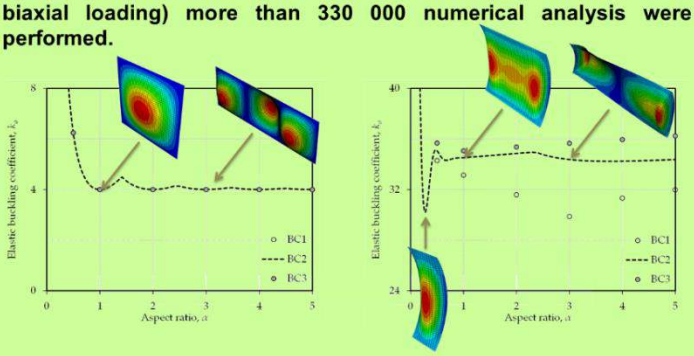
❑ ANALYTICAL STUDIES

$$k_{\sigma,\min} = 2\left[1+\frac{\sqrt{\pi^6+12\left(\pi^2-8\right)Z^2}}{\pi^3}\right]$$



❑ NUMERICAL STUDIES

- **Within the scope of 4 parametric studies (elastic critical stress and ultimate strength of curved panels under longitudinal stresses, imperfection sensitivity study of curved panels under pure compressive stresses and ultimate strength of curved panels under biaxial loading) more than 330 000 numerical analysis were performed.**

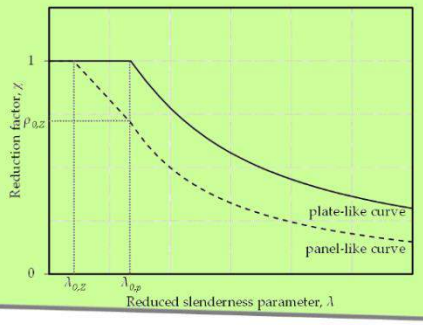


❑ NEW FORMULAE FOR COMPUTING THE ELASTIC CRITICAL STRESS AND ULTIMATE STRENGTH

$$\sigma_{cr} = k_\sigma \sigma_E = k_\sigma \frac{\pi^2 E}{12\left(1-\nu^2\right)}\left(\frac{t}{b}\right)^2$$

ψ	$1\geq\psi>0$	$0\geq\psi\geq-1$
EN1993-1-5:2006	$\frac{8.2}{1.05+\psi}$	$7.81-6.29\psi+9.78\psi^2$
New Approach	$\frac{A}{B+\psi}$ $A=a_1+a_2Z+a_3Z^2$ $B=b_1+b_2Z+b_3Z^2$	$\frac{A}{B}+C\,\psi+D\,\psi^2$ $C=d_1+d_2Z+d_3Z^2$ $D=d_1+d_2Z+d_3Z^2$

$$\begin{cases} \rho = 1 & \text{if} \quad \lambda \leq \lambda_{0,Z} \\ \rho = \dfrac{\lambda_{0,p}-\lambda+\rho_{0,Z}\left(\lambda-\lambda_{0,Z}\right)}{\lambda_{0,p}-\lambda_{0,Z}} & \text{if} \quad \lambda_{0,Z}<\lambda<\lambda_{0,p} \\ \rho = \dfrac{\overline{\lambda}-0.055a_Z(3+\psi)}{c_Z\lambda^2}+S_Z & \text{if} \quad \lambda \geq \lambda_{0,p} \end{cases}$$



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FCT Fundação para a Ciência e a Tecnologia
POPH PROGRAMA OPERACIONAL POTENCIAL HUMANO
UNIÃO EUROPEIA Fundo Social Europeu

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Jocelyn Erandi Reyes Nieto

Supervisors: Luís Simões da Silva, Vitor Murtinho and Constança Rigueiro

DEVELOPMENT OF SUSTAINABLE ALTERNATIVES TO REHABILITATE EXISTING DISTRICTS

❑ SCOPE

This PhD tries to develop sustainable solutions for inner cities neighborhoods (existing Districts) where global rehabilitation is necessary to know the shortcomings of the analyzed districts, to improve the functionality of them; to attract new inhabitants; to increase the quality of life in these neighborhoods; and to promote the concepts of: identity, collective memory, sustainability, urban spaces, green areas, cultural development, reuse and diversity of cultures inside the analyzed districts.

❑ OBJECTIVE

The main objective of this PhD is to generate two innovative concepts for rehabilitate existing districts:

- **The first one refers to a creation of a new Sustainable Assessment Methodology at the urban level, named "UISA" (Urban Integral Sustainable Assessment), which is responsible for measuring, assessing and processing information regarding to any community. Fig. 1 shows the UISA methodology configuration.**
- **The second one refers to a new model of city management on the basis of centralized street and sustainable infrastructures (such as community parking, community production and storage of renewable energies, community agriculture, etc.) by developing a reusable multi-purpose infrastructure building in steel that provides all of these functions. Fig. 2 shows the modular system dimensions of the multi-purpose building.**

To have a better idea of how these two sustainable alternatives works, within this PhD it will be conducted 2 study cases of them.

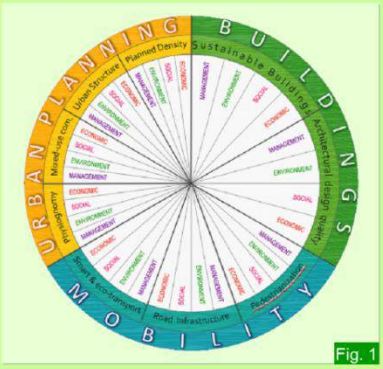
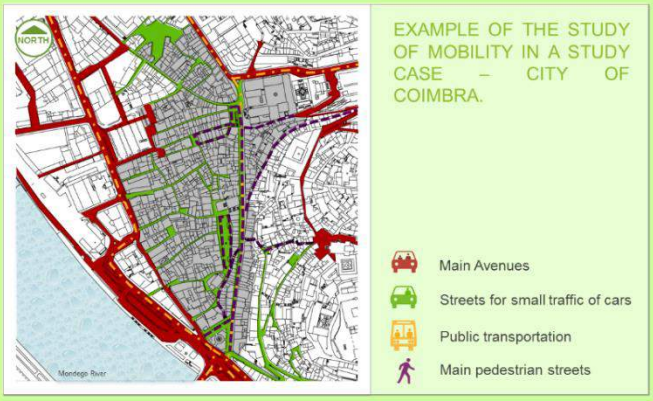


Fig. 1

Fig. 2



EXAMPLE OF THE STUDY OF MOBILITY IN A STUDY CASE – CITY OF COIMBRA.

❑ WORK PACKAGES AND TASKS

WP1 – Literature Review.
WP2 – Building Level Analysis.
WP3 – Multi-purpose Building Concept.
WP4 – Architectural Proposal.
WP5 – Urban Sustainable Assessment.
WP6 – Study Cases.

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José Conceição

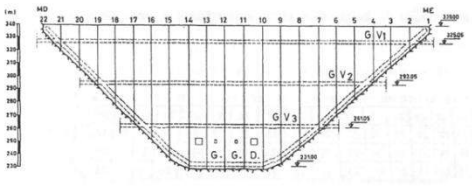
Supervisors: Rui Faria/ Miguel Azenha

ARRANGEMENT OF CONTRACTION JOINTS IN CONCRETE ARCH DAMS

❑ OBJECTIVES/ SUMMARY

- In arch dams, contraction joints are normally constructed at regular intervals of 15 m (see Fig.1). These vertical joints are very important due to shrinkage and thermal effects on mass concrete.
- For cost savings, designers try to reduce the number of joints as much as possible. However, the joints cannot be placed with a spacing greater than 15 or 20 m at the bottom part of the dam.
- An alternative method was applied in Vellón, Las Portas and Funcho arch dams (see Fig. 2). In this method, at arch crown the spacing between the joints can reach as high as 30 to 40m by stopping every second joint with an upstream/downstream gallery.
- The main objective of this research is to develop a contraction joint arrangement for an arch dam (see Fig. 3), based on the alternative method previously mentioned, in order to improve the monolithic behaviour and to optimize the construction plan.
- Additionally, this work intends to analyze the early-age behaviour of a large arch dam during construction.

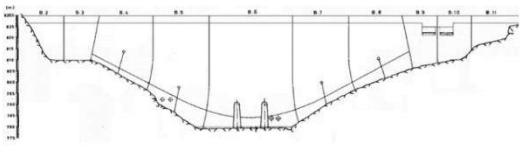
Conventional construction method



Alto Lindoso Dam - Downstream view

Fig. 1

Alternative construction method



El Vellón dam - Downstream view

Fig. 2

Case study (3D layout)

Plan view

Downstream view

Fig. 3

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José Granja

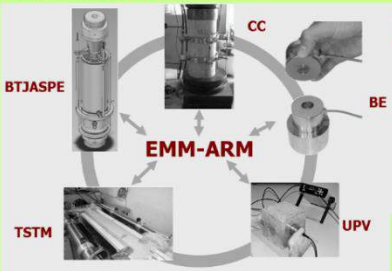
Supervisor: Miguel Azenha

CONTINUOUS CHARACTERIZATION OF STIFFNESS OF CEMENT-BASED MATERIALS: EXPERIMENTAL ANALYSIS AND MICRO-MECHANICS MODELING

❑ SCOPE OF THE WORK

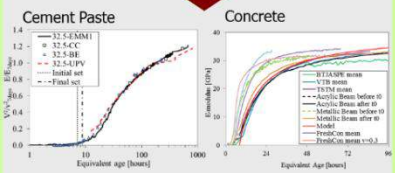
- Comprehensive validation of the methodology termed "Elasticity Modulus Monitoring through Ambient Response Method" (acronym: EMM-ARM).
- Introduce improvements to the EMM-ARM for overcoming the current limitations for systematic application in laboratory and in-situ.
- Optimization of the EMM-ARM for continuous monitoring of the modulus of elasticity of cementitious materials.
- Perform microstructural modeling of the stiffness evolution of cementitious materials by taking advantage of unprecedented quantitative experimental data that it will be possible to accumulate through the application of the EMM-ARM methodology.

❑ VALIDATION



To validate the methodology is necessary to:

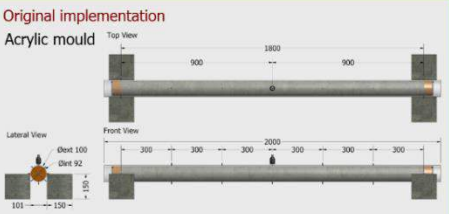
- Compare with other methodologies;
- Verify the robustness;
- Test the repeatability;
- Test the reproducibility.



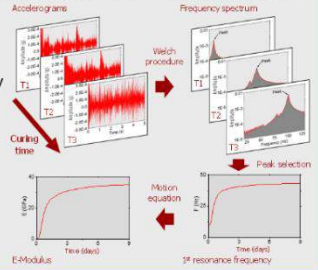
❑ OPTIMIZATION OF THE TESTING MOULD

Study and optimization of specimen geometry to increase the robustness and the reusability and to reduce the cost of each test.

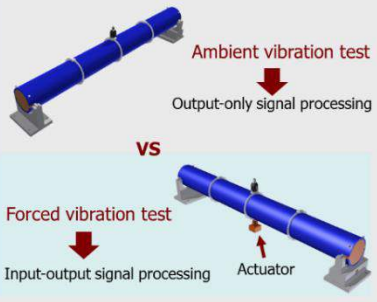
❑ EMM-ARM METHODOLOGY

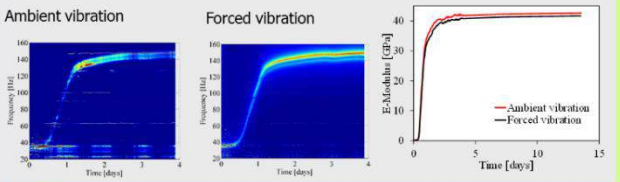


The EMM-ARM is a method that allows the automatic and continuous evaluation of the E-Modulus of cement based materials immediately after casting. This methodology is based on continuous modal identification of the first flexural resonant frequency of a composite beam. This beam is then placed horizontally, simply supported at both extremities, and vertical accelerations resulting from ambient vibration are measured at mid-span.

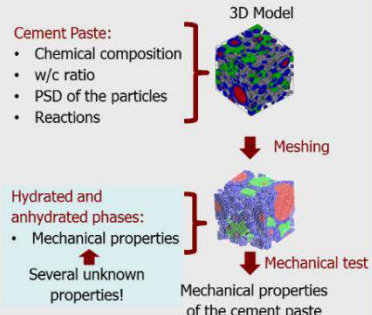


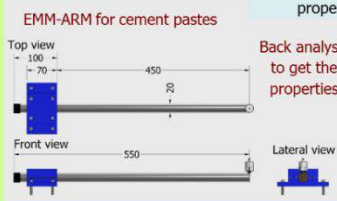
❑ SIGNAL PROCESSING





❑ NUMERICAL SIMULATIONS





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QREN Quadro de Referência Estratégico Nacional
POPH Programa Operacional Potencial Humano
Governo da República Portuguesa
European Union
European Social Fund

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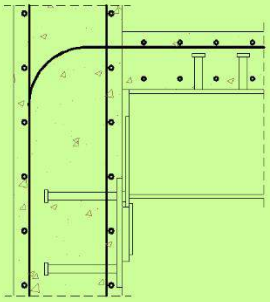
Behavior of joints: simple and efficient steel-to-concrete joints

José Henriques

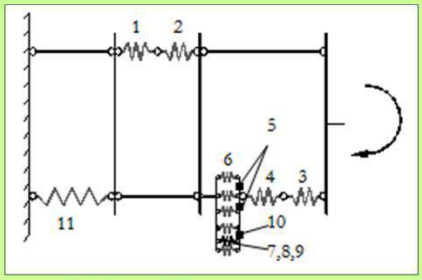
Supervisors: Luís Simões da Silva/ Isabel Valente

❑ Joint Configuration

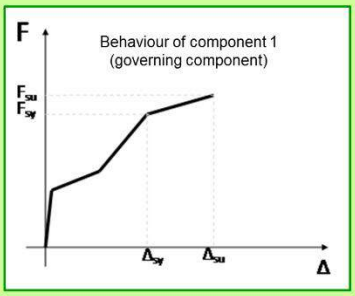
- Composite beam (IPE 300 + 16cm RC Slab) to RC Wall joint
- RC Slab and RC Wall concreting in separate stages → No Shear transfer
- Longitudinal Steel Reinforcement of Slab anchored in RC Wall
- Steel beam sits in Anchor Plate with steel bracket for shear
- Contact plate aligned with bottom flange of steel beam for compression



❑ Component model to bending moment

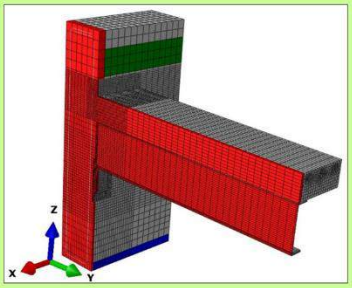


Component ID	Basic joint component
1	Longitudinal steel reinforcement bar in the slab
2	Slip of composite beam
3	Beam web and flange
4	Steel contact plate
5	Anchor plate in bending under compression
6	Concrete in compression
7	Headed anchor in tension
8	Concrete cone
9	Pull-out of anchor
10	Anchor plate in bending under tension
11	Joint link



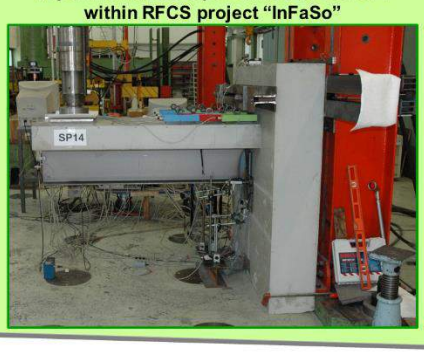
❑ Numerical model

- Finite Element Software: ABAQUS
- Type of elements: Solid (C3D8/R)
- Contact: Surface to surface contact
- Concrete Constitutive Law: Concrete Damage Plasticity
- Wall and Slab normal reinforcement model using embedment option
- Longitudinal reinforcement (component 1) – concrete interaction modelled with bond model

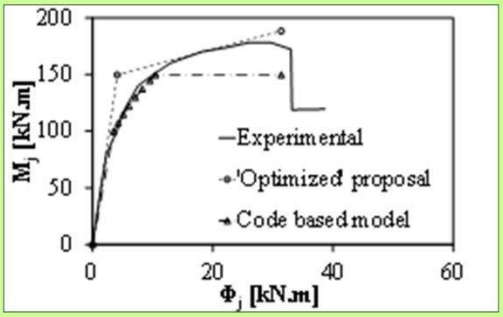


❑ Experimental validation

Experimental tests performed at USTUTT within RFCS project "InFaSo"



Comparison with experimental tests



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SUSTAINABLE STEEL CONSTRUCTION

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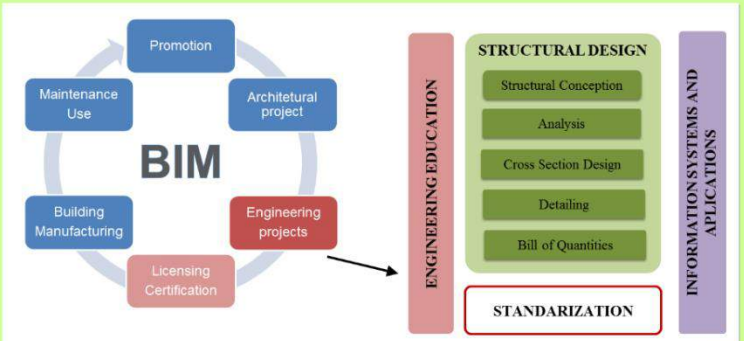
BIM's INTEGRATION INTO STRUCTURAL DESIGN: IMPLEMENTATION, STANDARDIZATION AND EDUCATION

José Carlos Lino

Supervisors: Miguel Azenha / Paulo Lourenço

❑ MAIN OBJECTIVES

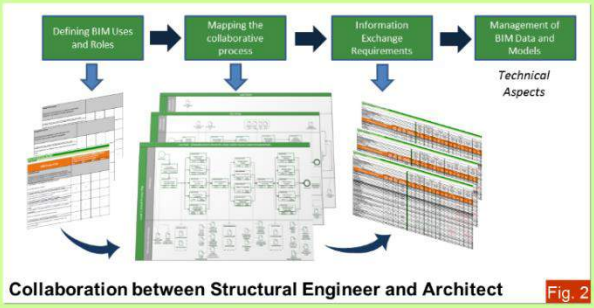
- **Main goal: To contribute to spreading and faster implementation of BIM in Portugal proposing practical procedures to the structural designer, on a collaborative way that will integrate the most recent developments on IT area.**
- **Objectives: Integrative approach during the project whole life cycle, compliance with most important standards and education of students and professionals spreading the necessary knowledge to a implement this methodology in Portugal.**



Research frame and field of study — Fig. 1

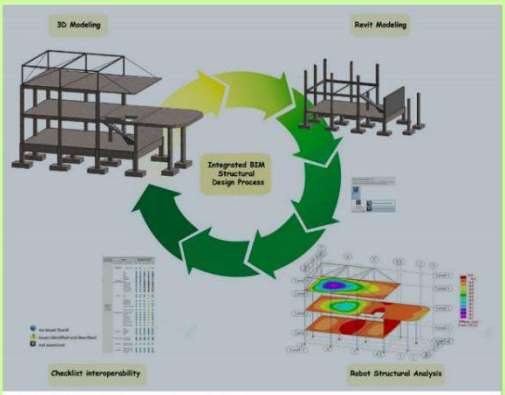
❑ MAIN TASKS: DEVELOPED WORK

- **BIM Execution Plan Proposal**



Collaboration between Structural Engineer and Architect — Fig. 2

- **Structural Design Process – BIM integration**



Workflow of structural design process — Fig. 3

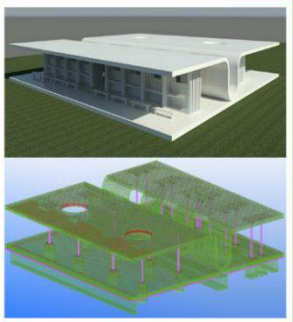
- **BIM Implementation proposal on a Structural Engineering office**

Implementation of BIM-FM Methodology and Structural Design Case Studies — Fig. 4

- **Education proposal**

Main contents:

- 1 – Introduction to BIM
- 2 – Parametric model
- 3 – Interoperability
- 4 – BIM in Architecture
- 5 – BIM in Struct. Eng.
- 6 – BIM in MEP
- 7 – BIM in Construction
- 8 – BIM Management



Educational Model — Fig. 5

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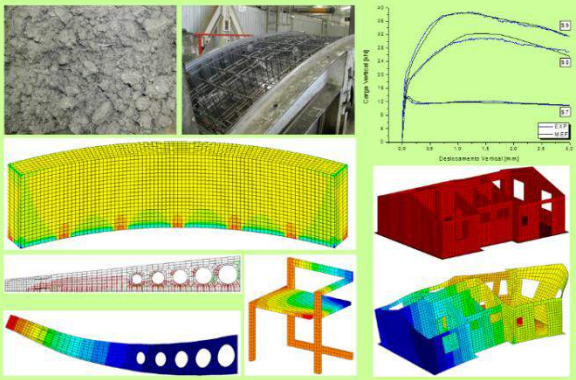
Lúcio Lourenço

Supervisor: Joaquim Barros

FRC: APPLICATIONS, INSPECTION AND STRENGTHENING TECHNIQUES FOR STRUCTURAL ELEMENTS AFFECTED BY FIRE

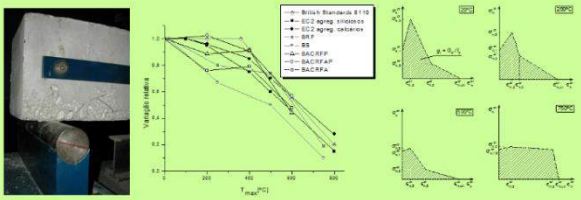
❑ FIBRE REINFORCED CONCRETE (FRC) – APPLICATIONS:

- The present work aims to contribute for the increase of the knowledge on the technology of Fibre Reinforced Concrete, FRC, the characterization of its behaviour from experimental tests, on its use of innovative structural systems and on the structural rehabilitation. In the design domain, advanced numerical tools were used in order to explore the post-cracking benefits provided by fibre reinforcement for the load carrying capacity of FRC structures. The constitutive law that simulates the fracture mode I of FRC/FRSCC was assessed from inverse analysis by using the experimental results recorded in three point notched beam bending tests, and obtaining the stress-crack width relationship from numerical simulations that fit as much as possible the experimental results.



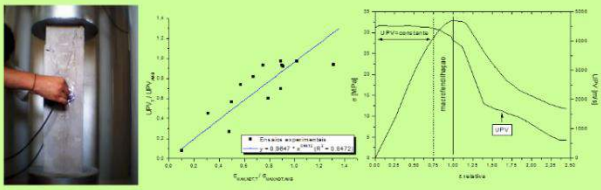
❑ FIBRE REINFORCED CONCRETE (FRC) – FIRE EXPOUSURE:

- In this work the influence of fibre addition on the relevant properties of concrete materials subjected to different level of maximum temperature of exposure was assessed by performing several experimental programs. The obtained results are the first step for reliable simulations of the material nonlinear behaviour of FRC/FRSCC structures subjected to high temperatures.



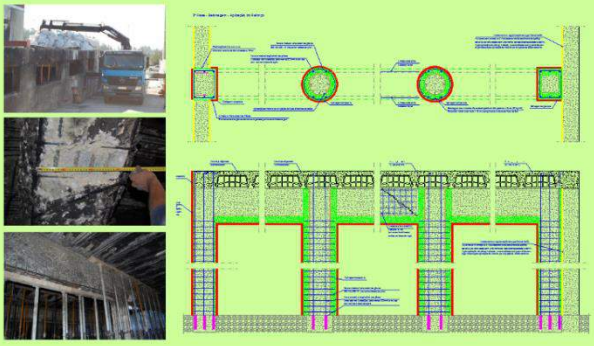
❑ INSPECTION TECHNIQUES FOR FRC STRUCTURAL ELEMENTS AFFECTED BY FIRE:

- The applicability of non destructive techniques for the assessment of the material and structural behaviour of damaged structures was also assessed. For this purpose experimental programs were carried out, and the results from non destructive techniques were compared with those obtained in conventional destructive tests in order to discuss their reliability and opportunity.



❑ STRENGTHENING TECHNIQUES:

- A methodology for the rehabilitation of a reinforced concrete building submitted to a fire was described. This methodology includes the assessment of the relevant properties of the materials constituting the structure, the load carrying capacity of the structure from load tests and advanced numerical simulations, and the use of steel-FRSCC for the increase of the load carrying capacity of the damaged structure.



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Luís Carlos Silva

Supervisors: Paulo B. Lourenço / G. Milani

HOMOGENIZED DYNAMIC ANALYSIS OF OUT-OF-PLANE LOADED MASONRY WALLS AND EVALUATION OF FRAGILITY CURVES

❑ SCOPE AND MOTIVATION

- **Natural events had caused a considerable number of disasters in the last decades. The World Bank (IEG) reported that the number of disasters increased, between 1975 and 2005, from an approximated number of 100 to more than 400 events. Earthquakes have a decisive role on this matter;**
- **Bearing the latter, vulnerability assessments have a key role for authorities, decision makers, stakeholders (*e.g.* insurance companies) and to the community itself.**

n = 100 — Natural disasters — n = 400

1975 — **Earthquakes** — 2005

Estimated +2.57±0.64 million fatalities until the end of the century

+ Cultural heritage buildings collapse (Fig. 1-3)


Fig. 1


Fig. 2


Fig. 3

❑ RESEARCH PROGRAM OBJECTIVES

- **Most collapses observed in masonry buildings after earthquakes are partial and essentially due to an insufficient out-of-plane strength and weak connections between components;**
- **The main goals of this research program are: (i) the dynamic analysis of masonry walls in two-way bending through a homogenisation approach; and (ii) the evaluation of fragility curves of structural elements (windowed panels and façades).**

❑ HOMOGENIZED DYNAMIC CODE

- **In the first phase, a homogenized dynamic code for masonry in two-way bending will be developed;**
- **It tries to fill the gap between micro- and macro-models. This strategy is based on the periodicity feature of masonry. The concept stands on the mechanical characterization of a representative volume element (RVE);**
- **The heterogeneous assemblage of mortar and units will be substituted with a fictitious homogenized material, exhibiting softening, orthotropy, low tensile strength and inelastic behaviour. In order to further improve efficiency, the walls will be discretized with rigid elements and inelastic interfaces.**

Micro-models – time consuming
suitable for small specimens
Macro-models – non-accurate failure solutions

Static Approaches

Give fast solutions
Precludes important dynamic phenomena's

Discrete Element Modelling (DEM)

Robust methods
Very time consuming for 3D problems
Random motion results are hardly objective

Homogenisation

Give fast solutions
Out-of-plane behaviour + dynamic action = **GAP**

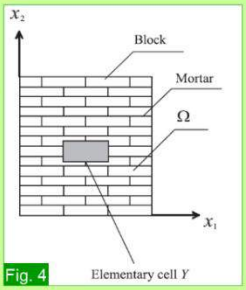

Fig. 4

- **The algorithm to use will be fully explicit, based on the well-known Newmark's approach, but extended to the Hilber-Hughes-Taylor (HHT) method to accommodate impulsive loading, when rocking occurs. The output of the code, when a prescribed accelerogram is applied to the structure, will be the displacement, velocity and acceleration history of each node, as well as the accumulated damage map on the entire structure.**

❑ EVALUATION OF FRAGILITY CURVES

- **Fragility curves will be estimated for several real scale façades applying different accelerograms within a direct Monte-Carlo sampling method of the input; focusing in particular on historical buildings and churches.**
- **Sensitivity analyses will be conducted, discussing the overall behaviour of the structure as a function of constituent material mechanical properties and texture considered at the meso-scale level, but also geometry, boundary conditions and seismic input, to calibrate the non-linear response of masonry at a structural level.**

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Institute for Sustainability and Innovation in Structural Engineering

Luís Luciano Gouveia Correia

Supervisors: José Sena Cruz / Paulo França

DURABILITY AND LONG-TERM BEHAVIOR OF RC SLABS FLEXURALLY STRENGHTENED WITH PRESTRESSED CFRP LAMINATES

❑ EXPERIMENTAL RESEARCH

- This research work program intends to contribute for the knowledge on the durability and on the short and long-term structural behaviour of reinforced concrete elements flexurally strengthened with prestressed carbon fiber reinforced polymer (CFRP) laminate strips.
- In order to achieve this goal a wide experimental program will be executed using 17 full-scale slab specimens (Fig.1) under various specific application environments, load conditions and chemical degradation.

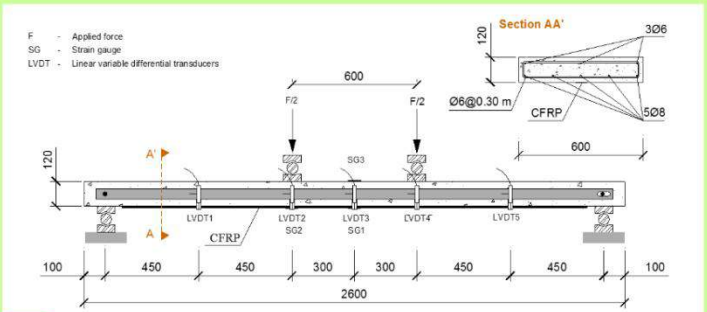
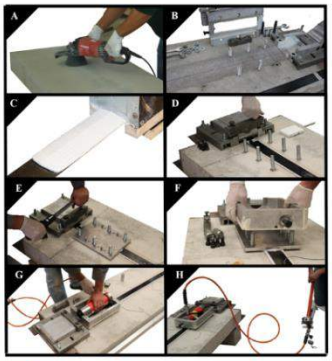


Fig. 1 Specimen's geometry and test configuration. Note: all units are in millimeters.

- The test results obtained from the experimental program will be used to predict the service life behaviour of prestressed slabs, as well as the ultimate strength supported in some numerical models. This PHD also intends to elaborate design recommendations using the results obtained in the experimental programs and derived from parametric studies performed by numeric simulations.

❑ STRENGTHENING PROCEDURES



- Firstly, the surface is prepared (A) and the anchor bolts are fixed. Then, the aluminium guides are placed in the right position to guide and fix the clamps units (B).
- The epoxy adhesive is prepared and applied to the CFRP strip (C). The clamps are closed (D) and the anchor plates are placed in the predefined location (E).
- The aluminium frames are placed on top of the anchor plates (F) in order to accommodate the hydraulic cylinder (G). Finally the prestress is applied with a manual hydraulic pump (H).

Fig. 2 Prestress procedure of the CFRP strip.

❑ OVERVIEW

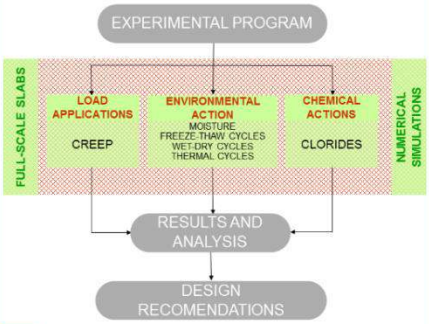


Fig. 3 Overview of the experimental program.

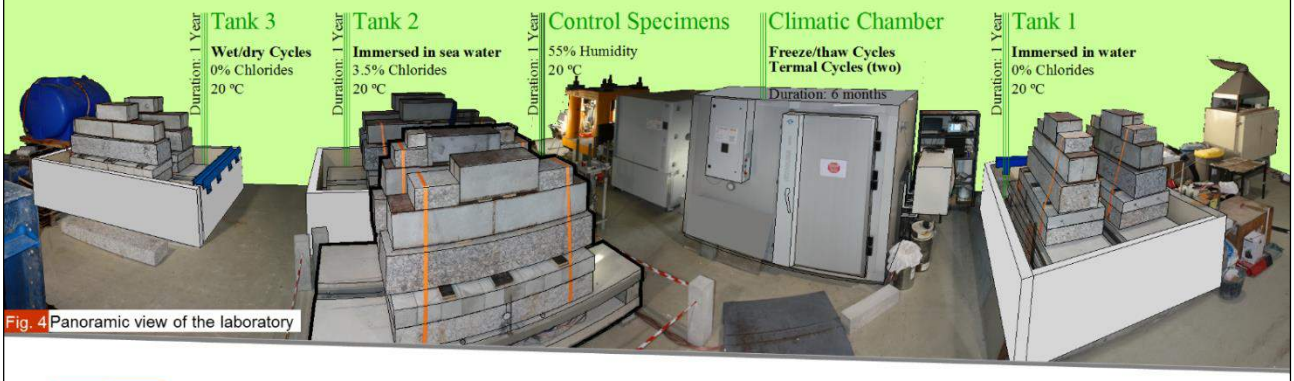


Fig. 4 Panoramic view of the laboratory

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COMPETE

QREN Quadro de Referência Estratégico Nacional

Institute for Sustainability and Innovation in Structural Engineering

Luís Miguel Silva

Supervisors: Paulo Lourenço / Graça Vasconcelos

INNOVATIVE SYSTEMS FOR EARTHQUAKE RESISTANT MASONRY ENCLOSURES IN RC BUILDINGS

❑ INTRODUCTION

The study of masonry enclosures walls is a current topic of study. In the past the investigation in this topic was unable to produce solutions, with appropriate behaviour to earthquakes and clear design rules to include in European design codes.

The recent earthquakes in Lefkada (Greece, 2003, Mw = 6.2), L'Aquila (Italy, 2009, Mw = 6.3), Van (Turkey, 2011, Mw = 7.1) and Emilia Romagna (Italy 2012, Mw = 6.0), among others, have shown that the behaviour of this type of walls, it is not appropriate, existing different situations of collapse, in-plane and out-of-plane, with loss of life and huge economic losses for repairs and replacements.

This work program aim to study experimental and numerically, new systems for masonry infill walls, which combine simplicity with low cost, and propose recommendations and calculation procedures for the design of this type of walls, filling an existing gap in current regulations.

❑ OBJECTIVES

The main objectives of this work program are:

- Developing new systems for construction of masonry infill walls;
- Validate their behaviour experimentally and numerically;
- Providing recommendations for improve the construction technology in this type of walls;
- Provide design recommendations for seismic actions to prevent excessive damage and the fragile collapse of the walls.

❑ METHODOLOGY

To accomplish the objectives were proposed two masonry infill systems (Fig.1) (Fig.2), which will be subject to experimental and numerical validation.

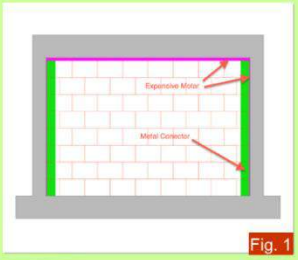

Fig. 1

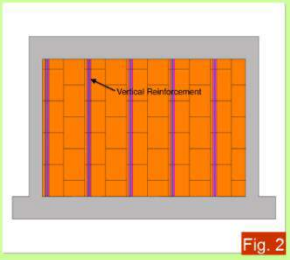

Fig. 2

▪ Experimental program

After the solutions defined, its behaviour will be studied experimentally for cyclic actions in-plane and for out-of-plane. For this will be used reduced scale frames using the test set-up as shown in Fig 3 and Fig. 4.

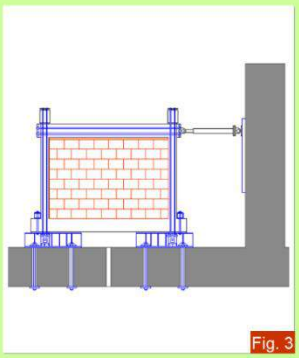
Fig. 3

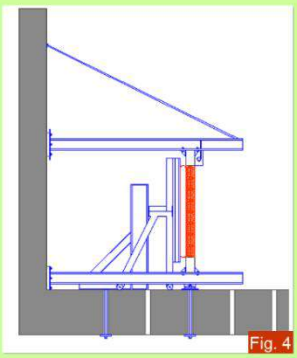
Fig. 4

In addition to these tests, experimental tests will also be performed to characterize the materials to obtain the mechanical properties of the materials. Tests will also be carried out for the characterization of the constitutive behaviour of masonry.

▪ Numerical analyses

This task aims to define strategies for modelling of reinforced concrete frames filled with masonry and will be held in two phases:

- Calibration of a finite element model (micro-modelling), based on experimental results and parametric analysis for a better understanding of the stress and deformation mechanisms designed to seismic action.
- Macro-modelling of reinforced concrete frame structures (modelling masonry infills using diagonal struts) when subjected to an earthquake, to evaluate the influence of the overall response of the structure on the local response of masonry infill walls.

This study will be extended to the nonlinear regime, to define how the structures behave based on the non-linear behaviour of the materials with the introduction of constitutive laws which define the walls non-linear behaviour when subjected to cyclic loads.

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Mahsa Taheri

Supervisor: Prof. Joaquim Barros

EVALUATION OF THE EFFECT OF FIBERS ON FLEXURAL RESPONSE OF R/FRC BEAMS

❑ MOTIVATION

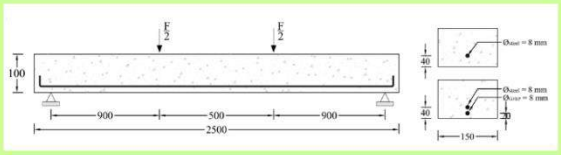
Evaluating the efficiency of steel fibers on load carrying capacity and crack spacing of beams reinforced with steel or steel/GFRP bars (R/FRC beam) failing in bending.

❑ MATERIAL PROPERTIES OF SFRSCC

Three series of steel fibre reinforced self-compacting (SFRSCC) reinforced with 45, 60, and 90 kg/m3 volumes of fibers, were utilized in three different concrete strength classes.

Mechanical properties of the used SFRSCCs			
SFRSCC	*f cc* (MPa)	*fct* (MPa)	*Ec* (GPa)
FRC45	12.74	0.85	23.3
FRC60	23.58	1.87	28.6
FRC90	43.99	3.27	35.2

Experimental specimens			
Beams series	Number of samples	Long. Steel bar	Long. GFRP bar
BS-FRC45	3	1Ø8 mm	-
BS-FRC60	3	1Ø8 mm	-
BS-FRC90	3	1Ø8 mm	-
BSG-FRC45	3	1Ø8 mm	1Ø8 mm
BSG-FRC60	3	1Ø8 mm	1Ø8 mm
BSG-FRC90	3	1Ø8 mm	1Ø8 mm

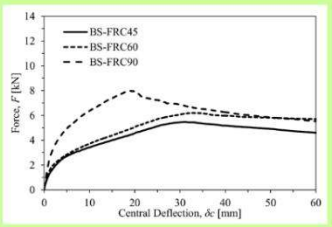


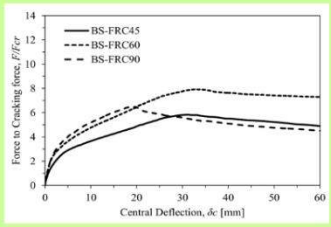
BEAMS' GEOMETRY

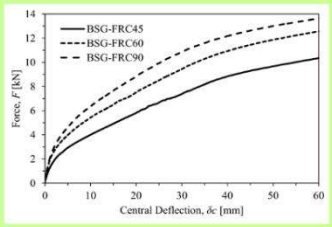
❑ TEST SETUP

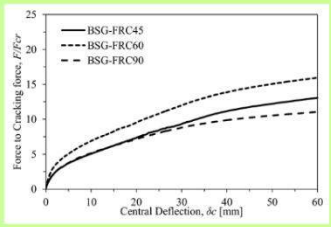
FOUR-POINT LOAD CONFIGURATION

❑ TEST RESULTS









Average crack spacing of BS series (mm)				
	pure bending length		Total length of beam	
SFRSCC	Bottom level	Steel level	Bottom level	Steel level
BS-FRC45	48.51	58.44	58.57	66.28
BS-FRC60	57.93	58.02	61.64	65.45
BS-FRC90	49.95	55.15	55.59	62.95

Average crack spacing of BSG series (mm)						
	pure bending length			Total length of beam		
SFRSCC	Bottom level	GFRP level	Steel level	Bottom level	GFRP level	Steel level
FRC45	56.56	50.72	54.19	64.11	62.12	64.44
FRC60	46.00	48.71	54.73	54.10	55.81	60.29
FRC90	50.60	47.41	48.44	55.19	53.18	57.38

❑ CONCLUSION

- **Addition of fibres in the both BS60 and BGS60 had higher impact on increasing the F/Fcr ratio when compared to the beams made by FRC45 and FRC90.**
- **The average spacing of flexural cracks is generally decreased with increasing the volume friction of fibres.**

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DEVELOPMENT OF AN INTELLIGENT EARTHWORK OPTIMIZATION SYSTEM

Manuel Afonso Parente

Supervisors: A. Gomes Correia / P. Cortez

❑ BACKGROUND

Earthwork tasks:

- **High costs and construction durations in transportation infrastructure projects;**
- **Involve combinations of repetitive tasks, while being strongly based on mechanical equipment;**
- **Highly susceptible to being optimized.**

Recent developments in the area of artificial intelligence enhance its use in earthwork optimization, resorting to tools such as:

- **Data mining (DM);**
- **Modern optimization (MO).**

❑ OBJECTIVES

Development of a knowledge base regarding earthwork tasks, as well as an intelligent system for decision support.

This knowledge base results of the application of DM techniques to earthwork databases, which can then be integrated with an optimizer based on MO techniques, so as to allow for a proper modelling of real problems.

In this framework, the expected outcome consists of an intelligent optimization system for selection and allocation of mechanical equipment in an earthwork construction, both in design and in construction phases.

❑OPTIMIZATION SYSTEM

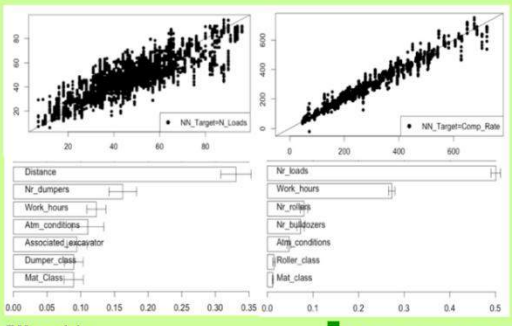
Spatial Module

Tool: Geographic information system

- Georeferencing capabilities;
- Possibility of integration with GPS;
- Optimization of transportation routes.

Routing optimization in earthwork construction site

Equipment Module



DM models

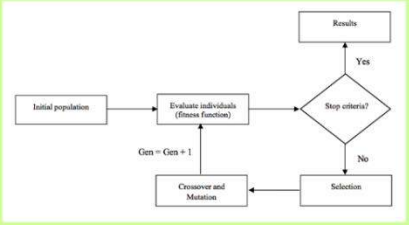
Tool: Data Mining

- Database concerning equipment specifications;
- Capabilities regarding parameter estimation (e.g., equipment productivity);

✓Model of construction site;
✓Determination of shortest routes for transportation equipment.

✓Equipment direct and indirect costs;
✓Estimates of equipment productivity values.

Optimization Module



Tool: Modern Optimization

- Robust search of solutions within reasonable time and computational effort;
- Optimization capabilities and flexibility to deal with dynamic and complex environments (i.e., earthworks).

Genetic algorithm

System output:

✓Selection of best equipment plant for optimal execution of earthwork construction project;
✓Optimal distribution of mechanical equipment throughout excavation and embankment fronts, including allocation of transportation equipment, for all construction phases.

❑ CONCLUSIONS

Implementation of the system has been successfully achieved, including validation with real construction data from a Portuguese construction site.

The project is presently in its last stages, consisting of preparation of final report and thesis.

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Maria Giovanna Masciotta

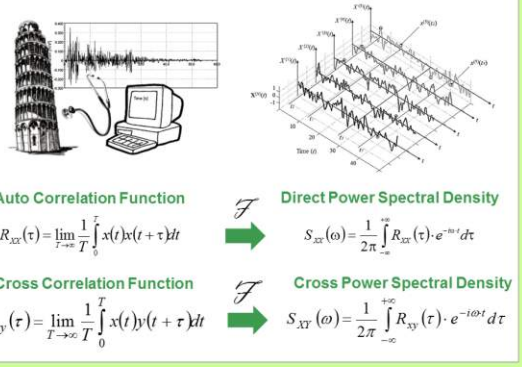
Supervisors: Paulo Lourenço / Luís Ramos

DAMAGE IDENTIFICATION OF STRUCTURES BASED ON SPECTRAL OUTPUT SIGNALS

❑ SCOPE & FOCUS OF THE RESEARCH

- The present study focuses on upgraded spectral analysis methods for early-stage damage identification of structures.
- The primary aim of the work is the development and evaluation of a damage localization spectral index based on a robust formulation, insensitive to user choices, suitable for output-only identification techniques as well as input-output identification techniques and applicable to any type of structure.

Step 1. Output signals acquisition and spectral densities estimation



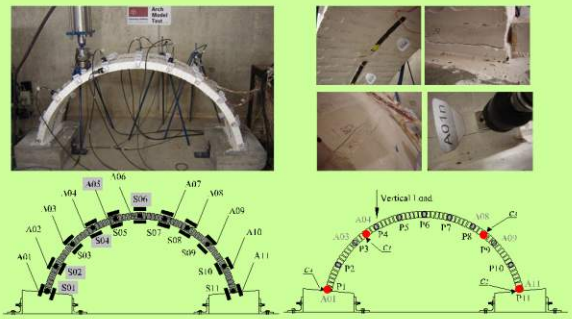
Auto Correlation Function $R_{XX}(\tau)=\lim_{T\to\infty}\frac{1}{T}\int_0^T x(t)x(t+\tau)dt$ → Direct Power Spectral Density $S_{XX}(\omega)=\frac{1}{2\pi}\int_{-\infty}^{+\infty}R_{XX}(\tau)\cdot e^{-i\omega\tau}d\tau$

Cross Correlation Function $R_{xy}(\tau)=\lim_{T\to\infty}\frac{1}{T}\int_0^T x(t)y(t+\tau)dt$ → Cross Power Spectral Density $S_{XY}(\omega)=\frac{1}{2\pi}\int_{-\infty}^{+\infty}R_{xy}(\tau)\cdot e^{-i\omega t}d\tau$

❑ APPLICATION TO A MASONRY ARCH

- The method is validated through the comparison of the results predicted by the spectral damage analysis with the ones obtained in experimental campaigns. One of the applications is presented hereafter.

TEST SETUPS



CRACK PATTERN

- The method stems from the consideration that changes in the structural stiffness caused by evolutionary damage scenarios are reflected by changes in the response power spectral density (PSD) matrix of the system. Given two structural scenarios (i.e. undamaged and damaged), the analysis of their spectral properties performed through the eigenvalue decomposition of both response PSD matrices can lead to detect and locate the damage. The spectral procedure can be summarized in three main steps.

Step 2. Eigenvalue decomposition of the output power spectrum matrix

$$\mathbf{S}_X(\omega)=\begin{bmatrix} S_{X_1X_1}(\omega) & S_{X_1X_2}(\omega) & \dots & S_{X_1X_n}(\omega) \\ S_{X_2X_1}(\omega) & S_{X_2X_2}(\omega) & \dots & S_{X_2X_n}(\omega) \\ \vdots & \vdots & \ddots & \vdots \\ S_{X_nX_1}(\omega) & S_{X_nX_2}(\omega) & \dots & S_{X_nX_n}(\omega) \end{bmatrix}$$

$$\mathbf{S}_X(\omega)=\Psi_X(\omega)\Lambda_X(\omega)\Psi_X^H(\omega)$$

Eigenvalues Matrix $\Lambda_X(\omega)=diag\{\lambda_1,\lambda_2,\dots,\lambda_j,\dots,\lambda_n\}$

Eigenvectors Matrix $\Psi_X(\omega)=[\psi_1\ \psi_2\ \dots\ \psi_j\ \dots\ \psi_n]$

λ_n Vibration mode energy

Ψ_n Mode shape estimation

Step 3. Computation of the damage localization spectral index

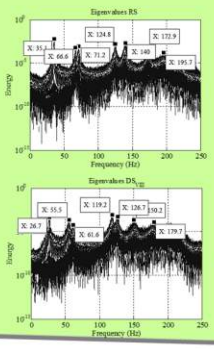
$$\Delta\psi=\sum_{j=1}^{n}\left|\sum_{i=1}^{m}\left[\psi_j^d(\omega_i)\cdot\sqrt{\lambda_j^d(\omega_i)}\right]-\sum_{i=1}^{m}\left[\psi_j^u(\omega_i)\cdot\sqrt{\lambda_j^u(\omega_i)}\right]\right|$$

Number of Modes; Frequency Range

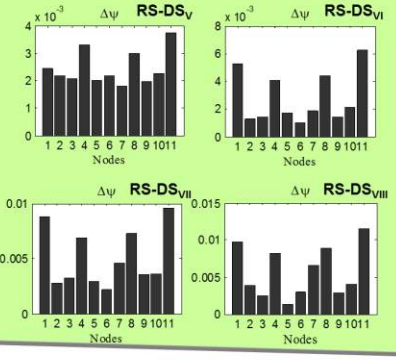
Spectral Mode Damage Scenario; Spectral Mode Reference Scenario

- The eigenvalues shifts warn of the presence of damage, whereas the spectral index identifies the damage position.

EIGENVALUES PLOTTING



SPECTRAL INDEX RESULTS



FCTUC FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE DE COIMBRA

University of Minho School of Engineering

Institute for Sustainability and Innovation in Structural Engineering

Maria Lurdes Martins

Supervisors: Graça Vasconcelos / Paulo B. Lourenço

EXPERIMENTAL ANALYSIS OF STONE MASONRY: THE LABORATORY CHARACTERIZATION TO THE CHARACTERIZATION IN SITU

❑ EXPERIMENTAL RESEARCH

- This work program, in the scientific domain of the structure of masonry stone, consists in improving the knowledge about the mechanical and physical properties of stone masonry structures, and its behavior face the acting of vertical, in plane and out plane actions. The approach followed will encompass experimental work associated with laboratory tests.
- The vernacular heritage is a symbol of the cultural and historical values. It is important to preserve the stone of these buildings to harmful environment conditions like freeze-thaw cycles and salt crystallization. For this, an experimental campaign of freeze-thaw and salt cycles were made.

❑ RESISTANCE TESTS: FREZE AND THAW CYCLES AND SALT CRYSTALLIZATION

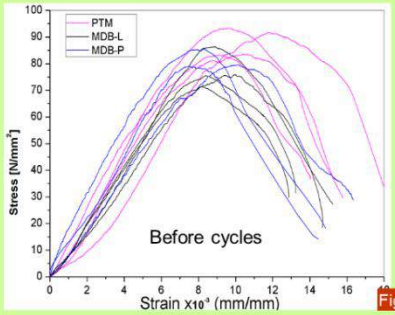
- The study of the influence of the freeze and thaw cycles (Figure 1))and the salt crystallization (Figure 2) on the physical and mechanical properties of the granite were developed.

Fig. 1

Fig. 2

❑ RESULTS

- The analysis of the damage progress resulting from the freeze-thawing and salt cycles is made based on the standard damage indexes and the variation of the ultrasonic pulse velocity and physical (Figure 3) and mechanical properties (Figure 4).
- The variation of the granite properties with the test of salt crystallization is show in Table.



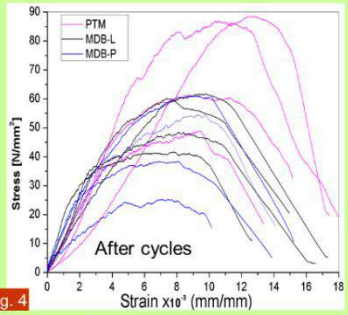
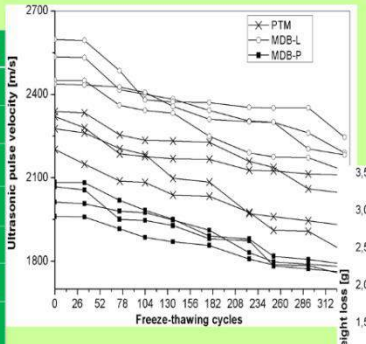


Fig. 4

	Before salt	After salt
Weight lost (gr)	0	5.1
UPV (m/s)	1551	1201
Dynamic modulus of elasticity (MPa)	5881	3372
Coef. capillary absorption (g/cm²h$^{1/2}$)	0.240	0.339
Absorption by immersion (%)	1.84	2.43
Porosity (%)	4.58	5.89
Compressive strength (N/mm²)	39.43	32.88
Modulus of elasticity (N/mm)	3061	1943



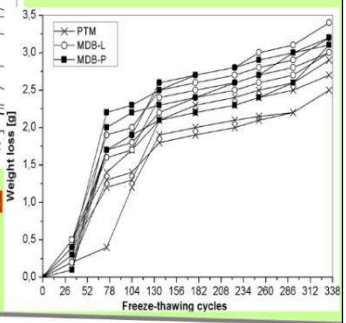


Fig. 3

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BOND BEHAVIOR OF FRP NSM SYSTEMS IN CONCRETE

Mário Rui Freitas Coelho

Supervisors: José Sena Cruz / Luís Neves

❑ THESIS OBJECTIVE

- **Development of a design methodology for the bond behavior of concrete structures strengthened with fiber reinforced polymers (FRP) using the Near-Surface Mounted (NSM) strengthening technique.**

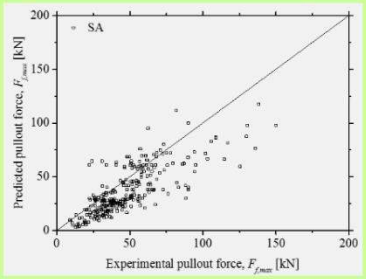
❑ BIBLIOGRAPHIC COMPONENT

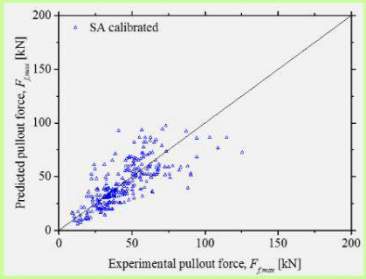
- **Compilation of the available works on FRP NSM systems, focusing: (i) experimental bond tests; (ii) proposal of analytical models; (iii) use of numerical models to study the bond behavior in FRP NSM systems in concrete.**
- **A data-base-web-tool was built in order to gather in a single place the bond tests collected. Already includes 363 Direct and 68 Beam Pullout Tests. Allows registered Users to apply the design formulations of ACI 440.2R-08 and SA HB305-08, as well as, formulations based on data mining (DM) algorithms.**

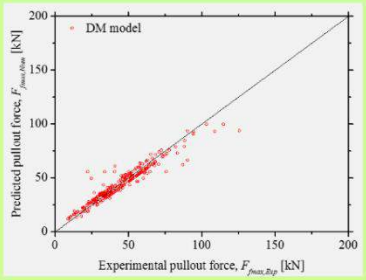
Available at www.bfn.civil.uminho.pt

❑ ANALYTICAL COMPONENT

- **ACI and SA guidelines' formulations: accuracy evaluation, recalibration and using DM models adopting the same input variables as the corresponding guidelines.**



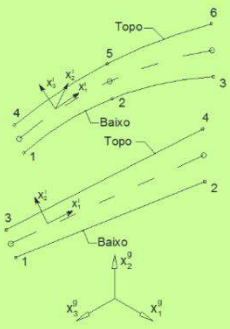




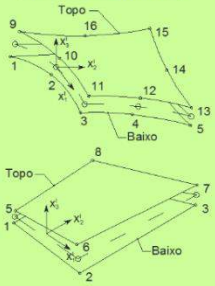
❑ NUMERICAL COMPONENT

- **Implementation in FEMIX 4.0 software of a constitutive model for zero-thickness interface elements. The model is based on the theory of plasticity, allows 2D and 3D nonlinear FEM simulations considering fracture modes I and II.**

Interface Line 2D/3D

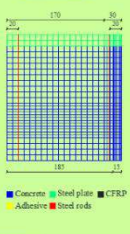


Interface Surface

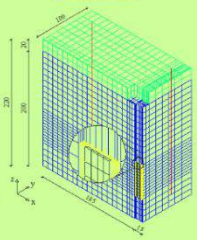


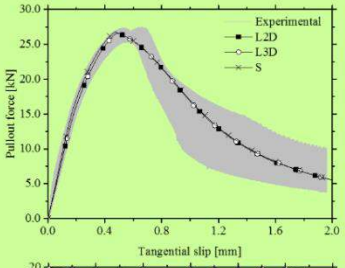
Direct Pullout test

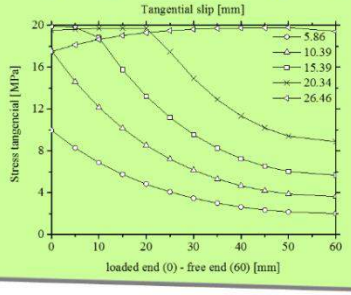
FEM 2D



FEM 3D







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Institute for Sustainability and Innovation in Structural Engineering

Marisa Mota Pinheiro

Supervisor: Tiago Miranda

INTEGRATED METHODOLOGY TO CHARACTERIZE HETEROGENEOUS ROCK MASSES

❑ OBJECTIVE

This work program, in the scientific domain of Geomechanics and Geotechnical Engineering, consists in the development of an integrated methodology to characterize the rock masses with explicit representation of their heterogeneities. The goal is to simulate the geomechanical parameters of the rock mass using Geostatistical techniques.

❑ METHODOLOGY

Using the results of geotechnical surveys and *in situ* tests it is possible to build a 2D or 3D model with explicit representation of geomechanical heterogeneities of the rock mass. The simulated parameters were the most common empirical systems in geomechanics, namely the *RMR* (Bieniawski, 1989), the *Q* (Barton, 1974) and *GSI* (Hoek et al.,1995) combined with the *in situ* data.

To define the best methodology (Fig.1) to use in the parameters simulation of the RMR_{basic} system was considered two different approaches (Fig.2).

- Approach 1: RMR_{basic} value simulation as a continuous variable.
- Approach 2: individual simulation of all 5 parameters assigned with their ratings as categorical variables;

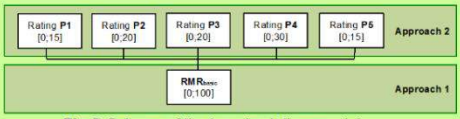

Fig.2. Scheme of the two simulations models.

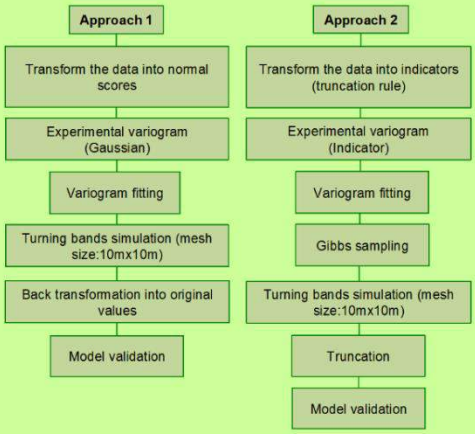

Fig.1. Adopted methodology to simulate Approach 1 and Approach 2.

❑ RESULTS

The proposed methodology was applied to a cavern in the Salamonde II Portuguese dam, located in the north of Portugal. In the geostatistical a total of 154 samples was used to simulate a 3D grid with a mesh size of of 2 x 2 x 1 m *for X, Y* and *Z* directions. The Turning Bands method combining with the Ordinary type of Kriging was the one used to perform the 100 simulation of this rock mass. An example of a realization for RMR_{basic} and *Q* is shown in Fig.3 and Fig.4, respectively.

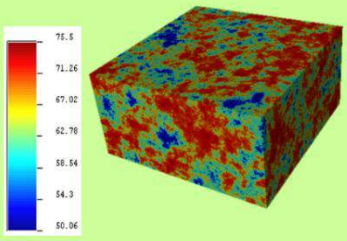

Fig.3. RMR_{basic} geostatistical simulation.

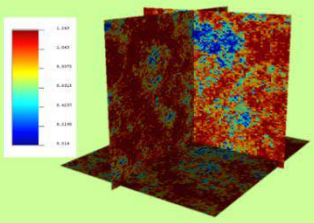

Fig.4. Q geostatistical simulation.

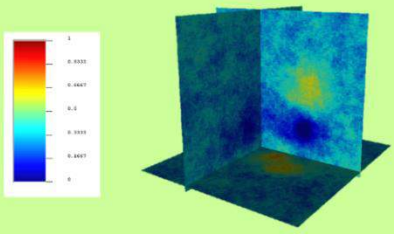

Fig.5. Probability map for RMR_{basic} higher than 70 (0 to 1).

A probability map can also be obtained for the RMR_{basic} reflecting the frequency of a threshold exceedance or non-exceedance observed over the realizations. This representation is of great value if one wants to identify regions where very high or low geomechanical properties would be present, and with which probability. As an example, the map shows the probability that the actual (unknown) RMR_{basic} exceeds a threshold of 70 is shown in Fig.5.

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A MULTI-PHYSICS APPROACH APPLIED IN MASONRY STRUCTURES BASED IN NON-HYDRAULIC LIME

isise Institute for Sustainability and Innovation in Structural Engineering

Mateus A. Oliveira

Supervisors: Paulo Lourenço / Miguel Azenha

KEYWORDS

Historical constructions, masonry, aerial lime, carbonation, numerical simulation, experiments and multi-physics problems

INTRODUCTION AND OBJECTIVES

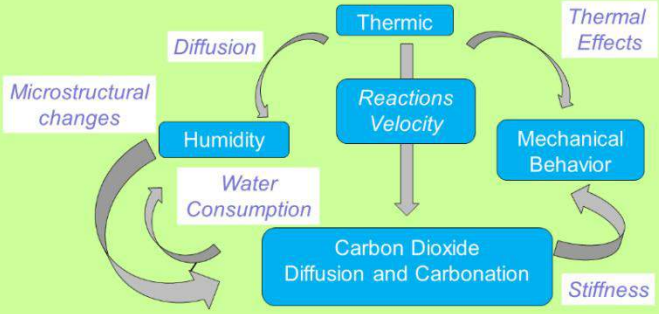
This PhD project aims to establish a multi-physics approach with numerical simulations a experiments to study the structural behavior of historic buildings comprised of masonry with non-hydraulic lime.

Coupled Model (Multi-physics)
Complex behavior

Model 1D/2D
Finite Difference Method

Model 3D
Finite Element Method

Experiments



• Moisture field

Drying process
Humidity diffusion
Interaction with other fields

$$\frac{\partial h}{\partial t} = \nabla \cdot (C\,\nabla h) + \alpha_2 \frac{\partial \Re}{\partial t}$$

• Carbon dioxide field

Diffusion process
Carbonation
Interaction with other fields

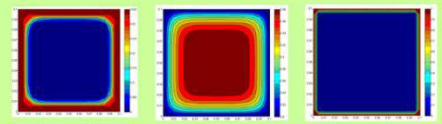
$$\frac{\partial c}{\partial t} = \nabla \cdot (D_c \nabla_c) - \alpha_3 \frac{\partial \Re}{\partial t}$$

• Reaction field

Carbonation depth

$$\frac{B\Re}{Bt} = v = \alpha_4 \cdot f_1(h) \cdot f_2(c) \cdot f_3(\Re) \cdot f_4(T)$$

• Example of results 2D - FDM code



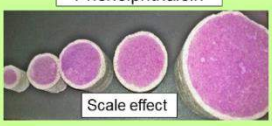
Carbon dioxide *Humidity* *Reaction*

• Experimental Campaign

Several tests were done to characterize the mortar behavior

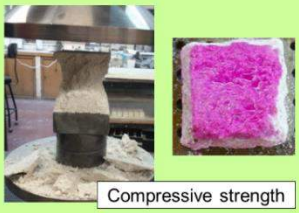
Humidity profile

Phenolphthalein

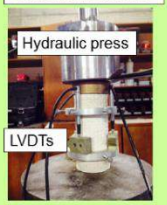


TGA discs

TGA + Phenolphthalein



Elastic modulus



• Mechanical behavior - Axisymmetric condition
Matlab ® + Experiments + TNO Diana®

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CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

Institute for Sustainability and Innovation in Structural Engineering

Matteo Breveglieri

Supervisors: Joaquim Barros / Alessandra Aprile

SHEAR STRENGTHENING OF RC BEAMS USING THE EMBEDDED THROUGH-SECTION TECHNIQUE

❑ EXPERIMENTAL RESEARCH

The Embedded Through-Section (ETS) technique is a promising technique for the shear strengthening of existing RC elements. According to this technique, holes are drilled through the beam section, and bars of steel or FRP material are introduced into these holes and bonded to the concrete with adhesive materials. An experimental program was carried out with RC T-cross section beams strengthened in shear using the ETS steel bars and ETS CFRP rods (Figs. 1 and 2). The research was focused on the evaluation of the ETS efficiency on beams with different percentage of existing internal transverse reinforcement (ρ_{sw}=0.0, 0.1, 0.17%). The effectiveness of different ETS strengthening configurations was also investigated. The good bond between the strengthening ETS bars and the surrounding concrete allowed the yield initiation of the ETS steel bars and the attainment of high tensile strains in the CFPR rods, leading to significant increase of shear capacity (in the interval of 5% to 136%), whose level was strongly influenced by the inclination of the ETS bars and the percentage of internal transverse reinforcement. The strengthening configurations of the tested beams are listed in Table 1 and the load-deflection for 2S-Series is presented in Fig. 3.

Fig. 1

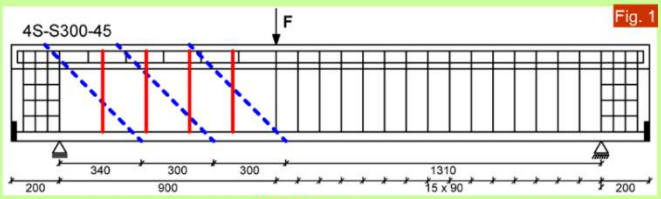


Fig. 2

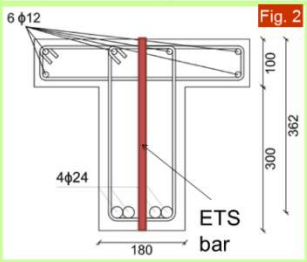


Fig. 3

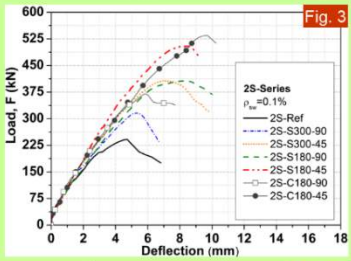


Table 1

Angle [θ_{fw}]	ETS bar spacing [s_{fw}]	ETS Reinforcing ratio [ρ_{fw}]	0S-Series	2S-Series	4S-Series
[°][a]	(mm)	[%][b]	(ρ_{sw}=0.0%)	(ρ_{sw}=0.10%)	(ρ_{sw}=0.17%)
90	300	0.15	0S-S300-90	2S-S300-90	4S-S300-90
45	300	0.21	0S-S300-45	2S-S300-45	4S-S300-45
90	180	0.24	0S-S180-90	2S-S180-90	4S-S180-90
45	180	0.34	0S-S180-45	2S-S180-45	4S-S180-45
90	180	0.16	--	2S-C180_90	4S-C180-90
45	180	0.22	--	2S-C180_45	4S-C180-45

S - steel ETS bars, C – CFRP ETS bars

Fig. 4

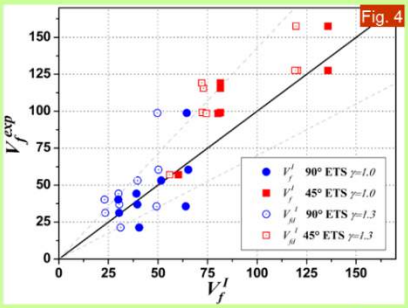
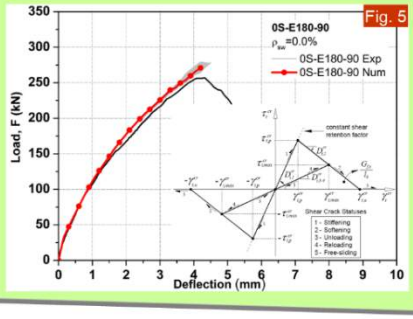


Fig. 5



❑ ANALYTICAL RESEARCH

The predicted performance of two different analytical models developed to calculate the contribution of ETS to shear resistance was assessed by using the experimental results. The first model follows an empirical approach (experimental-based approach), while the second model takes into account the physical and mechanical principles of the technique (mechanical-based approach). Fig. 4 presents the comparison between the experimental (V_f^{exp}) and analytical values ($V_f{}^{I}$). The two approaches have predicted values with similar level of accuracy, by adopting for both approaches a partial safety factor of =1.3, the shear strengthening contribution of 90% of the analyzed beams is less than the one recorded experimentally.

❑ NUMERICAL RESEARCH

An alternative strategy to the shear retention factor based on the adoption of a diagram describing the shear stress-shear strain Fig 5, for modelling the shear fracture energy diagram was investigated. The predictive performance was evaluated simulating the tested ETS strengthened beams. The parameters influencing the diagram are individually investigated and analyzed as a function of the mechanical and geometrical properties of the tested beams. A simple rule to estimate these values is provided and its predictive performance is assessed. Fig. 5 presents the comparison between the experimental and numerical load- displacement relationship for beam 0S-180-90.

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isise Institute for Sustainability and Innovation in Structural Engineering

Mohammadali Rezazadeh

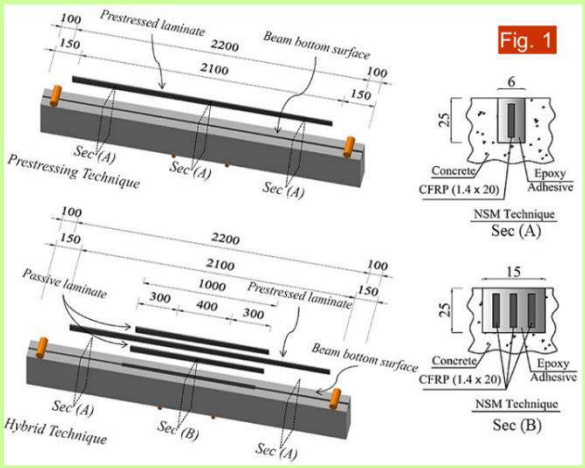
Supervisor: Prof. Joaquim Barros

INNOVATIVE METHODOLOGIES FOR THE ENHANCEMENT OF THE FLEXURAL STRENGTHENING PERFORMANCE OF NSM CFRP TECHNIQUE FOR RC BEAMS

❑ Experimental Investigation

- The main purpose of this research is to experimentally evaluate the efficiency of NSM CFRP strengthening techniques to enhance not only the load capacity at service and ultimate conditions, but also the ultimate deflection capacity when compared to the use of non-prestressed NSM CFRP technique.
- Hence, two experimental programs were organized to assess first, the influence of the prestress level on the flexural behavior of NSM CFRP strengthened beams and then, the potentialities of a new NSM hybrid methodology combining non-prestressed and prestressed CFRP laminates in the same application for the flexural strengthening of RC beams (Fig. 1).
- Moreover, the distribution of tensile strain and bond shear stress after the release of prestress force along the prestressed NSM CFRP reinforcement was experimentally evaluated.

Fig. 1



❑ Numerical Analysis

Fig. 2

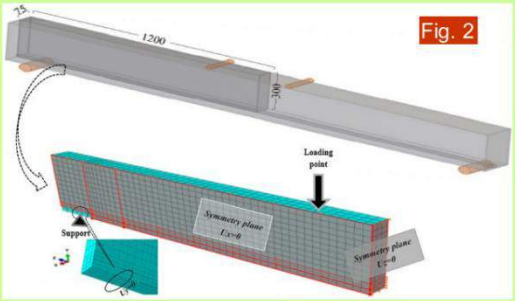


Fig. 3

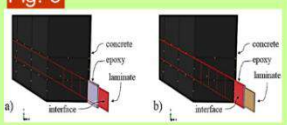
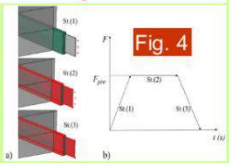


Fig. 4



- The experimental tests were simulated using a nonlinear FE model (Fig. 2), which considers:
  - a) the nonlinear behavior of the constituent materials;
  - b) the bond behavior between CFRP-epoxy adhesive and concrete-epoxy adhesive surfaces (Fig. 3);
  - c) modeling the prestress process of the CFRP elements adopted in the experimental tests (Fig. 4).

❑ Analytical Approaches

- A simplified analytical approach was proposed to predict the flexural behavior of simply supported RC beams flexurally strengthened with prestressed CFRP reinforcements using either EBR or NSM techniques.
- This design methodology also considers the ultimate flexural capacity of NSM CFRP strengthened beams when concrete cover delamination is the governing failure mode (Fig. 5).
- An analytical formulation, with a design framework, was developed for the prediction of the distribution of CFRP tensile strain and bond shear stress and, additionally, the prestress transfer length (Fig. 6).

Fig. 5

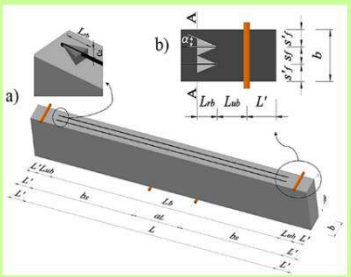
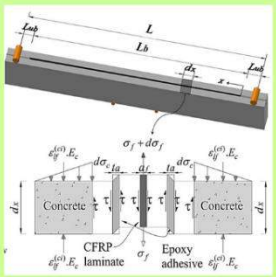


Fig. 6



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Mohammadreza Mostakhdemin Hosseini
Supervisors: Salvador Dias / Joaquim Barros

BEHAVIOR OF RC SLABS FLEXURALLY STRENGTHENED WITH PRESTRESSED NSM CFRP LAMINATES

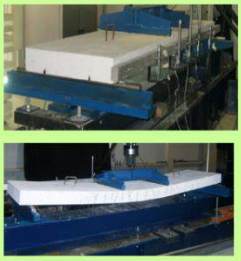
❑ Objectives

- To investigate the effectiveness of prestressed NSM CFRP laminates for the flexural strengthening of RC slabs by experimental research. To evaluate the influence of the following parameters: level of prestress; percentage of existing steel reinforcement; concrete quality; cycling load; effect of damage prior the application of the CFRP
- To define the basic procedures (guide application) to assure a rigorous quality control in all steps of CFRP application.
- To develop an analytical formulation to predict the contribution of the possible distinct prestressed NSM CFRP laminates configurations for the flexural strengthening of RC slabs.

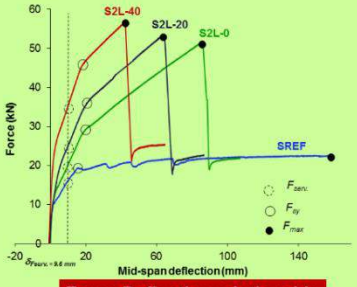
❑ Preliminary tests

- Preliminary tests for the validation of the proposal strengthening technique in RC slabs were already done that composed of the four RC slabs: a reference slab without CFRP (SREF) and three RC slabs flexurally strengthened using NSM CFRP laminates with different level of prestress: 0% (S2L-0), 20% (S2L-20) and 40% (S2L-40) of the ultimate tensile strength of the CFRP.

Application of prestress in RC slabs



Four point bending test

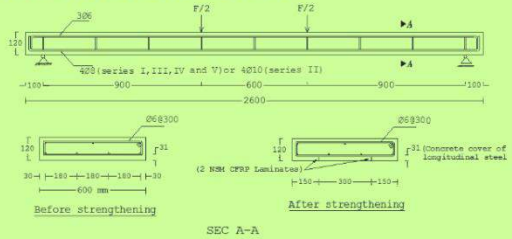


Force-Deflection relationship

- By strengthening RC slabs with prestressed NSM CFRP laminates resulted in a significant increase of load carrying capacity at serviceability and ultimate limit states. By applying 20% of prestress in the NSM CFRP laminates, the service and ultimate loads have increased, respectively, 55% and 136% when compared to the corresponding values of the reference slab, while 40% of prestress, has guaranteed an increase of 119% and 152%.

❑ Ongoing research

- To evaluate the influence of some parameters in the effectiveness of the NSM technique with prestressed CFRP laminates for the flexural strengthening of RC slabs an extensive experimental program that includes five series of RC slabs are be tested.



Geometry of the type of the RC slabs

General information about the series of RC slabs

Series	Study parameter	ρ_{sl} (%)	ρ_f (%)	Concrete class	Cyclic load	Damage
I	Prestress level	0.394 (4ϕ8)	0.077	C30/37	No	No
II	Percentage of tensile steel bar	0.623 (4ϕ10)	0.077	C30/37	No	No
III	Compressive strength of the concrete	0.394 (4ϕ8)	0.077	C16/20	No	No
IV	Level of fatigue load	0.394 (4ϕ8)	0.077	C30/37	Yes	No
V	Level of the damage	0.394 (4ϕ8)	0.077	C30/37	No	Yes

Number of specimens and level of the prestress in each series

Series	Ref	0%	20%	30%	40%	50%	Total
I	1	1	1	1	1	1	6
II	1	1	1	-	1	-	4
III	1	1	1	-	1	-	4
IV	-	2	2	-	2	-	6
V	-	2	2	-	2	-	6
Total	3	7	7	1	7	1	26

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Institute for Sustainability and Innovation in Structural Engineering

Neda H. Sadeghi

Supervisors: Daniel V. Oliveira / Mariana Correia

ADOBE VAULTED ARCHITECTURE IN THE MIDDLE EAST: CONSERVATION PRACTICE AND SAFETY ASSESSMENT

❑ MOTIVATION

- Middle East, is one of the most active seismic areas of the world, where a long series of catastrophic earthquakes have taken place. This study is focused on the earthen architecture with adobe vaults located in this region (Fig.1). Past earthquakes show that adobe vaults collapse and have caused fatalities due to their heavy weight and material brittleness.
- Since the strengthening of weak adobe architecture before earthquakes may reduce the fatalities, the loss of cultural heritage and the costs of post-earthquake repairing, a scientific and versatile safety assessment method is needed. Seismic safety of adobe-vaulted architecture should be evaluated to distinguish the need and also the degree of intervention.


Fig. 1

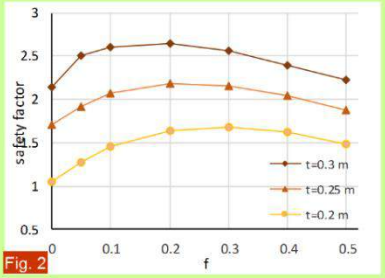

Fig. 2

❑ OBJECTIVE

- This PhD research work aims to assess the seismic safety of reinforced and unreinforced vernacular adobe vaults through conducting experimental and numerical works on the basis of conservation principles. To this end, the main objectives of this study can be categorized in three parts:

  1. Assessment the safety of adobe vaults under earthquake loading using numerical methods.

  2. Evaluation the efficiency of an appropriate intervention technique for adobe vaults based on the experimental works.

  3. Recommendations on the conservation of adobe vaults with respect to the original architectures.

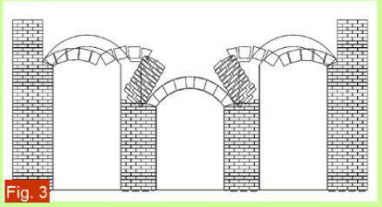
Fig. 3

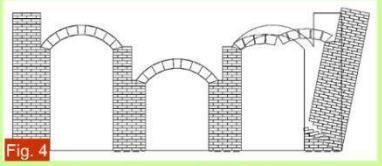
Fig. 4

❑ PLANNING OF THE RESEARCH

- Parametric numerical analysis of adobe vaults aiming at assessing their seismic safety using limit analysis theory implemented in Block2D software considering all influential parameters (Fig.2). Safety and stability of adobe-vaulted structure is evaluated under gravity loads (Fig.3) in a first step, and then under horizontal loads. (Fig.4)
- Experimental characterization of components; adobe, mortar and geotextile mesh as strengthening material.
- Experimental testing of unreinforced and reinforced adobe vaults (for strengthening of adobe vault, geogrid mesh embedded in mud plaster is used in two different ways: on extrados and on intrados of adobe vaults).
- Recommendation for seismic assessment and appropriate strengthening technique of adobe vaults in conservation process.
- A case study in order to study a vaulted architecture using both numerical tools and the conservational recommendations.

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Nelson Soares

Supervisors: José Costa/Adélio Gaspar/Paulo Santos

THERMAL ENERGY STORAGE WITH PHASE CHANGE MATERIALS (PCMS) TOWARDS BUILDINGS' ENERGY EFFICIENCY

❑ MAIN GOALS

- **To evaluate how PCMs can be used to improve the energy efficiency of different typologies of residential buildings (lightweight steel-framed and heavyweight constructions) in different climates;**
- **To develop a methodology for the dynamic simulation of energy in buildings considering the influence of latent heat loads from the phase change processes;**
- **To develop a methodology for the assessment of the heat transfer through small thermal energy storage (TES) units to be used in the design of new construction solutions.**

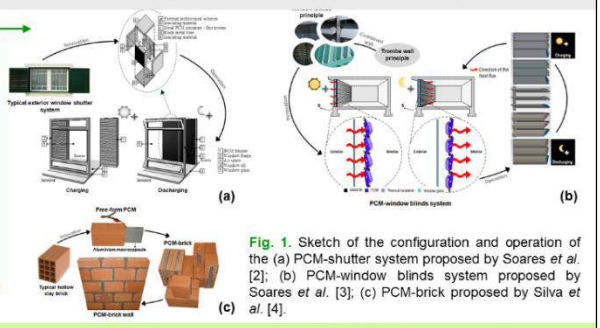

Fig. 1. Sketch of the configuration and operation of the (a) PCM-shutter system proposed by Soares *et al.* [2]; (b) PCM-window blinds system proposed by Soares *et al.* [3]; (c) PCM-brick proposed by Silva *et al.* [4].

❑ PART A – HEAT TRANSFER WITH PHASE CHANGE

❑ Experimental study of the heat transfer through a vertical stack of rectangular cavities filled with different PCMs (the free-form PCM – Rubitherm® RT 28 HC and the microencapsulated PCM – Micronal® DS 5001 X) [5].

Goals:

- To evaluate the melting and solidification processes;
- To discuss which PCM type is better for different buildings applications.

Methodology:

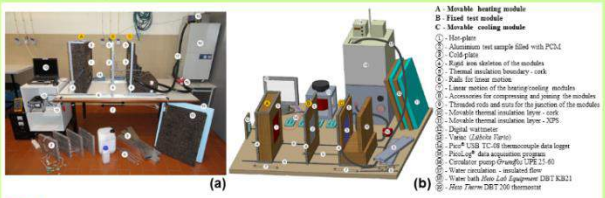

Fig. 2. (a) Photographic view and (b) 3D sketch of the experimental setup described by Soares *et al.* [5].

Results:

- Data for benchmarking and validation of numerical models;
- Assessment of the influence of natural convection and subcooling phenomena during charging and discharging.

❑ Heat transfer through small TES units filled with PCMs for vertical buildings applications: experimental and parametric analysis [6].

Goals:

- To evaluate the thermal performance of several TES units by considering 3 test samples filled with different cavity aspect ratios (*A*); 2 types of PCMs (free-form and microencapsulated PCMs); 2 input power levels during charging; and 4 temperatures of the cooling water flow during discharging.

Methodology:

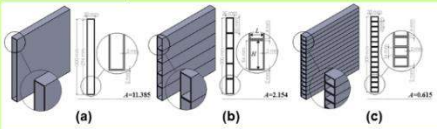

Fig. 3. Sketch of the 3 aluminum test samples used as PCM containers [6]: (a) 1 single rectangular cavity; (b) 5 cavities; (c) 15 cavities.

Results:

- The results allow discussing which arrangement is better for specific buildings applications considering the thermal regulation effect of the TES unit during charging; the influence of subcooling during discharging, and the influence of natural convection during both processes.

Nelson Soares acknowledges the support provided by FCT - PhD scholarship SFRH/BD/51640/2011.

❑ PART B – DYNAMIC SIMULATION OF ENERGY IN BUILDINGS

❑ Multi-dimensional optimization of the incorporation of PCM-drywalls in lightweight steel-framed (LSF) residential buildings in different European climates [7].

Goals:

- To optimize the impact of PCM-drywalls in the annual heating and cooling energy-saving of an air-conditioned LSF residential single-zone building, considering real-life conditions and 7 European climates (Köppen-Geiger climate classification).

Methodology:

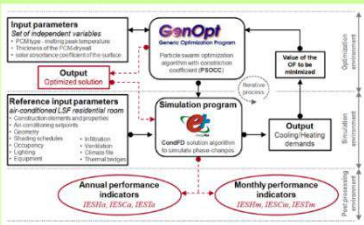

Fig. 5. Sketch of the methodology carried out and described by Soares *et al.* [7].

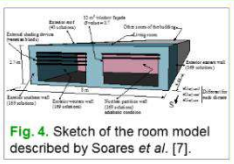

Fig. 4. Sketch of the room model described by Soares *et al.* [7].

Results:

- An optimum PCM-drywall solution was found for each climate leading to significant annual energy savings.

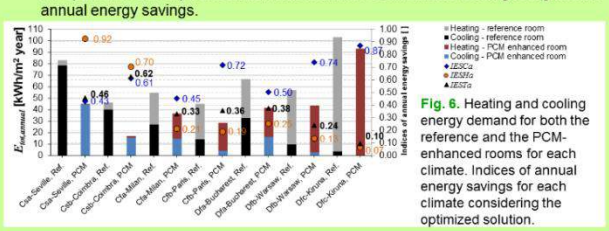

Fig. 6. Heating and cooling energy demand for both the reference and the PCM-enhanced rooms for each climate. Indices of annual energy savings for each climate considering the optimized solution.

❑ PCM-drywalls for reducing cooling demand and cooling peak loads in residential heavyweight buildings in Kuwait in the framework of the ongoing MIT-Kuwait Signature Project called "Sustainability of Kuwait's Built Environment" [8].

Goals:

- To discuss the existence of a fully-customized PCM-drywall solution regarding its thickness and the melting-peak temperature of the PCM; to evaluate the impact of PCM-drywalls in the reduction of both the cooling demand and the cooling peak loads; to provide some guidelines for incorporating PCM-drywalls in Kuwait, and to evaluate if they can contribute for improving the resilience of the electricity-grid during the summer peak-hours.

References

[1] Soares N, Costa JJ, Gaspar AR, Santos P. Review of passive PCM latent heat thermal energy storage systems towards buildings' energy efficiency. Energy and Buildings 2013;59:82–103.

[2] Soares N, Costa JJ, Samagaio A, Vicente R. Numerical evaluation of a phase change material-shutter using solar energy for winter nighttime indoor heating. Journal of Building Physics 2014;37(4):367–394.

[3] Soares N, Costa JJ, Vicente R, PCM_WindowWall – storage of solar thermal energy for buildings heating, in: 1st edition of the 'Prémio Ramos Catarino Inovação' Innovation Award, Coimbra, Portugal, February 4, 2012.

[4] Silva T, Vicente R, Soares N, Ferreira V. Experimental testing and numerical modelling of masonry wall solution with PCM incorporation: A passive construction solution. Energy and Buildings 2012;49:235–245.

[5] Soares N, Gaspar AR, Santos P, Costa JJ. Experimental study of the heat transfer through a vertical stack of rectangular cavities filled with phase change materials. Applied Energy 2015;142:192–205.

[6] Soares N, Costa JJ, Gaspar AR, Santos P. Heat transfer through small thermal energy storage units filled with phase change materials for vertical buildings applications: experimental study and parametric analysis. (submitted)

[7] Soares N, Costa JJ, Gaspar AR, Santos P. Multi-dimensional optimization of the incorporation of PCM-drywalls in lightweight steel-framed residential buildings in different climates. Energy and Buildings 2014;70:411–421.

[8] Soares N, Reinhart CF. PCM-drywalls for reducing cooling demand and cooling peak loads in residential buildings in Kuwait. (in preparation).

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Institute for Sustainability and Innovation in Structural Engineering

Onur Onat

Supervisors: Paulo Lourenço / Ali Koçak (TR)

AN EXPERIMENTAL STUDY TO ASSESS OUT-OF-PLANE BEHAVIOR OF INFILL WALLS SURROUNDED WITH REINFORCED CONCRETE FRAME SUBJECTED TO EARTHQUAKE LOAD

❑ EXPERIMENTAL RESEARCH

- The purpose of this work is to assess out-of-plane behaviour of infill wall subjected to bidirectional earthquake load. Two specimens are planned to be tested. One of them is Unreinforced Masonry Infill wall as seen in Figure 1, other of them is infill wall with Bed Joint Reinforcement as seen in Figure 2.
- Earthquake load is applied in six steps according to reference earthquake load. Reference earthquake load is selected according to return period. Return period of reference earthquake load is 475 years. Possibility in 50 years is 10 %.

Fig. 1

Fig. 2

❑ TEST SETUP & SHAKE TABLE TEST

- For this purpose, special test setup was produced to supply special boundary condition. This special steel piers and struts can be seen in Figure 3. First specimen was imposed to shake table test.

Fig. 3

STRUT MECHANISM

❑ TEST RESULT of URM

- First specimen was imposed to earthquake load. After first test, applied drift in longitudinal direction at last stage is 1.5 %. In addition, applied drift level in transversal direction is 0.6 %

- Motivation of this study was Angel (1994) and Komaraneni (2009)

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LONG-TERM BEHAVIOR AND DURABILITY PERFORMANCE OF RC SLABS FLEXURAL STRENGTHENED WITH NSM CFRP STRIPS

Institute for Sustainability and Innovation in Structural Engineering

Patrícia Moreira da Silva

Supervisors: José Sena-Cruz / Miguel Azenha

_OBJECTIVES AND MOTIVATION

The present research intends to contribute for the knowledge on the long-term deformational performance and durability of concrete structures strengthened with **carbon fiber reinforced polymer (CFRP)** according to the near-surface mounted (NSM) technique. For that purpose a wide experimental program has been executed using slab specimens submitted to **accelerated ageing tests.** The slabs were expose under various conditions of environment, load and chemical degradation. The results obtained from the experimental programs will be used for **predicting the service life** of structures strengthened with the NSM technique supported in **numerical models**.

_EXPERIMENTAL PROGRAM

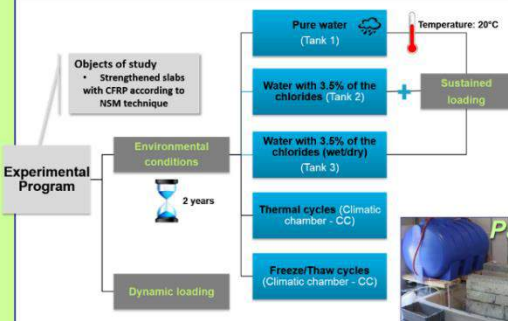
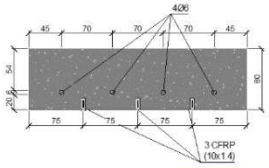
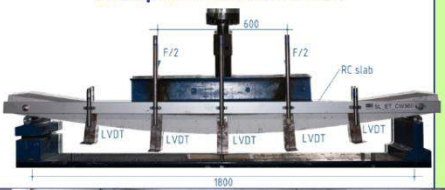


Diagram of experimental tests

Cross-section geometry

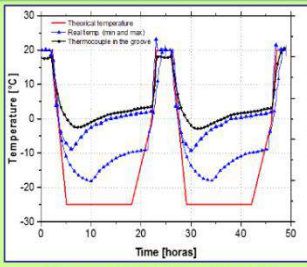


Set up of monotonic test

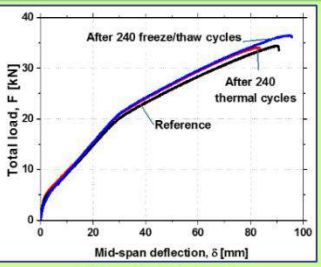


_RESULTS

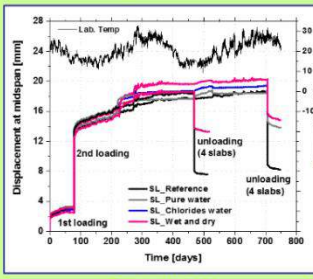
Monitoring of mid-span deformation during creep tests



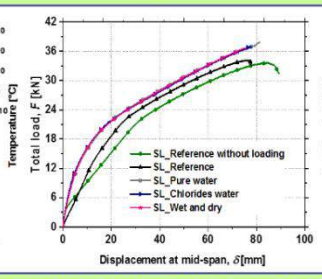
Freeze and thaw cycle



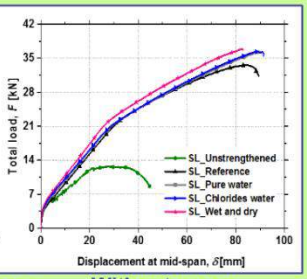
Monotonic tests



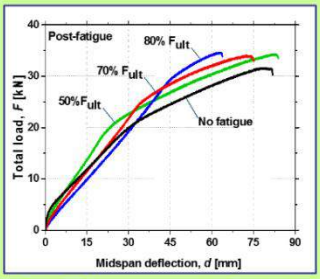
Creep tests



Monotonic tests after creep loading



Without creep loading



Post-fatigue monotonic tests

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Institute for Sustainability and Innovation in Structural Engineering

ROBUSTNESS OF STEEL STRUCTURES: BEHAVIOUR OF STEEL JOINT AFTER IMPACT LOADING

Pedro Barata

Supervisors: Aldina Santiago / João Paulo Rodrigues

❑ SCOPE

- This thesis is within in the research FCT project Impactfire - Robust Connections for Impact and Fire Loading.
- The work is focused on bolted beam-to-column joints subjected to quasi-static and impact load. Additionally, special attention is given to the combined scenario fire after impact load.

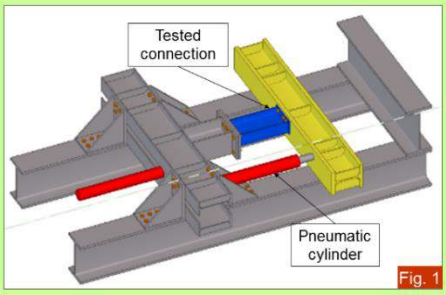

Fig. 1

❑ OBJECTIVES

- Characterization of the accidental loading scenarios.
- Characterization of steel joints in terms of resistance, stiffness, deformation capacity and failure modes, when subjected to accidental loadings.
- Robustness evaluation of steel structure when subjected to fire after accidental impact loading.

❑ DEVELOPED WORK

- Development of the testing layout to apply high rates of loading on steel joints (Fig. 1).
- Tests on T-stub component and reverse channel components in tension: reference quasi-static tests; elevated temperature tests and impact tests (Fig. 2 and Fig. 3).

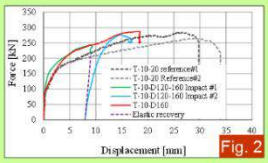

Fig. 2

Fig. 3

- Reference quasi-static bending tests on flush end plate joints and reverse channel joints.
- Impact tests on flush end plate joints and reverse channel joints (Fig. 4 and Fig. 5).

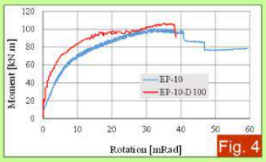

Fig. 4


Fig. 5

❑ WORK UNDER DEVELOPEMENT

- Tests on flush end plate joints subjected to sequential accidental loadings: fire after impact.
- Numerical evaluation of the robustness of a steel building (case study) when subjected to: i) impact loading; ii) fire after impact loading.

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SOARES DA COSTA

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Pedro Miguel Gomes Fernandes
Supervisors: José Sena-Cruz / José Xavier

LONG-TERM AND DURABILITY PERFORMANCE OF BOND BETWEEN CONCRETE ELEMENTS AND CFRP LAMINATES ACCORDING TO THE NSM TECHNIQUE

OBJECTIVES AND MOTIVATION

The present work aims to contribute for the knowledge on the long-term and durability performance of concrete structures strengthened with NSM CFRP systems, under various specific application environments, load conditions and chemical degradation. The main focus is on the bond between the CFRP and concrete. The work is composed by three components: experimental programs (through accelerated ageing tests), numerical and analytical simulations and design recommendations. The present poster summarizes some obtained results.

EXPERIMENTAL PROGRAM

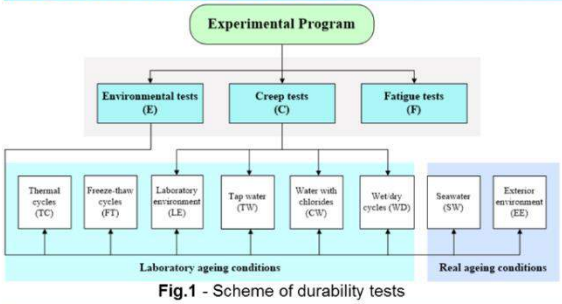


Fig.1 - Scheme of durability tests

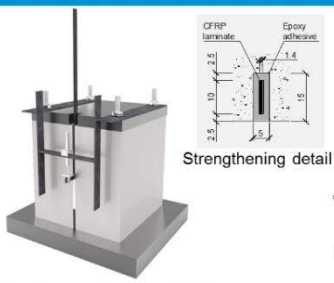


Fig.2 – Direct pullout test (DPT)

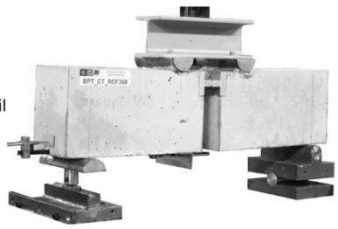
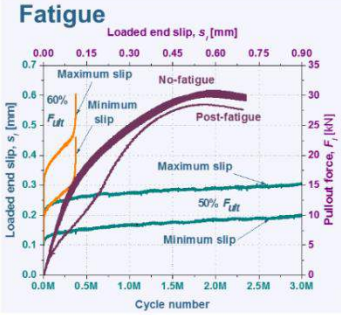
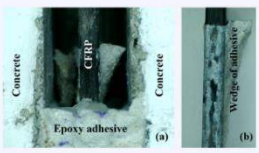


Fig.3 - Beam pullout test (BPT)

RESULTS

Fatigue

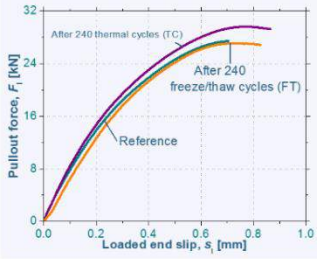




_Debonding failure at adhesive /laminate interface (D) occurred for 60% F_{ult}

_For 50% F_{ult} the specimens did not after fatigue cycles

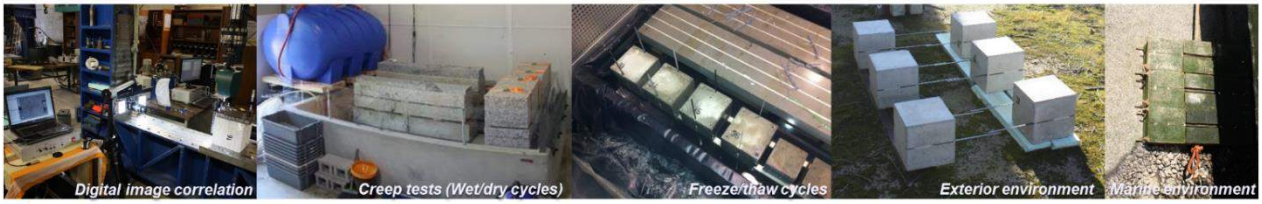
Thermal and freeze/thaw cycles



_FT cycles changes the failure mode from D to failure by concrete splitting

_The bond strength of the system was not affected by FT cycles

_DPT results showed a slight increase of bond strength (8.3%) when submitted to TC between -15°C and +60°C



CONCLUSIONS

In general, results of durability tests presented in this work showed that the effects of environmental and load conditions imposed, which can be considered quite severe, did not lead to a significant damage on NSM-CFRP strengthening system. In spite of the present results being credible and contributing for the knowledge in this area, further experimental work with significant aging time (e.g. 10 years) supported in analytical and numerical simulations, are needed to fully understand the long-term and durability behavior of the NSM-CFRP systems.

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NUMERICAL MODELS FOR THE SIMULATION OF THE CYCLIC BEHAVIOUR OF RC STRUCTURES INCORPORATING NEW ADVANCED MATERIALS

❑ OBJECTIVE

The research was aimed to develop a fiber/layered model and constitutive laws to simulate the behaviour of reinforced concrete structures strengthened with Carbon Fibre Reinforced Polymers (CFRP), submitted to cyclic and monotonic load configurations, taking into account the relevant nonlinear phenomena. Experimental investigation is carried out and the resulting data are used to calibrate constitutive model parameters and to appraise the performance of the numerical simulation. The research is focused to simulate adequately the characteristics of cyclic tests like strength and stiffness degradation, and pinching effect.

❑EXPERIMENTAL AND NUMERICAL APPROACH

EXPERIMENTAL INVESTIGATION

The experimental program is constituted by a series of twelve column prototypes, by varying the following parameters:
1. Concrete strength;
2. Longitudinal steel reinforcement ratio;
3. Percentage of NSM CFRP laminates and EBR CFRP strips.

NUMERICAL INVESTIGATION

Every structural element is discretized in fibres along its longitudinal direction. Each fibre is assigned a material model according to its mechanical characteristic. The collective response of fibres is assembled at section level and later transformed to structural level. The nonlinear phenomenon considers the response generated between the surface of diverse fibres using interface elements.

❑ CONSTITUTIVE LAWS

All the material models assume envelope curve defined by monotonic loading. For hysteresis the degradation in strength and stiffness is considered based on experimental data. The types of material for which the cyclic constitutive laws used are:
1.Concrete;
2. Steel;
3. CFRP confined concrete.

A constitutive law (bond model) based on bond strength of concrete and steel is implemented to characterise the interface, taking into account the degradation in envelope curve due to hysteresis of concrete and steel, and energy dissipation in loading cycles. The use of interface element in FEM is a sophisticated technique to model the slip of steel rebars.

❑ CONCLUSIONS

The proposed numerical response are compared with experiments carried out at University of Minho, at material and structural level. The layered model for slabs and shells is implemented in FEMIX. The research contribute to enhance the quality of the design guidelines that fib and ACI are working. It allow to design and assess the performance of CFRP-based strengthening strategies for RC structures of insufficient resistance to seismic loadings. It also contribute to the consolidation of the excellence of the research group in the field of the use of FRP systems for the strengthening of the built patrimony.

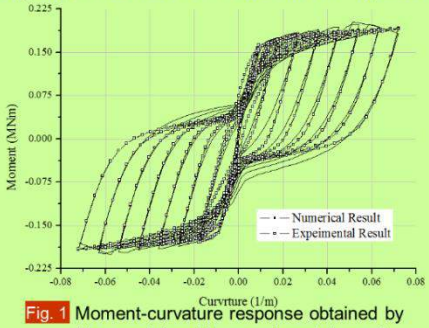

Fig. 1 Moment-curvature response obtained by fibre model and by experimental result (Gomes 1992).

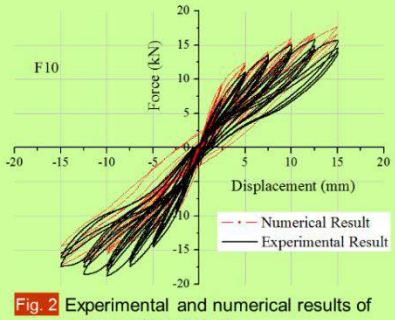

Fig. 2 Experimental and numerical results of column with bond-slip.

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SFRH / BD / 61677 / 2009

MATERIAL AND STRUCTURAL BEHAVIOR ASSESSMENT OF SCHIST MASONRY CONSTRUCTIONS

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Ricardo S. Barros

Supervisors: Daniel V. Oliveira / Humberto Varum

❑ EXPERIMENTAL RESEARCH

- The masonry schist constructions represent a very important cultural, architectural and historical heritage in Portugal and Europe.
- It is essential to understand the material and structural behavior of this kind of constructions to safeguard the heritage.

Schist masonry constructions.

❑ Geology of the Schist

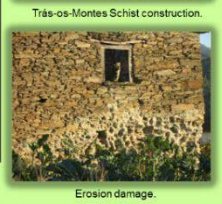
- Mainland Portugal is part of the largest morphostructural unit of the Iberian Peninsula.
- Schist is a metamorphic rock that has a regular parallel or prismatic schistose structure. The mineral layers of the schistose structure are visible to the naked eye.

Different types of schist rocks.

❑ Constructive and damage survey

Sheet for survey for schist constructions.

Trás-os-Montes Schist construction.

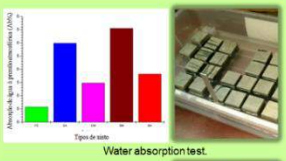


Erosion damage.

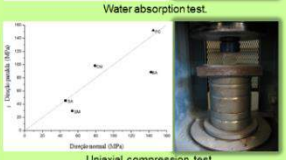
❑ SCHIST CHARACTERIZATION

Laboratory tests performed for the material characterization

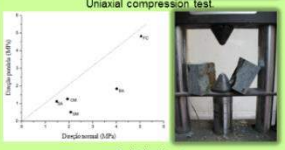
- Optical Microscopy
- Scanning Electron Microscopy
- Resistance to water absorption at atmospheric pressure (EN 13755: 2005)
- Resistance water absorption by capillarity (EN 1925: 2006)
- Ultrasonic test (ASTM E797-05)
- Resistance to the uniaxial compressive strength (EN 1926: 2006)
- Schmidt hammer test (EN 12504-4: 2003)
- Peak load resistance (IRSM 1985)
- Resistance to salt crystallization (EN 12370: 2001)



Water absorption test.



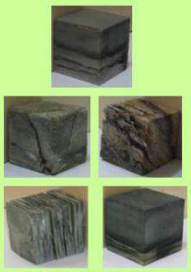
Uniaxial compression test.



Point load test.

Characterization of different schist's from Portugal.

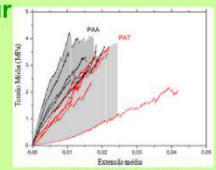
Region	Direction	Compressive strength	porosity	Resistance to salt crystallization
Vila Nova de Foz Côa	⊥	High	Very low	Resistant
	//	High		
Serra de Arga	⊥	Moderate	Low	Not resistant
	//	Moderate		
Carrazedo de Montenegro	⊥	High	Low	Not resistant
	//	High		
Sobral de São Miguel	⊥	Moderate	Low	Not resistant
	//	Moderate		
Barqueiros	⊥	High	Low	Not resistant
	//	High		



Salt crystallization test.

❑ Characterization of the structural behaviour

- Mortar characterization
- Analysis of the resistance to uniaxial compression
- Analysis of the resistance to diagonal compression
- Analysis of strengthening methodologies



Prisms stress-strain graph.

Diagonal Compression tests results.

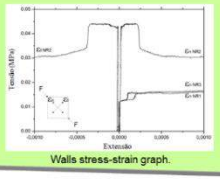
Walls	Shear strength (MPa)	Shear Modulus (MPa)
NR	0,03	32,50
DR	0,06	35,52
DRB	0,07	273,15

Uniaxial Compression tests results.

Prisms	Stress (MPa)	E (MPa)
PAT	3,76	101,07
PAA	3,88	119,97

Prisms with different mortars.

Diagonal Compression test.



Walls stress-strain graph.

Reinforced wall.

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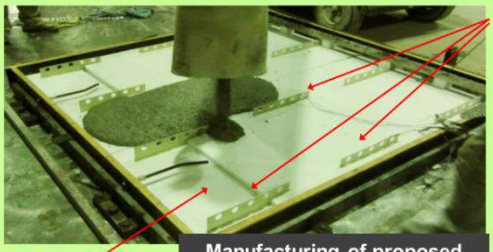
Rodrigo de Melo Lameiras

Supervisors: Joaquim Barros / Miguel Azenha

SANDWICH PANELS COMPRISING STEEL FIBRE REINFORCED SELF-COMPACTING CONCRETE AND GLASS FIBRE REINFORCED POLYMER CONNECTORS

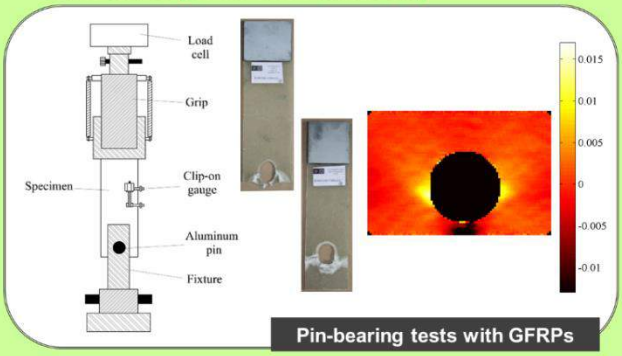
❑ GENERAL DESCRIPTION

In this work, an innovative structural sandwich consisted of steel fibre reinforced self-compacting concrete panels (SFRSCC) and glass fibre reinforced polymer connectors (GFRP) were developed. This system was intended to present a higher thermal performance than the existing technologies, while being costly competitive. Several experimental, analytical and numerical investigations, from materials features to structural behaviour, were carried out in order to optimize and to have a better understanding of thermal, mechanical, thermo-mechanical behaviour of proposed system. Some of the tests performed are illustrated in the figures below.

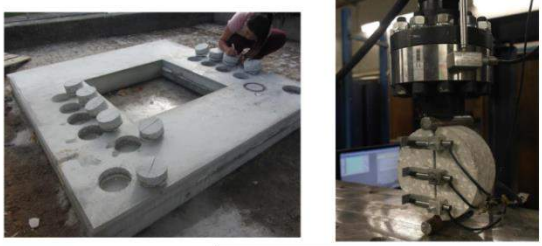


Manufacturing of proposed sandwich panel

❑ RESEARCH CONCERNING MATERIAL FEATURES (GFRP AND SFRSCC)

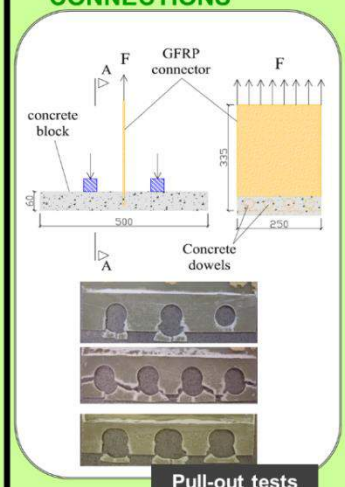


Pin-bearing tests with GFRPs

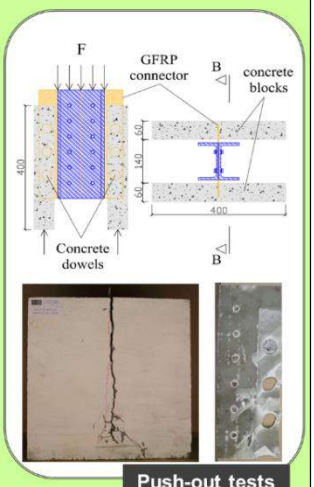


Investigations on flow-induced anisotropy of SFRSCC

❑ RESEARCH CONCERNING THE GFRP VS. SFRSCC CONNECTIONS

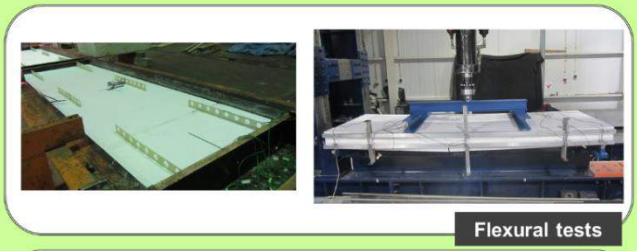


Pull-out tests



Push-out tests

❑ RESEARCH CONCERNING THE FULL-SCALE BEHAVIOUR OF PROPOSED PANELS



Flexural tests

Pseudo-static tests with cyclic horizontal load

MECHANICAL PERFORMANCE OF NATURAL FIBER-REINFORCED COMPOSITES FOR THE STRENGTHENING OF ANCIENT MASONRY

isise Institute for Sustainability and Innovation in Structural Engineering

Rosamaria Codispoti

Supervisors: Renato S. Olivito / Daniel V. Oliveira

OVERVIEW

The present PhD Thesis was developed thanks to the collaboration between the Civil Engineering Departments of University of Calabria (Italy) and University of Minho (Portugal). The main topic of this work concerned the study of natural fiber-reinforced composites. The study is composed of a vast experimental part, carried out in the Civil Engineering Laboratory and Fibrous Materials Laboratory at University of Minho, and a numerical part, with the purpose of analyzing the performance of natural fiber-reinforced polymer (NFRP) and grout (NFRG) applied to ancient masonry structures.

EXPERIMENTAL TESTS ON COMPOSITES

In the first part of the experimental program, mechanical characterization tests of matrixes and fibers was done, carrying out compressive and three point bending tests on mortar and tensile tests on resin and fabrics. Three different types of matrixes were used to produce composite materials: two thermosetting matrixes, epoxy and polyester resin (NFRP), and a mortar matrix(NFRG). Consequently of this, three composite materials were manufactured ($NFRP_{epoxy}$ – $NFRP_{polyester}$ – NFRG). Moreover, in order to analyze the performance of composites in terms of maximum load capacity, tensile strength, and Young's modulus, tensile tests were carried out in laboratory.

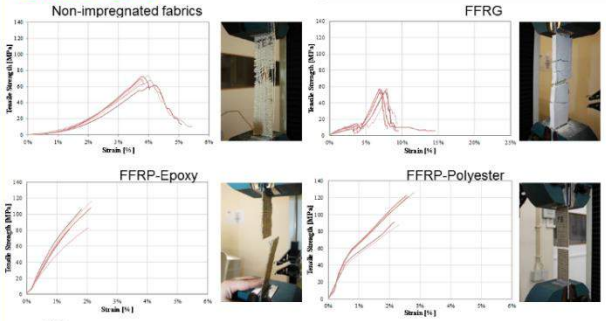
EXPERIMENTAL TESTS ON STRENGTHENED ELEMENTS

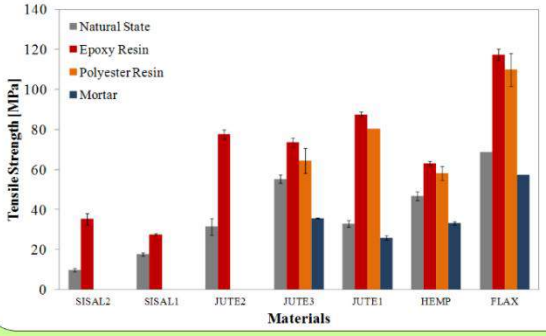
In the second part of the experimental plan, the bond behavior between composite materials (NFRP-NFRG) and masonry was investigated. For this purpose, pull-out tests, three point bending tests, and single-lap shear bond tests were carried out on masonry clay bricks reinforced externally with natural fiber-based composites. Finally, to get feedback with the current standards, a comparison with the theoretical approach provided by the Italian technical document (DT-200 R1/2012) was made. In addition to the characterization of mechanical properties of NFRP, also physical properties were calculated in terms of weight per unit area (GSM) and density..

MATERIALS

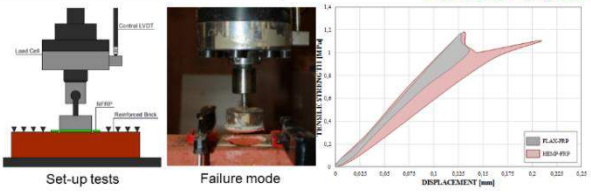
In order to fulfill the aim of this thesis, five types of natural materials have been used: flax, hemp, sisal, jute and coir. A total of seven kinds of bidirectional fabrics have been put in examination (figure 3.4), different for both density but also in composition, in fact, mixed fabrics, with the presence of different materials in each direction, were tested.

TENSILE TESTS

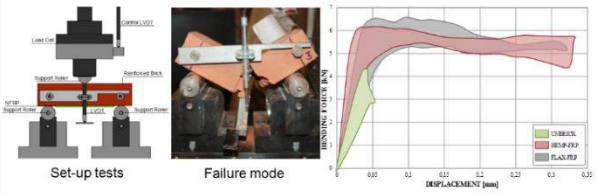




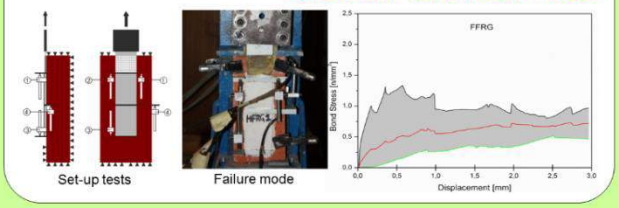
PULL-OUT TESTS



THREE-POINT BENDING TESTS

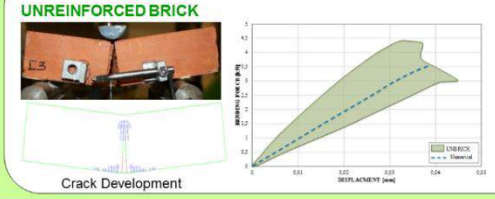


SINGLE-LAP SHEAR BOND TESTS

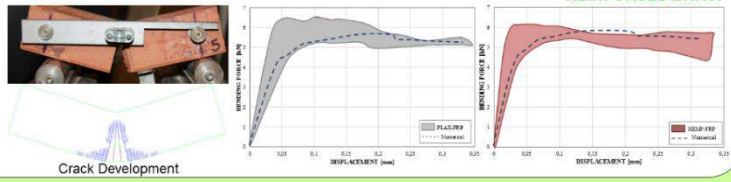


EXPERIMENTAL AND NUMERICAL RESULTS: COMPARISON

UNREINFORCED BRICK



REINFORCED BRICK



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Rui Manuel Maia Pinto de Matos

Supervisors: Carlos Rebelo / Paulo Pinto

STEEL TOWERS FOR WIND TURBINES

❑ OVERVIEW

- This study is focused on the theme of the renewable energy, namely the wind energy, which had registered a big increase over the last few years. The main objective is to study the feasibility of the production, assembly and use of higher towers for wind turbines.
- The use of higher heights will bring new problems to the design and the price of the towers, so this study will focus on some of those topics.
- In this work an overview and the design of several different solutions will be presented to be used on higher towers (150 to 200 m high), a study for a new typology of foundations as alternative for the current direct foundation, estimation of the pre-stress losses on bolts and monitoring of a fully functional wind tower.

❑ FOUNDATION DESIGN (EXPERIMENTAL AND NUMERICAL STUDY)

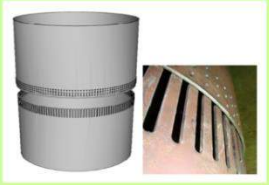
- The actual foundation typology for current wind towers (80 to 100m) is based on direct foundation and represents a big percentage of the total cost of the structure (about 20%). The purpose of this work is to check the feasibility of reinforce the current direct foundation by using steel micropiles and so, reduce the required diameter for the direct foundation.

Experimental tests

Numerical analysis

❑DESIGN RECOMMENDTIONS FOR HIGHER WIND TOWERS

The design recommendations for higher wind towers will be included taking into consideration several structural solutions (steel, concrete and steel+concrete). The use of a new friction connection between the tower segments to improve the tower fatigue behavior it will be considered in the recommendations with the results of a long term measurement.



Friction connection

Wind tower instrumentation levels

❑MONITORING

A fully function tower instrumented along the height will be monitored for a long time in order to estimate the stresses and the behavior of the tower for a high range of wind speed. As the final part of this work will be estimated a fatigue spectrum for the measured wind speeds in order to validate the design values or purpose new ones.

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LONG-TERM DURABILITY OF BOND IN FRP-MASONRY COMPONENTS

Seyed Hamid Maljaee

Supervisors: Paulo B. Lourenço / Bahman Ghiassi

❑ EXPERIMENTAL RESEARCH

- The study focuses on the durability and long-term behavior of bond between masonry brick and composite materials. The goal is to achieve the fundamental understanding of the effects of environmental degradation agents such as moisture and temperature on the individual constituent materials and bond performance. To this end, the specimens are exposed to different conditions, i.e. the water immersion and hygrothermal exposure. The bond degradation is to be characterized through performing pull-off and single-lap shear tests.
- The long-term performance of the bond between masonry and composite material under sustained loads (creep behavior) will be investigated.

❑ Water immersion

- The effect of water immersion on the bond between masonry brick and GFRP was investigated. Two periods of water immersion are considered in this study. First group of specimens immersed in water for one year. The next group will be exposed to water immersion continuously for 5 years. The effect of surface treatment on the degradation mechanism also was investigated in this study, selecting two sets of specimens. ORG is denoted to the specimens with no surface treatment and GR is denoted to those have grinded surface. The degradation of debonding force in both sets of specimens during 12 months of water immersion is shown in figure 1.

❑ Hygrothermal exposure

- The effect of hygrothermal conditions on the durability of bond between FRP and brick is assessing in this ongoing task. The specimens are being exposed to selected hygrothermal conditions in a climatic chamber (the cyclic temperature, between +10˚C and +50˚C, and constant relative humidity, 90%, conditions), see figure 2.

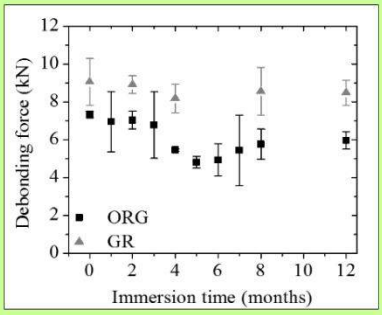

Figure 1

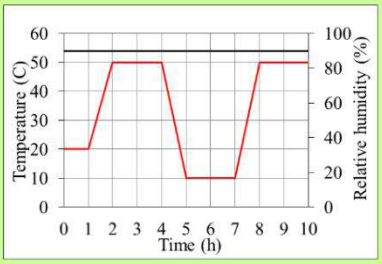

Figure 2

❑ Material characterization

- The effect of moisture absorption and environmental conditions on chemical and curing changes in epoxy resin and primer have been under study through DSC tests. The effect of curing time on the Tg value also is investigating. Figure 3 presents the DSC behavior of epoxy resin.
- Capillary tests on brick specimens.

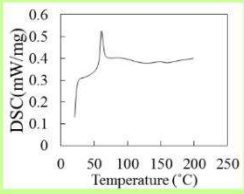

Figure 3

❑ Long-term creep tests

- The creep tests will be performed in two conditions of 60% R.H. and 90% R.H. with constant temperature of 23˚C. The specimens will be loaded under sustained load of 20%, 40% and 60% of the debonding force. The debonding progress and the FRP slip will be monitored with LVDTs and strain gauges. Creep tests will also be performed on epoxy, primer and GFRP coupon specimens under tensile loading conditions.

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University of Minho School of Engineering

Institute for Sustainability and Innovation in Structural Engineering

Seyedebrahim Hashemi Rafsanjani

Supervisors: Paulo Lourenço / Nuno Peixinho

HIGH STRAIN RATE CONSTITUTIVE MODELING FOR HISTORICAL STRUCTURES SUBJECTED TO BLAST LOADING

❑ INTRODUCTION

- The present study aims to address several topics dealing with high strain rate loads in the dynamic response of masonry structures, including constitutive material modelling and numerical prediction of response.

❑ A DYNAMIC COMPOSITE INTERFACE MODEL FOR MASONRY

- A dynamic interface model is developed for micro numerical simulation of masonry walls, see Fig. 1. Regarding this study, interface elements are applied to represent the mortar behavior within numerical modeling. Given, the variation of the parameters in the stress-strain relation of masonry subjected to loading in various strain rates, the failure envelop can expand or contract. Thus, in order to apply high strain rates effects in material model, after the implementation of the model in an explicit finite element code, recognition of the most relevant parameters and the corresponding coefficients that affect the failure envelop are the main aims of this part of study.

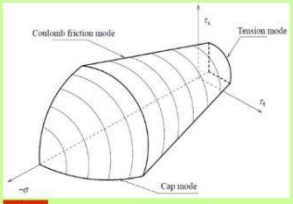

Fig. 1

❑ A STRAIN RATE DEPENDENT ANISOTROPIC CONTINUUM MODEL FOR MASONRY

- A dynamic anisotropic continuum model is developed for macro numerical simulation of masonry walls, see Fig. 2. Here, 3D solid elements are adopted to represent the global behavior of masonry during numerical modeling. Again, the failure envelope will extend or contract during the loading process and the same procedure is adopted here: Finite element implementation, followed by a study on the definition of relevant parameters and use of the model in real applications.

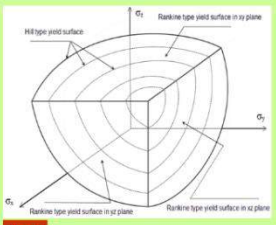

Fig. 2

❑ ENGINEERING APPLICATION: CASE STUDY- "AL-ASKARI" HOLY SHRINE IN SAMARRA, IRAQ

- The present study also aims to demonstrate the capacity of applying the new continuum plasticity model into an engineering application to solve a real problem. The full-scale numerical simulation of the blast response of Al-Askari holy shrine is considered to discuss the difficulties in this application and to validate the model capability. Besides the real explosion, two different scenarios are also defined to reflect the vulnerability of the mosque subjected to different sources of explosion.

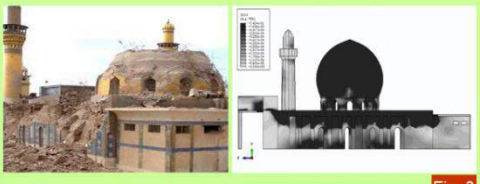
Fig. 3

❑ DESIGN RULES FOR MASONRY INFILL WALLS SUBJECTED TO EXPLOSIVE LOADS

- The P-I diagrams (Fig. 4) are presented for different masonry infill walls (Fig. 5) under blast and different loading conditions, which can be used as a simple tool by practitioners in preliminary design and evaluation of structural damage to establish reliable response limits and, as a result, make informed decisions.

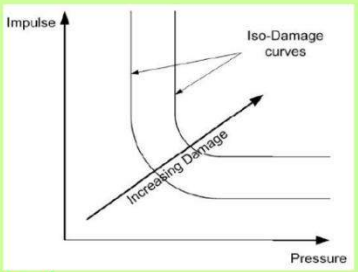

Fig. 4

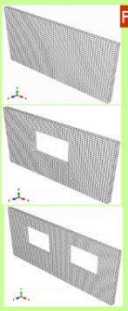
Fig. 5

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Institute for Sustainability and Innovation in Structural Engineering

Subramani Pichandi

Supervisors: Daniel Oliveira / Raul Fangueiro

DEVELOPMENT OF AUXETIC STRUCTURE & COMPOSITES FOR BLAST PROTECTION OF STRUCTURAL ELEMENTS

❑ EXPERIMENTAL RESEARCH

- This research work is in the area of Auxetic materials (possess negative Poisson's ratio) (Fig. 1). The main objective of this work is to develope novel auxetic structures and composites for strengthening of civil structural elements.
- Two different types of auxetic structures has been developed from braided composite rods (refer Fig. 2) using various technical fibers as core (glass, basalt, and carbob) and polyester multifilament as sheath.
- Mechanical properties (Poisson's ratio and Tensile strength) of developed auxetic structures were studied in detailed manner by varying their materials and structural parameters. This will help to develope structures for specific conditions.
- Auxetic composites from unidirectional carbon fiber sheet with epoxy resin through angle-ply technique was developed and studied their tensile and auxetic behavior. The no. Of layer used is 24 with the angle of ±30°. Weight of each layer is 100 gm/sqr. Meter.

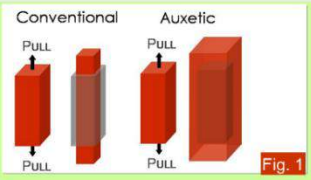
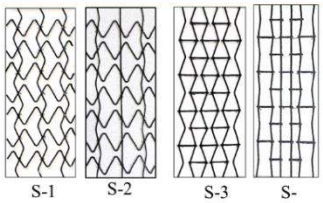


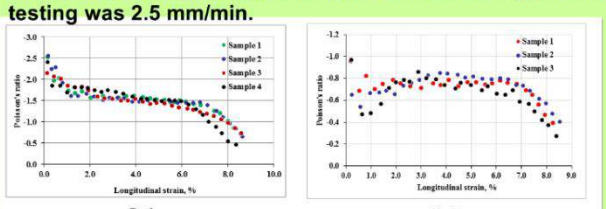
Fig. 1



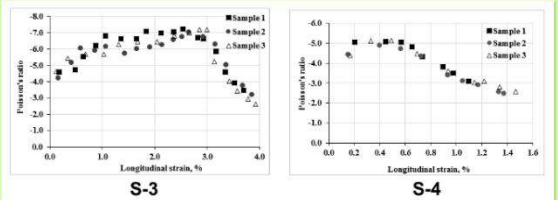
(S-1) Auxetic basic structure based on lozenge grid, (S-2) Auxetic structure modified based on lozenge grid, (S-3) Auxetic structure basic based on re-entrant hexagon and (S-4) Auxetic structure modified based on re-entrant hexagon. Fig. 2

❑ TESTING OF AUXETIC AND TENSILE BEHAVIOR

- The auxetic and tensile behavior of auxetic structures were studied by using universal tensile testing machine with cross head speed of 25 mm/min. The test dimensions of S-1 and S-2 were 40 cm in length and 14 cm in width. Whereas the dimensions of S-3 and S-4 are 40 cm in length and 11 cm in width. During testing videos were captured and later videos converted in to images. From the images, the transverse and longitudinal deformation (strain) of structures were calculated. Then, the Poisson's ratio of the structures were calculated using the formulae, Poisson's ratio = -(Transverse strain/Longitudinal strain). The Poisson's ratio of the structures were shown in the Fig. 3 and Fig. 4. Tensile results of the structures given in the table 1. The Poisson's ratio of the composites (sample size – 25 * 1.5 cm with gauge length of 15 cm) studied using tensile testing machine with Digital Image correlation (DIC) technique. The cross head speed used for testing was 2.5 mm/min.



Auxetic behavior of structures based on lozenge grid Fig. 3



Auxetic behavior of structures based on re-entrant hexagon Fig. 4

❑ PARAMETERS

- The parameters studied for the structures are type of core fiber, angle of vertical undulation rods, rib length, and BCRs diameter.
- The effect of layers on auxetic behavior of composites was studied.

Table 1. Tensile results of structures (glass, 4800 tex)

Sample	Avg. Max. Tensile Load, kN	Avg. Elongation at max. tensile load, %
S – 1	4.93 (15.2)	9.35 (6.32)
S – 2	3.45 (11.2)	8.89 (5.04)
S – 3	10.40 (8.33)	5.14 (5.45)
S – 4	15.23 (0.88)	4.04 (12.15)

❑ CONCLUSION

- The Poisson's ratio of the structures were significantly modified by varying their angle of vertical undulation rods.
- The strengthening of the structures were improved by modifying structures with vertical straight rods.
- The Poisson's ratio of the auxetic composites observed as -0.240.

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SEISMIC RETROFIT OF MASONRY-TO-TIMBER CONNECTIONS IN HISTORICAL CONSTRUCTIONS

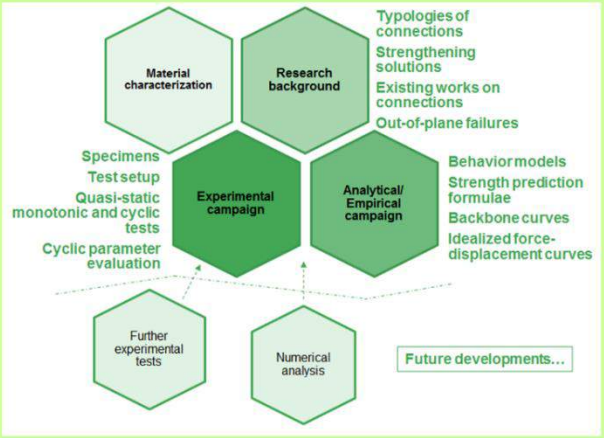
Susana Moreira

Supervisors: Luís F. Ramos / Daniel V. Oliveira

❑ MOTIVATION AND OBJECTIVE

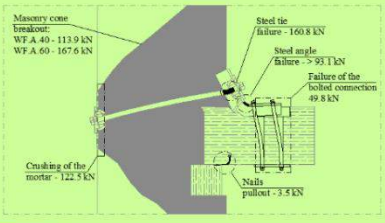
- **Out-of-plane collapse of masonry walls** in historical unreinforced masonry (URM) buildings is one of **the most observed failure modes**, in past and recent earthquakes;
- **Effective structural connections** can promote **global structural response** by preventing out-of-plane collapses;
- There is the **need to develop proper retrofit solutions for masonry wall to timber elements connections**.

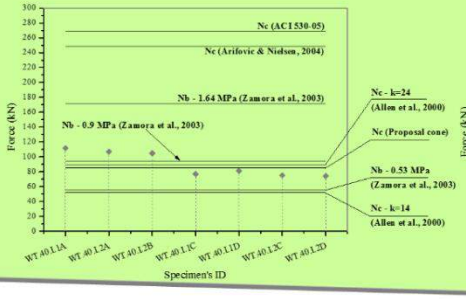
❑ METHODOLOGY



❑ ANALYTICAL DEVELOPMENTS

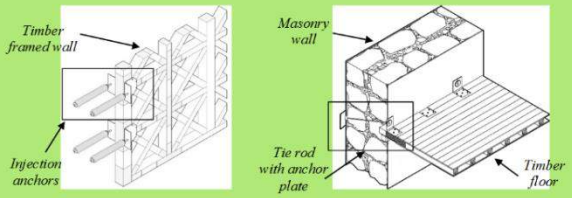
- **Existing strength prediction models** were adapted to better **fit the experimental results and estimate the capacity** of different failure modes;
- **Backbone curves** were obtained according to different methodologies and **idealized as bilinear and trilinear curves**;
- **Acceptance criteria** and design recommendations were proposed for **retrofit design**.

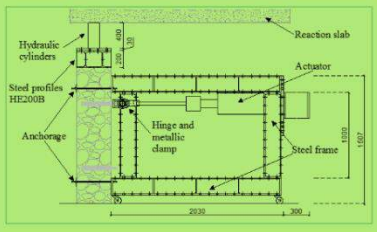




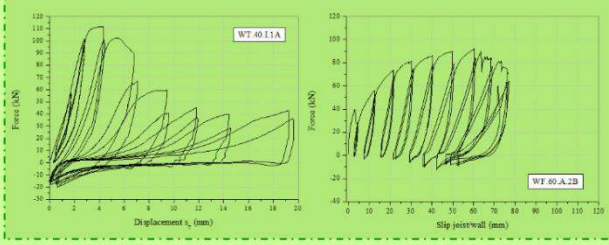
❑ EXPERIMENTAL CAMPAIGN

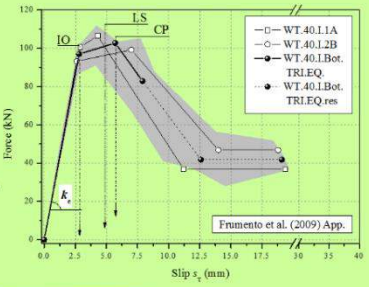
- A total of **20 quasi-static monotonic and cyclic pullout tests** were carried out in order to **characterize the cyclic response of retrofitted masonry wall to timber walls or floors;**





- **Injection anchors**: **combined cone-bond** failure;
- Strengthened **wall-to-floor connections**: failure of the **bolted connection steel angle/timber joist**;
- Parameters analyzed: **hysteretic curves, energy dissipation, stiffness, ductility**, etc.





Universidade do Minho
Escola de Engenharia

NIKER

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Tiago Jorge da Cruz Manco
Supervisor: Prof. Luís Simões da Silva

BEHAVIOUR OF STEEL MEMBERS SUBJECTED TO HAZARDOUS LOADING IN SUPPORT OFFSHORE STRUCTURES

❑ BACKGROUND

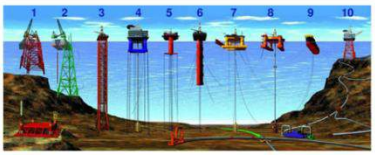
- The behaviour of steel members in support offshore structures subject to hazardous loading is a critical aspect in offshore structures and a hot topic in research nowadays. Despite design offshore standards already providing specifications for the avoidance of progressive collapse, they omit specific provisions to prevent it.
- Typical accidental events are:
  - — Ship collision
  - — Dropped objects
  - — Fire
  - — Explosion

❑ OBJECTIVES

- The main objective of this PhD work is the development of predictive models for the behaviour, including progressive damage, of steel members in support structures of offshore platforms subjected to hazardous loading leading to design guidelines.
- It is expected to develop analytical models capable of predicting the resistance of cylindrical tubes and stiffened shells. The influence of the local member failure on the structural robustness of the support structure will be evaluated, allowing the assessment of the applicability of simplified robustness methodologies for buildings to jacket structures.

❑ TASKS

- Task 1 – Characterization of the various types of offshore structures and relevant associated hazards;
- Task 2 – Performance of structural elements in normal loading conditions;
  - Resistance of cylindrical tubes and stiffened shells according to standards;
  - Experimental and numerical assessment of the referred structural elements;
- Task 3 – Performance of individual elements subjected to selected hazardous loads;
  - Resistance of cylindrical tubes and shells according to standards for the relevant hazards;
  - Experimental tests and numerical analysis on individual elements subjected to hazardous loads;
  - Development of analytical models and design rules at the element level;
- Task 4 –Robustness analysis of offshore structures;



Description:	
1, 2)	conventional fixed platforms;
3)	compliant tower;
4, 5)	vertically moored tension leg and mini-tension leg platform;
6)	Spar;
7,8)	Semi-submersibles;
9)	Floating production, storage, and offloading facility (FPSO);
10)	sub-sea completion and tie-back to host facility;

Fig. 1. Types of offshore structures in the scope of the thesis.
Source:
http://oceanexplorer.noaa.gov/explorations/06mexico/background/oil/media/types_600.html

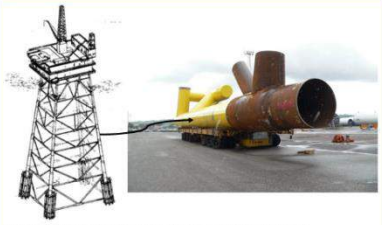


Fig. 2. Main Structural elements in fixed structures (steel tubular elements).
Source:
Left - Chakrabarti, S. (2005). "Handbook of Offshore Engineering". vol. I & II. Elsevier, Illinois, USA ;
Right - http://www.harland-wolff.com/Projects/Renewable-Energy-Project-Synopsis/Bard-1-Transformer-Platform-and-Jacket.aspx

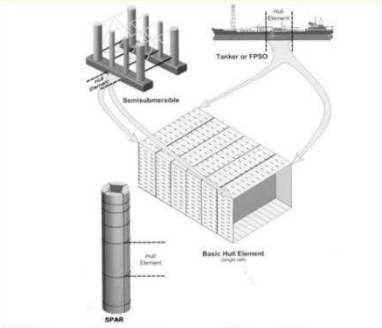


Fig. 3. Main structural elements in floating structures (stiffened steel shells).
Source:
Chakrabarti, S. (2005). "Handbook of Offshore Engineering". vol. I & II. Elsevier, Illinois, USA.

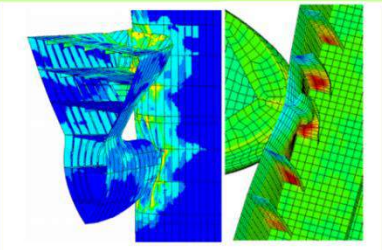


Fig. 4. Numerical analysis of the damage for a ship impact against a floating platform.
Source:
Storheim, M. and Amdahl, J. (2014). "Design of offshore structures against accidental ship collisions". Marine Structures, Vol. 37, pp. 135-172, Elsevier

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Institute for Sustainability and Innovation in Structural Engineering

Trayana Tankova

Supervisors: Luís Simões da Silva / Liliana Marques

CONSISTENT SAFETY ASSESSMENT AMONG EUROCODE 3 STABILITY DESIGN RULES FOR STEEL MEMBERS

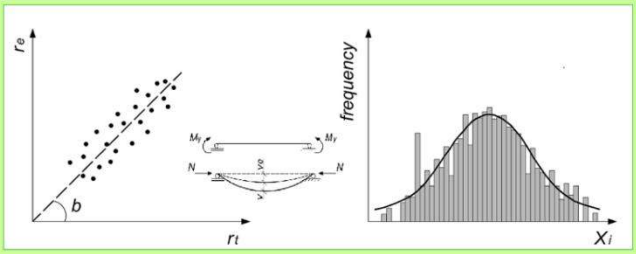
❑ RESEARCH OBJECTIVES

❑ Development of a safety assessment procedure for semi-ductile failure modes of steel structures focused on stability, consistent with other failure modes for steel structures leading to a proposal for the partial safety factor γ_{M1} in EC3-1-1;

❑ Extension of the existing analytical models and rules for flexural buckling of web-tapered columns and lateral-torsional buckling of web-tapered beams, to a wider range of loading and cross-section shape combinations;

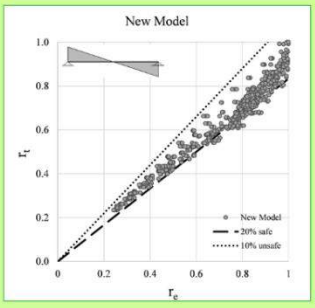
❑ RESEARCH PLAN

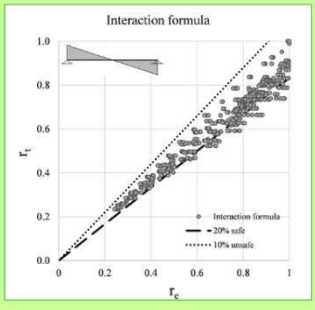
✓ **TASK 1** - Safety assessment procedure for stability failure modes in line with EN1990;



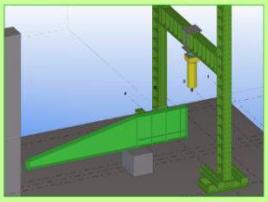
✓ **TASK 2** - Statistical characterization of basic variables necessary for the verification of stability failure modes

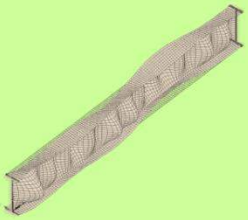
✓ **TASK 3** - Safety assessment of available design rules for stability of steel members





✓ **TASK 4** - Experimental program on tapered beams, columns and beam-columns





✓ **TASK 5** - Extension of stability verification non-uniform members

✓ **TASK 6** - Code conform guidelines and examples

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Institute for Sustainability and Innovation in Structural Engineering

Ziaaddin Zamanzadeh

Supervisors: J.A.O. Barros / L.A.P. Lourenço

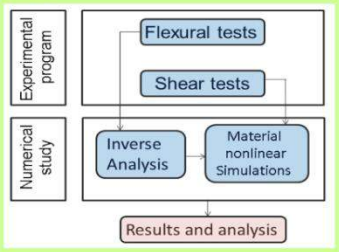
EXPLORING DERIVED MATERIALS FROM TIRE RECYCLING INDUSTRY FOR INNOVATIVE AND SUSTAINABLE STRUCTURAL SYSTEMS

❑ Objective

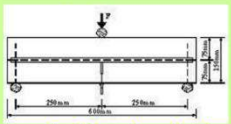
- **The present work proposes to explore derived materials from the tire recycling industry for innovative and sustainable structural systems. This mainly consists of two parts: (1) investigation of the mechanical behaviour of Recycled Steel Fibre Reinforced Concrete (RSFRC), aiming at evaluating whether the addition of RSF could greatly contribute to reduce the disadvantages related to the use of conventional steel rebars, considering the promising results already available when Industrial Steel Fibres (ISF) are used in substitution of the traditional reinforcement; (2) exploring the use of RSF for the production of thin cement based panels reinforced with relatively high content of RSF. This type of panels can be used in the construction of innovative structural systems, such as sandwich panels and unrecoverable molds, by introducing benefits in terms of a faster execution of a structure, improvement of its durability and maintenance costs.**

❑ Methodology

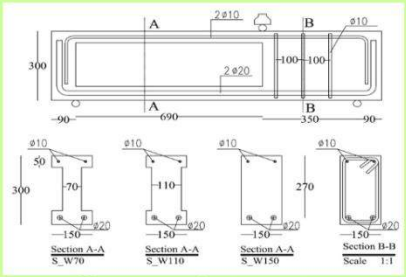
- **Overview**



- **Experimental program**



Three point bending test setup

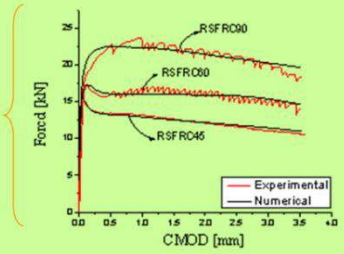


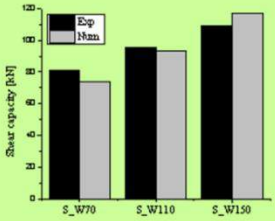
Shear capacity test setup

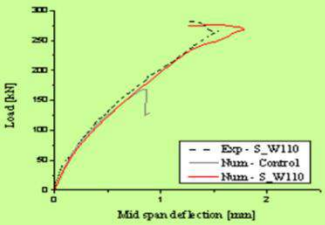
Crack pattern at failure of the beam (S_W110)

- **Relevant results and numerical study**

Average experimental load vs CMOD (three point bending tests) and numerical load vs CMOD obtained from inverse analysis.



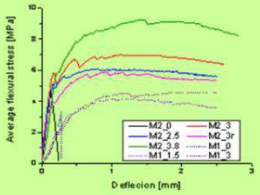




Comparison of the shear capacity of the RC beams registered experimentally and obtained from numerical simulations

❑ Ongoing research

- **Preliminary assessment on the development of the recycled steel fibre reinforced cement based mortar (flexural, ultrasonic and durability tests).**



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Post-Docs

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Bahman Ghiassi

Supervisors: Prof. Paulo B. Lourenco

SUSTAINABLE STRENGTHENING OF MASONRY STRUCTURES WITH INNOVATIVE COMPOSITE MATERIALS

❑ INTRODUCTION

Composite materials, such as FRPs, have been increasingly used for externally bonded reinforcement of masonry structures. Although FRPs provide interesting advantages for strengthening purposes, issues such as durability and compatibility indicate the need for development of new materials and techniques especially for strengthening of historical heritage.

This research deals with development and investigation of innovative composite materials (mainly based on natural fibers embedded in inorganic matrices) for EBR strengthening of historical masonry. The main focus will be on characterization of the short- and long-term (durability) bond behavior. Different parameters such as fiber type, mortar and strengthening layout will be considered in the short-term bond tests. The durability of bond will be investigated by performing real exposure and accelerated ageing tests.

Moreover, a refined computational model based on multi-physics and probabilistic approaches will be developed and calibrated, in order to predict the short- and long-term performance of the strengthened elements.

Strengthening of a masonry arch with fiber reinforced mortars. Courtesy of Ruredil S.p.A.
(*Taken from http://www.structuremag.org*)

❑ WORKPLAN

- **According to the objectives described above, the work plan consists of 4 main tasks:**

Task 1. State-of-the art

Task 2. Materials selection

Task 2. Experimental tests
- **Short-term bond behavior**
- **Long-term bond behavior (environmental durability)**

Task 3. Numerical modeling and optimization
- **Bond FE modeling**
- **Degradation modeling**
- **Mutli-scale modeling**

Task 4. Dissemination of results and design recommendations
- **Bond performance database for innovative composite materials (inorganic-based matrices)**
- **Standardization of accelerated ageing tests**
- **Computational framework for long-term performance assessment**
- **Design and assessment recommendations**
- **Publications and knowledge dissemination**

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Filippo Gentili

Supervisor: Luís Simões da Silva

3DJOINTS: THREE-DIMENSIONAL BEHAVIOUR OF STEEL JOINTS

❑ OBJECTIVE

- The project aims at the development of a consistent design approach for prediction of the three-dimensional behavior of steel joints under arbitrary loading. Subsequently, the incorporation of the real joint behavior in the 3D structural model is intended.

❑ MOTIVATIONS

- Recent concerns regarding robustness requirements impose that joints present a minimum level of resistance for any arbitrary loading. In such conditions, resistance around the minor axis or to torsion may also be required. Designers are therefore faced to a strong need to predict the 3-D behavior of steel joints.

❑ METHOD

- The incorporation of the real behavior of the connections in the structural model (Fig.1) can only be achieved in a practical way with implementation of a generalized joint element (GJ). The generalized joint element (Fig. 2) is then composed by several generalized connections (GC) and a generalized column web panel (GWCP) as illustrated in Fig. 3. Each generalized connection element and generalized column web panel element contains the appropriate degrees-of-freedoms where each stiffness coefficient must correspond to the condensation of the appropriate component model. The generalized joint element comprises the sub-element of matrix (1).

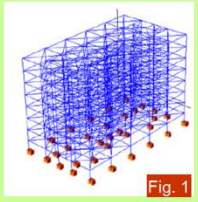
Fig. 1

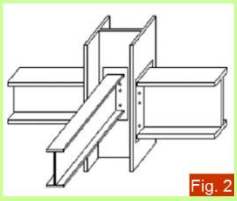
Fig. 2

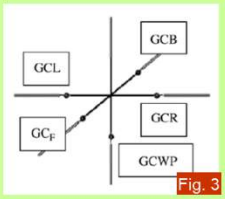

Fig. 3

$$GJ = \begin{bmatrix} GC_R^{MJ} & 0 & 0 & 0 & 0 \\ 0 & GC_L^{MJ} & 0 & 0 & 0 \\ 0 & 0 & GCWP & 0 & 0 \\ 0 & 0 & 0 & GC_F^{MI} & 0 \\ 0 & 0 & 0 & 0 & GC_B^{MI} \end{bmatrix} \quad (1)$$

❑ WEB PANEL CHARACTERIZATION

- Simplified mechanical model composed of extensional springs and rigid links are formulated. Two macro-elements are described, covering nodes connecting beams with the same (Fig.4) and with different (Fig. 5) beam depths. The developed FEM elements are implemented in OpenSees and are validated with some benchmark examples.

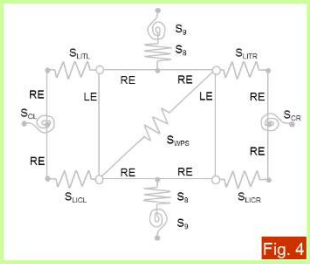

Fig. 4

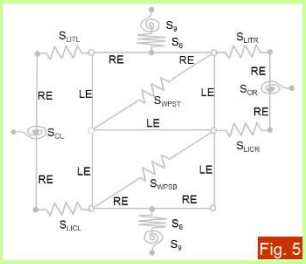

Fig. 5

S_{WPS}	Column web panel in shear
S_{WPST}	Column web top panel in shear
S_{WPSB}	Column web bottom panel in shear
S_{LITR}	Load introduction in Tensile - Right side
S_{LITL}	Load introduction in Tensile - Left side
S_{LICR}	Load introduction in Compr. - Right side
S_{LICL}	Load introduction in Compr. - Left side
S_{CR}	Connection - Right side
S_{CL}	Connection - Left side
S_s	Axial stiffness of column
S_g	Bending stiffness of column
RE	Rigid Element
LE	Link Element

❑ CHARACTERIZATION OF 3D JOINT BEHAVIOUR

- For the characterization of the joints under loading conditions activating the 3D behavior of the joints, experimental work is performed on different joint configurations (Fi.g. 6). Further numerical simulations will complement the limited number of tests. The joint behavior is at the end characterized in terms of moment-rotation curves for the different directions (and shear-deformation curves).

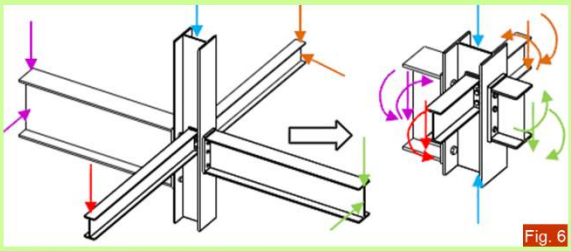
Fig. 6

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Institute for Sustainability and Innovation in Structural Engineering

Hélder S. Sousa

Supervisor: Jorge M. Branco

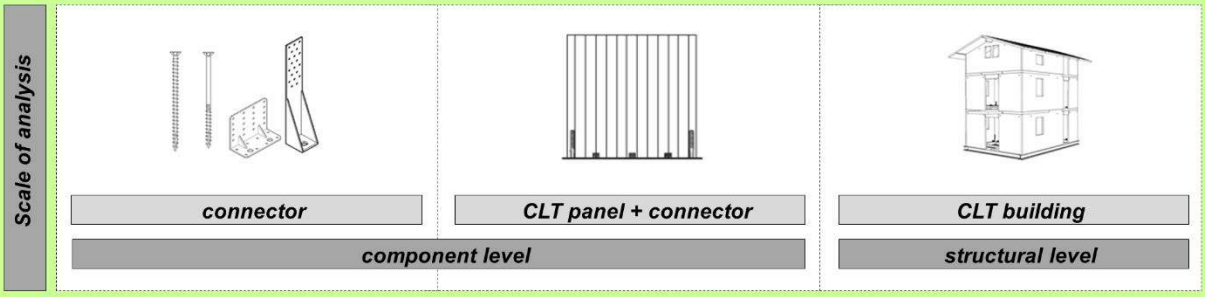
SEISMIC DESIGN OF MULTI-STOREY CROSS LAMINATED TIMBER BUILDINGS

❑ OBJECTIVES OF THE RESEARCH

- Current design procedures and standards lack of proper description and guidelines for the use of CLT, specially for seismic design. This research aims at the optimization of design methods and construction practices, by analysing the different components and scales of a CLT building structural system.
- This research also aims at the promotion of CLT among the scientific and professional communities, as to make them aware of its advantages and specific requirements for seismic design.

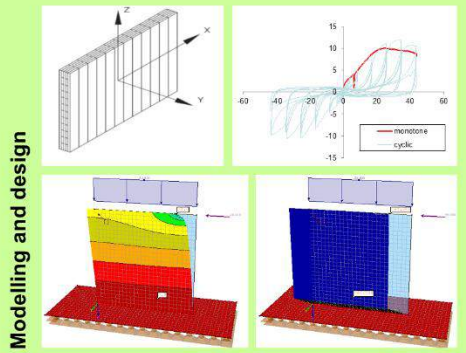
❑ METHODOLOGY

- The different components are analysed taking into account available analytical and numerical models and a multi-scale parametric analysis is considered to analyse the influence of different typologies of commonly used connections in CLT structures.
- The results from different experimental databases at different scales (component and structural levels) are considered for the calibration of the proposed guidelines.



❑ RESEARCH ACTIVITIES

- The research activity is divided into different tasks in order to evaluate several aspects of design and to obtain a more reliable and holistic framework. The initial part of the research considers the state-of-art of CLT multi-storey construction techniques and design including the structural performance of different components, the results of experimental campaigns and numerical modelling.
- The research also considers the analysis and numerical modelling of different properties of connections for CLT buildings, on both monotonic and cyclic behaviour. Different configurations of shear walls are designed analytically and different approaches for numerical modelling are considered. The results are compared to empirical results from different case studies, aiming at the optimization of the construction process.



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A DECISION SUPPORT SYSTEM FOR SLOPE MANAGEMENT AND REPAIR

Joaquim Agostinho Tinoco

Supervisors: A. Correia / P. Cortez / D. Toll

❑ BACKGROUND

- In the area of geotechnical transportation infrastructure, scarce research has been performed to assist decision makers in deciding whether a slope failure should be repaired. The few amount of data available is one of the main obstacles for decision making on slopes maintenance and rehabilitation. Moreover, the high number of factors affecting the slope stability is also an important aspect.
- Some of the most well known decision support systems found on the literature are supported mostly on subjective principles, using few data and based on simple data analysis tools, which may fail to detect complex relationships within the data (see Fig. 1).

Fig. 1

❑ PROJECT GOALS & TASKS

- This project intends to develop a decision support system (Fig. 2) for sustainable slopes management and repair, being a deep insight in quantitative risk management principles using advanced quantitative methods for slope hazard and risk zoning that intending to be applied for roads and railways can be extended for planning. It contemplates the following tasks:
  - a) develop a slope classification system intending to identify "similar slopes", (data mining techniques);
  - b) develop influence diagrams, sustained on powerful and flexible statistics analysis;
  - c) develop quantitative methods for slope hazard and risk assessment based in order to predict slope performance (Bayesians Networks);
  - d) Identify the key parameter that control slope instability phenomena and its effect, (sensitivity analysis and numeric simulations);
  - e) develop decision models for mitigation or repair strategies, combining the slope performance prediction, risk and costs analysis of the proposed solution, for a given specific time horizon;
  - f) develop a computation application, incorporating the different stages of the proposed decision support system and produce a guideline for planning, project and maintenance works for road.

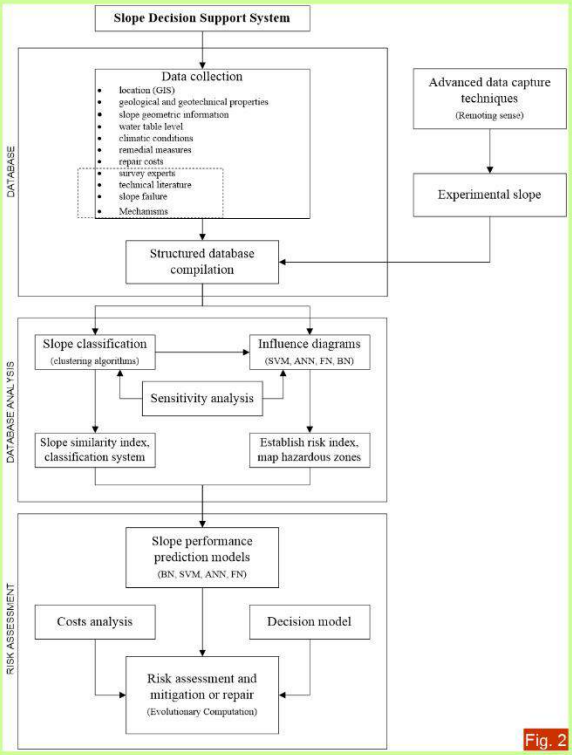

Fig. 2

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LILIANA MARQUES

Supervisor: Luís Simões da Silva

GENERALIZATION OF THE STABILITY VERIFICATION PROCEDURES OF NON-UNIFORM STEEL MEMBERS

❑ METHODS FOR STABILITY VERIFICATION OF NON-UNIFORM MEMBERS

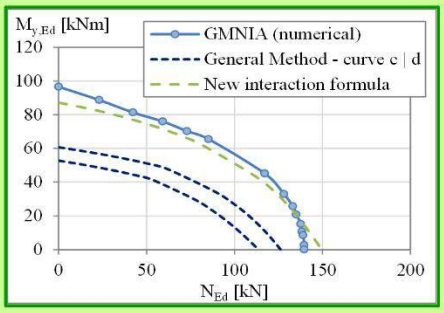
❑LIMITATIONS IN EC3 VERIFICATION PROCEDURES:

❑Interaction formulae (clauses 6.3.1 to 6.3.3 of EC3-1-1)
- Not applicable to non-uniform members:

❑General Method (clause 6.3.4 of EC3-1-1)
- Suitable however not reliable

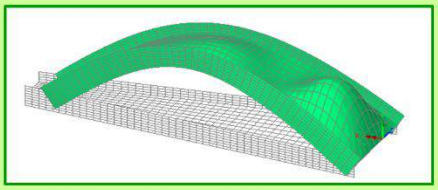
❑Non-linear numerical analysis (EC3-1-5 – Annex C)
- Powerful however there is not enough guidance

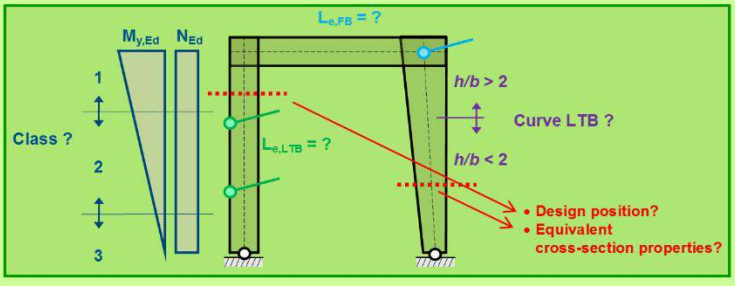
Barajas Airport, Madrid



❑OBJECTIVES OF THE PROPOSED WORK:

- ❑ Extension of analytical models for the relevant buckling modes for non-uniform columns, beams and beam-columns, to a wider range of loading and cross-section shape combinations;
- ❑ Development of a mechanical generalized slenderness model for the any stability phenomena of non-uniform isolated members;
- ❑ Properly account for the interaction between local cross-section and member bucking phenomena;





- ❑ Assessment and guidelines for the stability verification of complex structural systems and members with arbitrary boundary conditions;
- ❑ Contribution towards the revision of EC3-1-1, by achieving transparent, simple and straight-forward unified stability check procedures.

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EXPERIMENTAL AND NUMERICAL ANALYSIS OF COLD-FORMED STEEL STRUCTURAL BEAMS UNDER FIRE CONDITION

Luís Miguel S. Laím

Supervisor: João Paulo C. Rodrigues

❑ OBJECTIVE

- Study the effect of the instability phenomena on cold-formed steel beams under uniform fire conditions, basing on the results of a large programme of experimental tests and several numerical simulations.
- Investigate the influence of the cross-sections, the axial restraint to the thermal elongation of the beam and the rotational stiffness of the beam supports on the failure mode and on the critical temperature of this kind of beams.
- Provide experimental and numerical results for the development of simplified calculation methods for fire design of cold-formed steel beams, so that they may be considered for a future revision of Eurocode 3, Part 1.2.

Fig. 1 – Experimental set-up for CFS columns and beams.

❑ PARTNERS

1. **University of Coimbra, PT – Coordinator.**
2. PF – PERFISA – Fábrica de Perfis Metálicos, S.A.

❑ RESEARCH PLAN

- The experimental programme consisted of 36 structural fire tests of CFS beams, 12 of which were just simply supported beams (fig. 1), 12 others were the same beams but with restrained thermal elongation, and the others were beams with axial and rotational restraint. So, for each series of 12 fire tests, 3 tests for each type of beam were carried out (4 types of beams were studied (fig. 2)), in order to obtain a better correlation of the results.
- The numerical results were obtained through shell finite element analyses performed using the ABAQUS program (fig. 3).

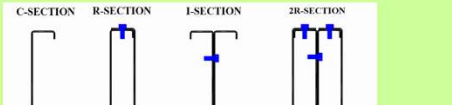

Fig. 2 – Scheme of the cross-sections of the tested beams

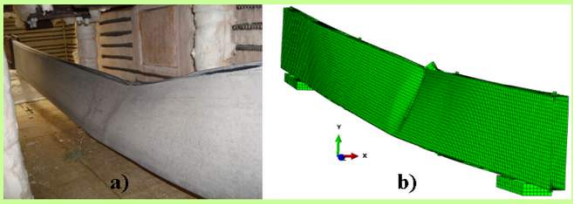

Fig. 3 – Experimental (a) and numerical (b) configuration of the deformed R beam with no restraints after fire test

❑ RESULTS AND CONCLUSIONS

- In general the axial restraint has a bad effect on the fire resistance of beams in contrast to the rotational restraint (fig. 4), but it must be remembered that their effect depends strongly on the relation between the axial stiffness of the surrounding structure and the elastic axial stiffness of the beam.
- The limit of 350 ºC for the maximum temperature of the CFS beams may be over-conservative, especially when the serviceability load of the beams is too low, less than 30% of load level.
- The critical temperature method presented in the Eurocode 3, Part 1-2 for hot rolled steel members should not be used for CFS beams since in this method the critical temperature almost does not change when the non-dimensional slenderness changes and that is far away from the truth.

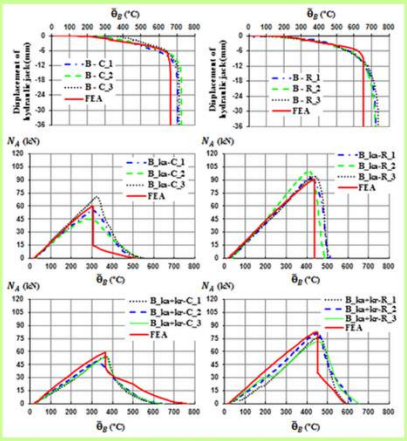

Fig. 4 – Comparison of the FEA and experimental results

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Nuno Mendes

Supervisor: Graça Vasconcelos

DISPLACEMENT-BASED METHODS FOR SEISMIC ASSESSMENT OF EXISTING MASONRY BUILDINGS

❑ INTRODUCTION

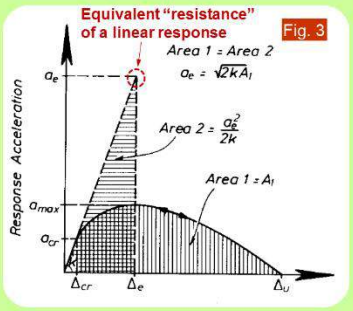
- According to the World Bank, from 1975 to 2005 the number of natural disasters increased approximately from 100 to more than 400. These events lead to important economic impacts, deaths and losses.
- It is predicted that in the current century the total fatalities caused by earthquakes increase for about 2.57±0.64 million. The recent seismic events caused severe damage in a considerable number of existing masonry buildings (Fig. 1 and 2), such as the earthquakes in Canterbury earthquakes (New Zealand, 2010 and 2011) and in L'Aquila (Italy, 2009).

Fig. 1 New Zeland (2011)

Fig. 2 Italy (2009)

- Existing masonry constructions present in general high seismic vulnerability, which is mainly due to the following aspects: (a) low tensile strength and ductility of masonry; (b) weak connections between orthogonal walls and between walls and horizontal diaphragms; (c) high mass of masonry; (d) flexible horizontal diaphragms; (e) absence of seismic requirements at its time of construction.
- Initially, the design methods for structures were based on the application of lateral forces proportional to the mass, in which the seismic assessment of the structure is evaluated through elastic forces. Between 1940 and 1950, the methods began to take into account the influence of the vibration period to determine the inertial forces. However, the design methods were still based on elastic forces. Between 1960 and 1970, the concept of ductility was first presented. This concept led to the development of force-based methods considering a reduction of the lateral forces through behavior factors (Fig. 3). These methods are present in the current seismic codes and are often used for design. Between 1980 and 1990, the concept that the deformation of structure relates better with the damage caused by different amplitudes of the seismic actions was implemented. Since, several authors have proposed new methods of seismic analysis based on displacement, namely for reinforced concrete and steel structures.

Fig. 3



❑ MAIN OBJECTIVES AND WORK PLAN

- This work aims to develop new displacement-based methods for design and assessment of masonry buildings.

TASK 1	Literature review on force-, displacement- and energy-based methods for masonry buildings	TASK 4	Development of new displacement-based methods for seismic assessment of masonry buildings	OUTPUTS
TASK 2	Definition of limit states and collapse mechanisms based on shaking table tests	TASK 5	Fragility curves for masonry buildings	
TASK 3	Application of traditional force-, displacement- and energy-based methods	TASK 6	Guidelines for design and assessment of masonry structures	

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Rui Marques

Supervisor: Paulo B. Lourenço

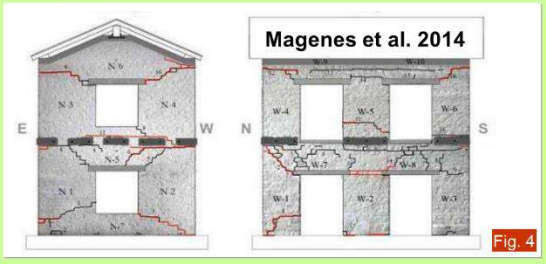
INFLUENCE OF CONNECTIONS AND FLOORS ON THE SEISMIC BEHAVIOUR OF ANCIENT MASONRY STRUCTURES

❑ BACKGROUND AND OBJECTIVE

- Out-of-plane mechanisms are the main cause of seismic damage and deaths in ancient masonry buildings (Fig. 1), which are mostly due to failure of connections and reduced diaphragm effect of floors. This is also a very actual experimental issue, e.g. Fig. 2.
- This work aims at the study of the influence of those factors on the seismic behaviour of old masonry structures, before and after strengthening with traditional and innovative techniques.
- The main objective is the development of a strategy with interrelated numerical models for the several structural and behavioural components, in order to establish a global analytical approach for seismic analysis of ancient masonry buildings.

❑ THE METHOD, AND EXISTING EXPERIMENTAL TESTS AS VALIDATION DATA

- Several approaches will be considered regarding the modelling at micro (structural details) and macro (building) levels, using finite, discrete and macro elements. Time-history, pushover and limit analyses will be considered.
- The work will be developed and validated against experimental tests of wall-to-wall and wall-to-floor connections, e.g. Fig. 3. There will also be considered shaking table tests of masonry structures, before and after strengthening with traditional and innovative techniques, being developed worldwide, e.g. Fig. 4.



❑ INNOVATIVE PROCEDURES FOR SEISMIC VULNERABILITY ASSESSMENT

- Finally, performance-based procedures for seismic assessment of ancient masonry buildings are to be developed.
- These procedures will consider the in-plane and out-of-plane components contemporaneously. An evaluation is then made at both global and local levels, respectively through control of displacements and through reduction of accelerations and stress concentration.

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Rui André Martins da Silva
Supervisor: Daniel V. Oliveira

DEVELOPMENT OF COMPATIBLE SOLUTIONS FOR THE REPAIR AND STRENGTHENING OF THE RAMMED EARTH BUILT HERITAGE

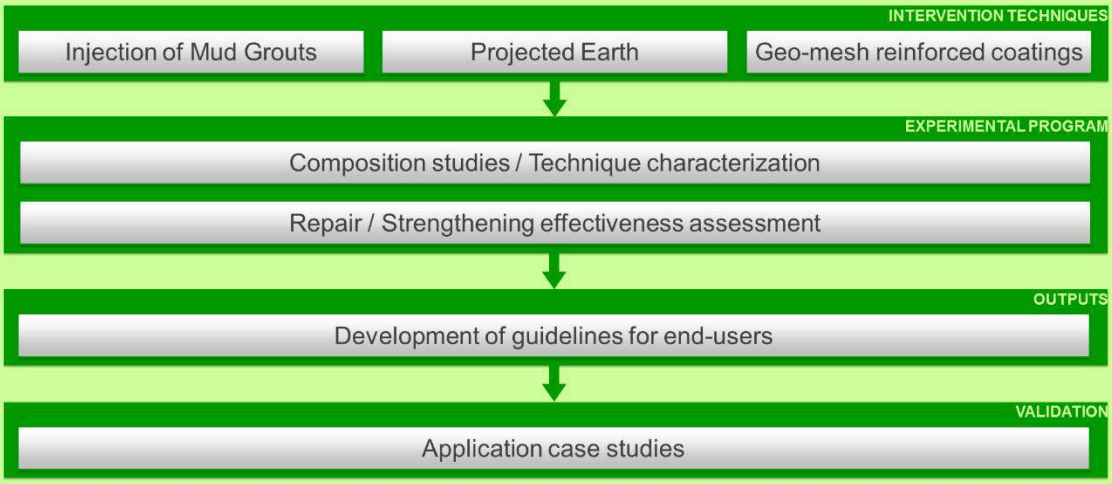
❑ Introduction

Rammed earth constructions are present in several countries around the world, where they constitute an important percentage of the built stock. This building technique also assumes great importance among the cultural heritage sites. Furthermore, rammed earth constructions are characterized by high seismic vulnerability are often found built on regions with important seismic hazard, which compromises their preservation and puts in danger the life of their inhabitants. The proper preservation of this heritage requires adopting compatible solutions and materials. With this respect, the use of mud grouts injection, projected earth and geo-mesh reinforced coatings appear nowadays as suitable solutions (Fig. 1).

This research work intends to contribute for the development of the aforementioned solutions and materials. This objective will be fulfilled by means of a detailed experimental program aiming at comprehend the behaviour of unmodified and modified mud grouts, projected earth mixtures and the efficiency of geo-mesh reinforced coatings. The knowledge generated will result into the development of guidelines and methodologies for the correct design and application of the solutions. Finally, the design methodologies will be validated through application case studies.

Fig. 1

❑ Workplan



U C FCTUC FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE DE COIMBRA
University of Minho School of Engineering

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

Books

5th IOMAC - International Operational Modal Analysis Conference

Proceedings of the fifth International Operational Modal Analysis Conference (IOMA13), Guimarães, 13-15 May, 2013

Editors: Álvaro Cunha, Luís F. Ramos, Elsa Caetano, Paulo B. Lourenço

Publisher: School of Engineering, University of Minho

ISBN: 978-972-8692-83-4

Year: 2013

Editions and print run number per edition: 150 prints

Foreword

These proceedings contain the papers presented at the 5th International Modal Analysis Conference, Guimarães, Portugal, May 13-15, 2013.

The Conference is jointly organised by University of Minho, University of Porto and University of Southern Denmark, with the institutional sponsorship of Brüel & Kjaer and Structural Vibration Solutions.

From the establishment of Experimental Stress Analysis in the decade of 40 of the last century to the present time, Experimental Structural Dynamics has undertaken an enormous progress, with the consolidation of testing techniques, the improvement and diversified use of sensors and acquisition systems, the development of modern algorithms for identification and detection of damage and the increased storage and data transmission capacities, which have determined an increased understanding of the structural behaviour of complex structures.

In this context, Operational Modal Analysis has played a very significant role enabling the use of more and more sophisticated and accurate algorithms and computational tools for the estimation of relevant dynamic structural properties based only on the measurement of the response to natural excitations.

This Conference covers all major aspects of Operational Modal Analysis, with focus on the following topics: identification techniques, measurement techniques, signal processing, noise control, comparison with traditional modal analysis, model validation, model updating, damage detection, load estimation, structural modification, response simulation, fatigue and vibration level.

Beyond a good number of interesting papers on these topics, presented by researchers, technical specialists and students, the Conference comprehends a Keynote Lecture by Dr. Bart Peeters and a Lecture of Honour by Dr. Reto Cantieni, two prestigious members of the OMA community.

As the previous IOMAC Conferences, held in 2005 and 2007 in Copenhagen, in 2009 at Ancona and in 2011 in Istanbul, scientists, applicants, vendors and students have the occasion to share their knowledge in this rather fascinating field and to improve their specific skill.

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8th RILEM International Symposium on Fibre Reinforced Concrete (BEFIB 2012): Challenges and opportunities

Proceedings of the 8th RILEM International Symposium, Guimarães, 19-21 September, 2012

Editors: J. Barros, J. Sena-Cruz, R. Ferreira, I. Valente, M. Azenha, S. Dias

Publisher: University of Minho

ISBN: 978-2-35158-132-2

Year: 2012

Editions and print run number per edition: 1st edition | 200 Prints

Foreword

Fibre reinforced concrete (FRC) is a cement based material reinforced with discrete fibres that has been used for more than 40 years in the construction industry by mixing or spray-up process. By restraining the crack opening propagation, fibres increase the post-cracking residual strength of cement-based materials, providing significant increase of load carrying and energy dissipation capacities, mainly when the structures have high degree of support redundancy.

Flooring and tunnelling have been the major part of FRC applications, but in the last 20 years FRC is becoming gradually used for the development of innovative structural systems through partial or total replacement of conventional reinforcement. FRC is also gaining an increase role on structural rehabilitation, being integrated in competitive and sustainable strengthening techniques. Steel fibres have been the most used, but synthetic, natural and hybrid systems are proving to be competitive alternative solutions. Nano fibres and textile systems are also widening the potentialities of FRC. The advances in the mixing design methods and the availability of high performance superplasticizers and admixtures that allow the development of FRC of self-compacting requisites and ultra-high fluidity are providing new opportunities for the innovation in the Civil Construction Industry. The continuous growth of knowledge of the fibre reinforcement mechanisms is supporting the development of new generation of FRC with tensile strain-hardening character, with properties that can be engineered in order to fit certain design purposes, such as durability, integrity and outstanding capacity of energy dissipation. The use of recycled fibres is also being explored for infra-structure applications.

These advances on FRC from the material and technological perspectives are being complemented by the development of more reliable design guidelines and constitutive models. For the first time, the CEB-FIP Model Code has dedicated two chapters for FRC, covering the material characterization and design approaches. This is a significant step towards a more reliable and rational use of FRC, which is expected to enlarge the applicability of this extraordinary composite material.

However, some challenges still exist in the technology, design and quality control. The possibility of using fibres of different material properties and geometric characteristics demands for rational methodologies that correctly explore the optimum phases of the reinforcing mechanisms of these fibres. A continuous effort should be done on the reliability of the design guidelines, by considering the influence of fibre distribution and orientation. The bridge between stress-crack width and stress-strain design formats requires a simple but credible methodology. The definition of the most appropriate test setups for the material characterization and to provide data for the development of constitutive models for design guidelines and advanced FEM-based analysis is not yet well consolidated. The quality control tests also require deeper discussion in order to adequately define those that are the best representative of different FRC applications.

These and other opportunities and challenges of FRC are discussed in these proceedings, which include 125 papers from authors coming from 36 countries and 123 institutions. On behalf of the Organizing Committee of BEFIB2012, I would like to express our deep gratitude for the valuable contribution of the members of the scientific committee. The support provided by the private sponsors and the collaboration of non-profitable institutions are also gratefully acknowledged.

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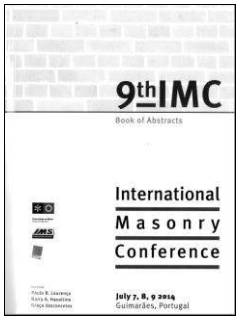
9th International Masonry Conference

Proceedings of the 9th International Masonry Conference (9IMC), Guimarães, 07-09 July, 2014



Editors: Paulo B. Lourenço, Barry A. Haseltine, Graça Vasconcelos

Publisher: University of Minho

ISBN: 978-972-8692-85-8

Year: 2014

Editions and print run number per edition: 1st edition | 500 prints

Foreword

The 9th International Masonry Conference took place at University of Minho, Guimarães, Portugal, between 7 and 9 July 2014, co-organized by University of Minho and the International Masonry Society. This Conference series has become one of the most important international events in the masonry world and takes place every four years.

Over 450 participants from more than 40 countries, registered in the conference, which provided a platform for discussion and exchange ideas and to gain new insights on the possibilities and challenges of new and ancient masonry construction. The future of modern masonry and of building conservation is limited only by the designer, contractor or industry inability to adopt a masonry perspective on a building challenge.

The present book includes contributions from authors all over the world in topics such as Innovation for Masonry, Masonry Materials and Testing, Earthquake Resistance, Repair and Strengthening, Conservation and Historic Buildings, Masonry and Building Physics, Architecture with masonry and Case Studies. Special sessions have been organized in Energy Efficiency, Sustainability and eco-materials, Earthen Architecture, and Masonry infills and earthquakes.
We thank all professional engineers and architects, building officials, educators, researchers, students, masonry industry and construction professionals, among other interested in the art and science of masonry, that accepted to exchange their experiences and to contribute to the success of masonry practice, research and innovation. We are sure that the valuable contributions of this book will be a precious guidance for others.

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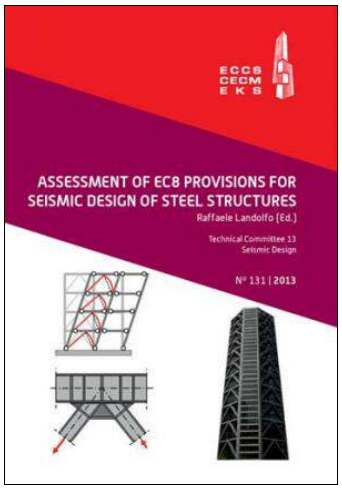
Assessment of EC8 Provisions for Seismic Design of Steel Structures



Editors: Raffaele Landolfo

Publisher: ECCS

ISBN: 978-92-9147-112-6

Year: 2012

Editions and print run number per edition: 1st edition

Foreword *(excerpt)*

This publication describes and discusses the aspects and issues in EN 1998-1:2004 that need clarification and/or further development. This book is the result of the activities carried out within the framework of technical Committee "Seismic Design" (TC13) of the European Convention for Constructional Steelwork (ECCS) in the field of codification and technical specifications. The publication is organized in twelve Sections and one Annex. The basic topics discussed in the text are "material overstrength", "selection of steel toughness", "local ductility", "design rules for connections in dissipative zones", "new links in eccentrically braced frames", "behaviour factors", "capacity-design rules", "design of concentrically braced frames", "dual structures", "drift limitations and second-order effects", "new structural types" and "low-dissipative structures".

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Casas de Madeira

Proceedings of the Timber houses Seminar, LNEC Lisbon, 17 April, 2013

Editors: Paulo B. Lourenço, Jorge M. Branco, Helena Cruz, Lina Nunes

Publisher: University of Minho

ISBN: 978-972-8692-82-7

Year: 2013

Editions and print run number per edition: 1st edition

Foreword

Constructive solutions entirely made of timber elements are common in countries of central and northern Europe (Austria, Finland, etc.). In those countries, traditional construction uses wood and wood based products for the most varied structural and non-structural applications. In Portugal, despite the revival of some interest in this type of architecture, the use of constructive solutions entirely made of timber elements is still concentrated in the construction of modular houses and on single family houses. In recent years, several companies launched housing solutions in wood for the national market, mostly exploring the environmental characteristics of timber construction and also considering the options given by the possibility of prefabricated and modular solutions. The developed technical efforts have focused on the development of constructive solutions and in ensuring their structural safety and stability.

This seminar is intended as a discussion forum of ideas and solutions in the field of timber houses, with the presentation of the latest trends, allowing to create a bridge to the more traditional solutions and some reflections on technical aspects of performance, energy efficiency and sustainability in construction.

This publication brings together contributions from many experts, national and international. The communications address the key issues on the national panorama of the timber houses sector, covering legislation, durability, fire behavior and seismic performance. Special attention is given to energy efficiency and sustainability evaluation. Several national and international achievements, whose value has been recognized through a significant number of national and international awards, are also presented in this publication.

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Characterization, Modeling, and Evaluation of Geotechnical System

Geotechnical special publication no. 248: Selected papers from the Proceedings of the
Geo-Hubei 2014 International Conference on Sustainable Infrastructure, Yichang, Hubei, China, 20-22 July, 2014

Editors: Louis Ge, James C. Ni, Antonio Gomes Correia, Mingzhou Bai

Publisher: ASCE

ISBN: 978-0-7844-7848-6 (e-book); 978-0-7844-1359-3 (CD)

Year: 2014

Editions and print run number per edition: Edition 2014 (e-book)

Foreword

ASCE-Geotechnical Special Publication 248 contains 13 peer-reviewed papers on the characterization, modeling, and evaluation of geotechnical engineering systems.

Topics include: soils and rock instrumentation and modeling; foundation failure and repair; and embankments and ground subsidence.

This GSP will be of interest to both researchers and practitioners in geotechnical engineering.

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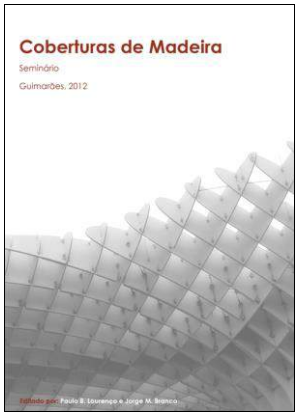
Coberturas de Madeira

Proceedings of the Timber roofs Seminar, Guimarães, 19 April, 2012



Editors: Paulo B. Lourenço, Jorge M. Branco

Publisher: University of Minho

ISBN: 978-972-8692-68-1

Year: 2012

Editions and print run number per edition: 1st edition

Foreword

Roof structures are probably the most significant building typology of timber buildings. Timber has always been present in the roof structures and it is in these structures that timber evidences its advantages over other materials. In Portugal, traditional roofs are made of timber, consisting of trusses with current spans up to 7 meters. With the Expo 1998, and the construction of the Atlantic Pavilion, began a new cycle for timber structures, particularly for large span roofs. Today, there are already many examples of swimming-pool, sports centers and warehouses roofs in Portugal, which are based on a timber framework structure.

The national market for timber roofs proves to be active, managing to attract several European companies. In Portugal there are several examples built by companies from Spain, Switzerland, Germany, Austria, etc.

The challenges that timber roofs face are the search for innovative solutions for structural systems, connections, shapes, materials, finishes, and also without forgetting the current concerns in the field of sustainability.

This seminar aims to mobilize and create awareness on architects, engineers and other national technicians to timber's structural capabilities, that are proven by numerous examples that have survived to the present day, and to the impact of new systems that allow bolder and aesthetically appealing solutions. Furthermore, timber remains an economical material, with a renewable origin and of easy obtaining.

This publication brings together contributions of national and international experts who have shown their work in the creation of iconic timber structures, in the presentation of innovative solutions in the conservation and rehabilitation of the built heritage and on the reflection on technical aspects of performance and sustainability in construction.

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Concrete properties and structural behaviour since early ages

E-book of the Workshop: Concrete properties and structural behaviour since early ages, Guimarães, 30th October 2013

Editors: Miguel Azenha, José Granja, Jacinto Silva

Publisher: University of Minho

ISBN: 978-989-95961-8-4

Year: 2013

Editions and print run number per edition: 1st edition

Foreword

Currently existing regulations for structural concrete (at a worldwide level) are revealing incapable of coping with the increasing demands of society in terms of serviceability behaviour and assurance of feasible maintenance-free periods. One of the main reasons for these limitations of existing codes is related to the simplicity of their design approaches that mostly disregard complexities associated to modern concrete compositions (e.g. with supplementary and/or recycled materials) and the multi-physics phenomena that influence behaviour since early ages. This situation has been directly acknowledged by Jost Walraven (former fib president and convenor of special activity group on MC2010), who recently stated that the next generation of regulations needs to come up with strategies that no longer rely solely on compressive strength for classification, but should simultaneously account for an actual set of properties and performance in the expected service environments (J. Walraven, 2013).
In agreement with the above reasoning the Structural Composites research group at ISISE/ UM has been working on advanced testing and modelling of concrete behaviour since early ages, with intricate collaborations with IFSTTAR (Institut Français des Sciences et Technologies des Transports de l'Aménagement et des Réseaux), ULB (Université libre de Bruxelles) and FEUP (Faculty of Engineering of the University of Porto). This workshop aims to disclose some of the most recent findings that result from the individual and collaborative works of these four institutions, in coincidence with the closure of two funding programs:

FCT – Pessoa Transnational Collaboration Project 441 (Hubert Curien Program) entitled: "Testing methods for E-modulus of concrete and mortar since very early ages: a round robin test series";
FCT National research Project – SeLCo - PTDC/ECM/099250/2008 entitled "Service life behaviour of concrete structures: a multiphysics approach to self-induced stresses".

This E-book contains a compilation of the 12 presentations performed in the Workshop disclosing the latest results regarding advanced testing and modelling of concrete behaviour since early ages.

The researches were performed thanks to the "Hubert Curien" Partnerships passed, on one hand, between IFSTTAR & the University of Minho (Pessoa project – Proc 441, together with the Portuguese Foundation for Science and Technology - FCT) and, on the other hand, between IFSTTAR & ULB (Tournesol project), . A special thank is addressed to the Campus France agency (http://www.campusfrance.org) for their management of these partnerships.

Financial support provided by FCT (Portuguese Foundation for Science and Technology) through PhD grants (SFRH / BD / 80682 / 2011) and (SFRH / BD / 74500 / 2010) to the second and third authors, respectively, to the research project PTDC/ECM/099250/2008, as well to the Research Unit ISISE is gratefully acknowledged.

The Town Hall of Guimarães is thanked for providing the photo of the Castle of Guimarães, which was utilized for the graphic identity of this event

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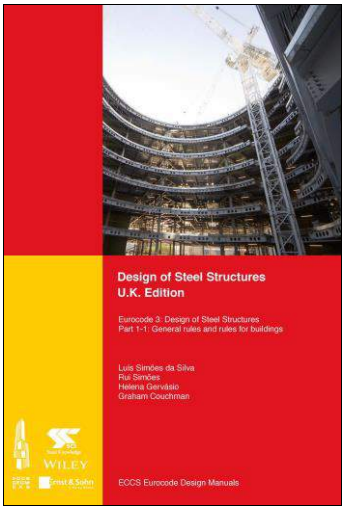
Design of Steel Structures

1st Edition, revised second impression



Authors: Luís Simões da Silva, Rui Simões ,Helena Gervásio and Graham Couchman

Publisher: ECCS – European Convention for Constructional Steelwork

ISBN ECCS: 978-92-9147-123-2
ISBN (Ernst & Sohn) 978-3-433-0313-53

Year: 2014

Editions and print run number per edition: 1st edition

Foreword

This book is the first in a series of joint SCI-ECCS publications, a series we believe will be extremely helpful in guiding UK designers through the changes that the Eurocodes represent. It is a derivative of the general ECCS book "Design of Steel Structures", and includes complementary UK-specific information relating to the National Annexes and common practice. The level of detail provided means this UK edition will help designers, whatever their previous experience, apply Eurocode 3 easily and correctly in the United Kingdom.

The book details the fundamental concepts of Eurocode 3, Part 1-1: General rules and rules for buildings and considers their practical application. Following a discussion of the Eurocode basis of design, including the principles of reliability management and the limit state approach, the steel material standards and their use alongside Eurocode 3 are covered. Structural analysis and modelling are presented in a chapter that will assist the designer in the early stages of that process. This is followed by a major chapter that presents the various design criteria and approaches that should be used for different types of structural member. The format of presentation is uniquely designed to ensure that rules for practical application are a true reflection of the Eurocode theory. The following chapters expand on the principles and application of elastic and plastic design of steel structures. Throughout the book, many design examples are used to facilitate the understanding of the reader and thereby enable a smooth transition from earlier national standards to the Eurocodes.

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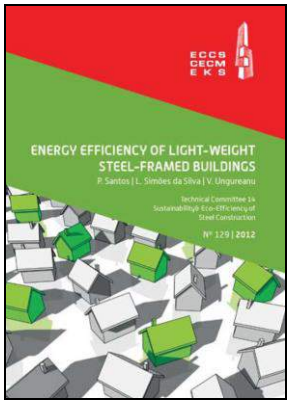
Energy Efficiency of Light-weight Steel-framed Buildings

European Convention for Constructional Steelwork (ECCS), Technical Committee 14 - Sustainability & Eco-Efficiency of Steel Construction



Authors: Paulo Santos, L. Simões da Silva, Viorel Ungureanu

Publisher: ECCS – European Convention for Constructional Steelwork

ISBN: 978-92-9147-105-8

Year: 2012

Editions and print run number per edition: 1st edition | 500 prints

Foreword

The Technical Committee TC14 "Sustainability and eco-efficiency of steel construction" was founded within the European Convention for Constructional Steelwork (ECCS) with the main goal of promoting the developments in industry, in research and teaching communities that lead toward increased understanding and capabilities in relation to sustainable steel construction.

One suitable approach to promote and disseminate sustainability and ecoefficiency of steel construction is to support the publishing of brochures, leaflets, scientific papers, "red books" or European recommendations, and design manuals addressing these issues. Therefore, several working groups were created within TC14 in order to define scope, contents and contributions from the TC14 members.

Three main themes were defined: (1) Energy-efficiency of steel-framed buildings; (2) Eco-design of steel-framed buildings; and (3) Integral lifetime design of bridges. Moreover it was agreed that energy efficiency is a top priority due to tightening regulation and new action plans of the EU.In this context, the present ECCS "red book" entitled "Energy Efficiency of Light-weight Steel-framed Buildings" is the first publication of the TC14. This publication intends to provide guidelines for achieving good thermal behaviour and high energy efficiency in cold-formed low-rise residential buildings, in order to reduce greenhouse gas emissions and energy bills, maintaining levels of thermal comfort of occupants.

In relation to the recent CEN standards on Sustainability of Construction Works, this publication copes with module B6 "Energy use to operate building integrated technical systems". The remaining modules addressed in these standards will be covered in future TC14 publications.

The book is structured in two main parts: (1) Design guidance; and (2) Design example. The first part is organised in seven chapters dealing with several relevant issues, namely: Sustainable energy; Climate characterization; Low-rise residential light-weight steel framing; Calculation methods to assess energy performance of buildings; Thermal bridges; Thermal inertia; and Design guidance. In the second part of this publication a case-study is presented for the design example: Low rise residential building in Portugal.

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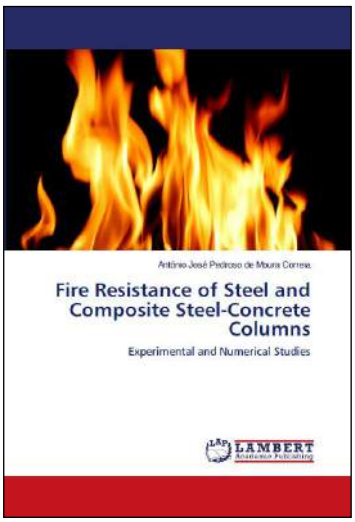
Fire Resistance of Steel and Composite Steel-Concrete Columns

Experimental and Numerical Studies



Editors: António José Pedroso de Moura Correia

Publisher: LAMBERT – Academic Publishing

ISBN: 978-3-659-53425-6

Year: 2014

Foreword

The purpose of this work was to assess the influence of several parameters on the fire resistance of steel and composite steel-concrete columns in buildings. The contact with brick walls, stiffness of the surrounding structure, load level, and slenderness of the columns, were the target of the study.

Experimental tests were performed on steel H columns embedded on walls, bare steel H columns and composite steel-concrete partially encased H columns with restrained thermal elongation. Results of the experimental tests were compared with numerical studies, with the purpose of providing valuable data for the development or improvement of analytical designing methods. A geometrical and material non-linear analysis with imperfections was performed with the finite element code ABAQUS. The major outcomes of this research work were proposals for the assessment of the temperature evolution within the cross-section of unevenly heated steel columns in contact with walls, proposals for the calculation of the critical temperatures and fire resistance of steel bare columns, and plastic axial force – bending moment diagrams for steel beam columns at elevated temperatures.

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FRPRCS-11: 11th International Symposium on Fiber Reinforced Polymer for Reinforced Concrete Structures

Proceedings of the 11th International Symposium on Fiber Reinforced Polymer for Reinforced Concrete Structures (FRPRCS-11), Guimarães, 26-28 June, 2013

Editors: J. Barros & J. Sena-Cruz

Publisher: University of Minho

ISBN: 978-972-8692-84-1

Year: 2013

Editions and print run number per edition: 1st edition | 200 Prints

Foreword *(excerpt)*

Fiber reinforced polymer (FRP) composites for the reinforcement and strengthening of concrete structures become one of the most attractive areas in the civil engineering field, involving numerous and very active technical and scientific communities, as well as agents with direct or indirect activities on the rehabilitation of the built patrimony and on the construction of more sustainable buildings and infra-structures. By taking advantages of the properties of fiber and matrix phases of a FRP system, combining these phases correctly, and using advanced production techniques, outstanding composites of engineered stiffness, strength and other aimed properties can be produced. In fact, non-corrodible FRP reinforcement systems of several configurations and fiber types are being combined with advanced cement based materials for the production of structures of higher life cycle and lower maintenance costs. Considerable efforts are also being done on the best use of FRP systems for the strengthening of concrete, masonry and timber structures. In this respect, significant advances on the exploring of the potentialities of FRP systems are being obtained, mainly by using pre-stress and post-tension techniques in the externally bonded reinforcement (EBR) and near surface mounted (NSM) strengthening techniques. It is also notable the development of pre-fabricated thin panels combining high stiff and strength FRP composites with ductile cement based materials in order to constitute very effective strengthening systems, capable of providing enhanced protection in terms of durability and resistance to high temperatures. The use of advanced monitoring systems capable of indicating the real efficacy of FRP systems is also being explored. The production technology of some FRP are especially appropriate for the development of self-monitored FRP systems, whose advantages can be used for new generation of internal reinforcements and more reliable and effective strengthening interventions. Significant advances on the characterization of instantaneous and long term behavior of FRP materials and structures reinforced and strengthened with FRP systems at different working-representative environmental conditions are also impressive. Improvements on the design and numerical assessment of the behavior of FRP reinforced and strengthened structures, by using more reliable models, are also notable.

This conference proceedings aims to be the present state-of-the-art on the use of FRP for the reinforcement and strengthening of concrete structures. For this purpose, it includes peer reviewed papers in the topics proposed by the organization of the FRPRCS-11. To contribute for the assessment of the reliability of available design guidelines, analytical formulations and numerical models, as well as to stimulate the development of new design approaches, the FRPRCS-11 proposed a competition for the prediction of the behavior of a CFRP strengthened concrete beam (SC@UM competition). These and other opportunities, challenges and initiatives of FRP are discussed in this conference proceedings, which includes 148 papers from authors coming from 35 countries. On behalf of the Organizing Committee of FRPRCS-11, we would like to express our deep gratitude for the valuable contribution of the members of the scientific and steering committees. The support provided by the private sponsors and the collaboration of non-profitable institutions are also gratefully acknowledged.

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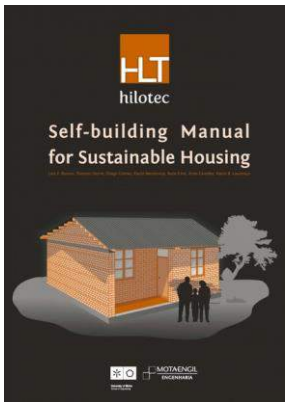
HiLoTec - Self-Building Manual for Sustainable Housing

Simple, economical and sustainable earth technology to build your own house



Authors: Luís F. Ramos, Thomas Sturm, Diogo Gomes, Paulo Mendonça, Rute Eires, Aires Camões, Paulo B. Lourenço

Publisher: University of Minho

ISBN: 978-972-8692-88-9

Year: 2014

Editions and print run number per edition: 1st Edition | 90 prints

Foreword

The future of the construction industry will require changes at many levels. One is the ability of companies to adapt to new challenges, converting needs to opportunities and simultaneously contributing to the solving of social and environmental problems. In the coming decades we will see a change in attitude in the industry, with a strong tendency to adopt natural and recycled materials, as well as bet on green technology and social innovation oriented to emerging countries.

On the other hand, emerging countries have a high demand for housing construction on a large scale, but the current techniques in the developed countries for building requires a large amount of natural resources and skilled labor. This contextualization brings sustainability problems for the construction sector in emerging countries, often with scarce natural resources and with the construction sector underdeveloped.

Through a cooperative action between the construction company Mota-Engil Engineering and the University of Minho in Portugal, a construction technology was developed based on the use of Compressed Earth Blocks as part of a social concept for innovative small houses, favoring the adoption of local and natural materials and with the main premise of being dedicated to self-construction.

The HiLoTec project - Development of a Sustainable Self-Construction System for Developing Countries was based on this idea. One of the several results of this project is this construction manual.

To Mota-Engil the project was a platform for incubation of knowledge about earth construction and to obtain a constructive solution validated technically and scientifically, suitable to be implemented in the markets where it operates.

For the University of Minho the project was an opportunity to strengthen skills in research, laboratory and scientific development, through the development of engineering studies, architecture and sustainability, as well as supporting the doctoral scholarships and dissemination of scientific publications.

May the knowledge of this project be of benefit, in the future, for the welfare of those who build a HiLoTec house.

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I Congresso Luso-africano de Construção Metálica Sustentável

Editors: Luís Simões da Silva |Filipe Santos |Resende Nsambu | Vicente Miranda | José Dias | Molares d'Abril | Carlos Camuenho

Publisher: CMM – Associação Portuguesa de Construção Metálica e Mista

Sales:CMM

ISBN: 978-989-95605-3-6

Year: 2012

Editions and print run number per edition: 1st edition | 200 prints

Prefácio

A Associação Portuguesa de Construção Metálica e Mista (CMM) promoveu, no dia 27 de Julho de 2012, o 1ºCongresso Luso-Africano de Construção Metálica Sustentável, que decorreu na Universidade Agostinho Neto em Luanda, Angola. A CMM pretende divulgar as mais recentes inovações no âmbito das estruturas metálicas sustentáveis, dar a conhecer as linhas de orientação da investigação neste campo e difundir as principais inovações, com o objectivo de promover as potencialidades de parcerias entre Portugal e países africanos na construção metálica sustentável.

Foram apresentadas obras importantes realizadas em África, mostrando o que de melhor se faz neste continente, bem como o trabalho desenvolvido pelas empresas Portuguesas.

O congresso foi, também, um local privilegiado para o intercâmbio de ideias e experiências entre os vários intervenientes na concretização dos empreendimentos representativos deste sector de construção (donos de obra, projectistas, construtores, etc.).
As sessões do Congresso decorreram em simultâneo com uma Exposição Técnica.

Índice

II Congresso Luso-africano de Construção Metálica Sustentável

Livro de actas do II CLA, Maputo, Moçambique, 19 de Julho de 2013

Editors: Luís Simões da Silva, Filipe Santos, Américo Dimande, Vicente Miranda, Tiago Mendonça

Publisher: CMM – Associação Portuguesa de Construção Metálica e Mista

ISBN: 978-989-95605-6-7

Year: 2013

Editions and print run number per edition: 1st edition | 250 prints

Prefácio

A 1ª edição do Congresso Luso-Africano de Construção Metálica Sustentável, realizada em 2012, em Luanda, Angola, obteve um sucesso assinalável, quer em número e qualidade de artigos apresentados, quer em número de congressistas e empresas apoiantes. Assim, a cmm resolveu dar continuidade a este evento realizando o 2º Congresso Luso-Africano de Construção Metálica Sustentável, em Maputo, Moçambique.

O sector da construção metálica tem-se afirmado como um motor de inovação e exportação, quer no sector das estruturas para a exploração mineira e hidrocarbonetos, , quer em pontes e quer ainda no sector dos edifícios. O aço pode facilmente ser produzido em África originando riqueza através do aumento das exportações e garantindo soluções mais económicas que a construção em betão armado. Além disso, num período em que as preocupações com as alterações climáticas se tornam cada vez mais avassaladoras, a construção em aço permite soluções que minimizam a emissão de CO2, já que é o único material infinitamente reciclável sem perda de propriedades ou valor. Pelas razões expostas, o aço tem potencial para se tornar o material de eleição na construção em África.

Com este evento pretende-se alertar os decisores locais para as diversas vantagens da construção metálica, que deverão ser tidas em conta em cada novo projeto. Incentivar a criação dum "cluster do aço" que reúna todos os intervenientes da fileira da construção metálica de forma a garantir um crescimento deste sector e por consequência o crescimento dos respetivos países. Divulgar a construção metálica pelas empresas e pelos técnicos locais, criando um evento onde seja possível reunir os vários intervenientes deste sector potenciando a transferência de conhecimento entre eles. É também objetivo deste evento a divulgação pelas empresas portuguesas da construção metálica nos países africanos, mostrando o que de melhor se faz nestes países, bem como, evidenciar aos decisores locais as capacidades das empresas portuguesas que já atuam nestes mercados diferenciando-as positivamente em relação à concorrência.

Finalmente, assinalo a publicação deste livro de atas do congresso, o qual revela bem a adesão da comunidade do aço (técnica e científica) a esta iniciativa, com um número de artigos que demonstra uma actividade e qualidade muito acima da média.

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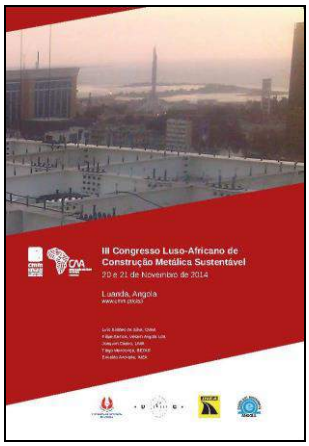
III Congresso Luso-africano de Construção Metálica Sustentável

Livro de actas do III CLA, Luanda, Angola, 20 e 21 de novembro de 2014



Editors: Luís Simões da Silva, Filipe Santos, Joaquim Caeiro, Tiago Mendonça, Erivaldo Andrade

Publisher: CMM – Associação Portuguesa de Construção Metálica e Mista

ISBN: 978-989-99226-0-0

Year: 2014

Editions and print run number per edition: 1st edition | 200 prints

Prefácio

Após a realização da 1ª edição do Congresso Luso Africano de Construção Metálica Sustentável, em 2012, em Luanda, Angola e da 2ª edição, em 2013, em Maputo, Moçambique, onde se obteve um sucesso assinalável, quer em número e qualidade de artigos apresentados, quer em número de congressistas e empresas apoiantes, a cmm resolveu dar continuidade a este evento realizando o III Congresso Luso-Africano de Construção Metálica Sustentável, em Angola, em parceria com a Universidade Metodista de Angola.

O sector da construção metálica tem-se afirmado como um motor de inovação e exportação, quer no sector das estruturas para a exploração mineira e hidrocarbonetos, , quer em pontes e quer ainda no sector dos edifícios. O aço pode facilmente ser produzido em África originando riqueza através do aumento das exportações e garantindo soluções mais económicas que a construção em betão armado. Além disso, num período em que as preocupações com as alterações climáticas se tornam cada vez mais avassaladoras, a construção em aço permite soluções que minimizam a emissão de CO2, já que é o único material infinitamente reciclável sem perda de propriedades ou valor. Pelas razões expostas, o aço tem potencial para se tornar o material de eleição na construção em África.

Com este evento pretende-se alertar os decisores locais para as diversas vantagens da construção metálica, que deverão ser tidas em conta em cada novo projeto. Incentivar a criação dum "cluster do aço" que reúna todos os intervenientes da fileira da construção metálica de forma a garantir um crescimento deste sector e por consequência o crescimento dos respetivos países. Divulgar a construção metálica pelas empresas e pelos técnicos locais, criando um evento onde seja possível reunir os vários intervenientes deste sector potenciando a transferência de conhecimento entre eles. É também objetivo deste evento a divulgação pelas empresas portuguesas da construção metálica nos países africanos, mostrando o que de melhor se faz nestes países, bem como, evidenciar aos decisores locais as capacidades das empresas portuguesas que já atuam nestes mercados diferenciando-as positivamente em relação à concorrência.

Finalmente, assinalo a publicação deste livro de atas do congresso, o qual revela bem a adesão da comunidade do aço (técnica e científica) a esta iniciativa, com um número de artigos que demonstra uma atividade e qualidade muito acima da média.

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IX Congresso de Construção Metálica e Mista e I Congresso Luso-Brasileiro de Construção Metálica Sustentável

Livro de actas do IXCMM, Porto, Portugal, 24 e 25 de Outubro de 2013

Editors: Luís Simões da Silva, Filipe Santos, Américo Dimande, Vicente Miranda, Tiago Mendonça

Publisher: CMM – Associação Portuguesa de Construção Metálica e Mista

ISBN: 978-989-95605-7-4

Year: 2013

Editions and print run number per edition: 1st edition | 350 prints

Prefácio

O IX Congresso de Construção Metálica e Mista coincide com o 16º aniversário da cmm.

Ao cabo destes 16 anos, a Associação está prestes a atingir a "maioridade", facto que permite repensar assuntos com alguma maturidade e perspetivar novas iniciativas. Uma primeira iniciativa diz respeito à realização do 1º Congresso Luso-Brasileiro de Construção Metálica Sustentável, o qual ocorre em simultâneo com o IX Congresso. A realização conjunta destes dois Congressos proporcionará a toda a comunidade um conhecimento mais aprofundado sobre os trabalhos técnicos e científicos de maior impacto que tenham ocorrido em Portugal e no Brasil. Por outro lado, corresponde também ao culminar de uma profícua história de cooperação e colaboração entre investigadores e engenheiros dos dois países. Espera-se que este 1º Congresso Luso-Brasileiro seja bem sucedido e que próximas edições, a repartir entre o Brasil e Portugal, possam incrementar o sucesso da construção metálica e mista nos dois países. No contexto destes congressos, sublinha-se a realização de sessões plenárias por individualidades nacionais e internacionais de relevo em várias áreas temáticas (arquitetura, produção de estruturas metálicas, regulamentação, grandes projetos, sustentabilidade).

Finalmente, refere-se o lançamento de mais um manual da cmm dedicado à conceção e construção de estruturas em "aço leve" (Light Steel Framing – LSF), o qual se espera vir a ser útil aos agentes neste tipo de solução estrutural.

Uma segunda iniciativa da cmm, igualmente relevante, refere-se à realização da ISCE 2013 – International Steel Construction Exhibition, que decorre em paralelo com os congressos, na EXPONOR, no âmbito da CONCRETA - Feira Internacional da Construção para uma Regeneração Urbana Sustentável. Em Portugal, é a primeira grande exposição internacional dedicada exclusivamente ao setor da construção metálica e mista, e pretende promover a construção metálica e mista num contexto internacional, com foco na Península Ibérica, países lusófonos e da Europa do sul, não descurando a sua perspetiva industrial, produtiva, científica e técnica.

Por último, releva-se a criação da marca Portugal Steel (http://portugalsteel.com) em 2013. O projeto Portugal Steel, encerra em si a ambição de todo um setor empresarial cuja importância para a economia nacional se tem mostrado vital, através da enorme dinâmica das empresas deste setor, e da sua forte componente de exportação. Um dos objetivos do Portugal Steel consiste em atrair a atenção dos decisores públicos e privados, quer locais, quer nacionais, através do reconhecimento dos benefícios da construção metálica e das vantagens decorrentes de uma aposta estratégica neste setor. Tem sido realizado um conjunto de eventos Portugal Steel em todo o território nacional bem como publicitado nos media as vantagens da construção metálica, nomeadamente face às novas exigências de sustentabilidade e competitividade. Perante um cenário dramático do setor da construção actual, tem-se realçado o papel do setor da construção metálica na recuperação económica e social de Portugal, tendo como ponto de partida a dinâmica de internacionalização que as empresas deste setor têm vindo a demonstrar, a qual tem permitido a sobrevivência de grande parte delas, assim como a manutenção dos postos de trabalho de milhares de Portugueses.

Índice

Manual de Dimensionamento de Estruturas Metálicas

(3ª edição – 2014)

Eurocódigo 3: Projeto de Estruturas Metálicas, Parte 1.1: Regras gerais e regras para edifícios.

Editors: CMM – Associação Portuguesa de Construção Metálica e Mista

Publisher: CMM

ISBN: 978-989-95605-9-8

Foreword

Neste livro, denominado por Manual de Dimensionamento de Estruturas Metálicas, são apresentados os conceitos teóricos de base, bem como as principais disposições e modelos regulamentares aplicáveis ao cálculo e dimensionamento de elementos (pilares, vigas, escoras, tirantes, etc…) em estruturas metálicas correntes. Para além de fornecer os conceitos teóricos necessários para uma boa compreensão dos fenómenos envolvidos, este manual pretende essencialmente ser uma ferramenta de apoio à utilização da nova regulamentação europeia de cálculo e dimensionamento de estruturas metálicas – Eurocódigo 3: Projeto de Estruturas de Aço, Parte 1-1: Regras gerais e regras para edifícios; de forma a cumprir este objetivo, no final de cada capítulo são apresentados diversos exemplos de aplicação resolvidos, relativos à análise de estruturas metálicas e ao dimensionamento de elementos submetidos aos diversos tipos de esforços, atuando isoladamente ou combinados.

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Modelagem de Estruturas de Aço e Mistas

Editors: Vellasco, P, Lima, L., Andrade, S., Vellasco, M. e Simões da Silva L.

Publisher: Elsevier Editora, Ltda

ISBN: 978-85-352-7197-3

Year: 2014

Editions and print run number per edition: 1st edition

Foreword *(excerpt)*

Os autores apresentam uma importante contribuição sobre os fundamentos da modelagem de estruturas, acompanhados de um conjunto de exemplos que ilustram distintos aspectos da investigação sobre estruturas de aço e mista: análise experimental, numérica e computacional.

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fib commission 5. Seminar on durability of concrete structures

Proceedings of the *fib* commission 5 Seminar on durability of concrete structures, Guimarães, 8 May, 2014

Editors: Brett Pielstick, Jose C. Matos, Miguel Azenha, José Granja, Hugo Guimarães

Publisher: University of Minho

ISBN: 978-989-95961-9-1

Year: 2014

Editions and print run number per edition: E-Book (on-line)

Foreword

Commission 5 and the fib in conjunction with Professor Jose Matos and Minho University are pleased to provide this free seminar on the Durability of Concrete Structures. Commission 5 is one of about ten Commissions organized by the fib that gather experts in the field from across the world to collaborate and develop state of the art and technical reports as well as codes for the advancement of durability practices for the industry worldwide. This first of its kind seminar will provide unique access to these experts and the current and past work done within Commission 5 along with topics from these experts individual research and work applying durability principles to practice. Durability is a key component to the sustainability of concrete structures and serves a vital role in the design, construction and rehabilitation of these structures. We have also invited several distinguished local speakers to participate and provide there insight to the local industry. We invite you to participate in this unique experience and training that we hope will spark a desire for further research in durability of concrete structures and the application of these principle in everyday practice.

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SPREB-FRP 2014: 2nd Seminar on the Design of RC Structures Strengthened in FRP Materials

E-Book of SPREB-FRP 2014 Seminar, Guimarães, 19 September, 2014

Editors: José Sena-Cruz, Patrícia Silva, Pedro Fernandes, Mário Coelho

Publisher: University of Minho

ISBN: ISBN 978-989-8793-00-3

Year: 2014

Editions and print run number per edition: 1st edition

Foreword

Over the last two decades, extensive research has been developed on the strengthening of reinforced concrete (RC) structures using the externally bonded reinforcement (EBR) technique with fiber reinforced polymer (FRP) materials. This technique yielded several scientific publications, design guidelines and practical projects, worldwide. More recently, the near-surface mounted (NSM) FRP reinforcement technique has attracted an increasing amount of research, as well as practical applications. The NSM technique consists of inserting FRP bars into saw cuts grooves made in the concrete cover of the elements to be strengthened (see Fig. 1). The FRP is fixed to concrete with a groove filling material, e.g. epoxy adhesive. The NSM technique became a real alternative to the EBR one, due to the several advantages, namely: (i) reduction of amount of site installation work; (ii) less prone to the debonding; (iii) easier to anchor into adjacent members to prevent debonding failures; (iv) higher strengthening effectiveness; (v) more protected by the concrete cover and so are less exposed to accidental impact and mechanical damage, fire, and acts of vandalism; (vi) the aesthetic of the strengthened structure is virtually unchanged; (vii) in some cases, the ultimate strength of FRP can be reached. When compared with the EBR, the existing knowledge on the NSM reinforcement is much more limited. However, international institutions, such ACI (American Concrete Institute) recently included in the document ACI 440.2R-08 design guidelines for the flexural strengthening with the NSM technique and fib (Federation Internationale du Béton) TG 9.3 are currently considering revisions to their documents to include NSM-related provisions.

The SPREBFRP 2014 included 4 keynote lectures: Prof. Gonçalves da Silva from Univ. Nova of Lisbon, Prof. João Ramôa Correia from Univ. of Lisbon, Prof. Luis Juvandes from Univ. of Porto and Eng. Filipe Dourado from S&P, on the durability and long-term behavior of RC strengthened with FRP materials. Additionally the main results obtained in the Cutindur - Long-term structural and durability performance of concrete elements strengthened with the NSM technique R&D Project were also presented and discussed in the SPREBFRP 2014 seminar.

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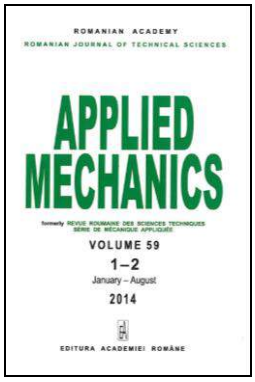
Stability and Nonlinear Analysis of Steel Structures: Research Advances

SPECIAL ISSUE, The Romanian Journal of Technical Sciences, Applied Mechanics, 59(1-2), Jan-Aug 2014 (2014).



Editors: Dubina, D., Snijder, B. and Simões da Silva L. (guest editors)

Publisher: Editura Academiei Române

ISBN: ISSN 0035-4074

Year: 2014

Editions and print run number per edition: Special edition, published 3 times a year

Foreword *(excerpt)*

Scientifically, buckling is a mathematical instability, leading to a failure mode. The formal meaning of the notion is found in engineering and sciences, concerning stability of systems. Broadly speaking, structural stability can be defined as capacity of a slender structure to recover equilibrium.

Stability is an essential requirement for all structures. Theoretically, for a structural system, buckling is caused by a bifurcation in the solution to the equations of static equilibrium. At a certain stage under an increasing load, further load is able to be sustained in one of two states of equilibrium: an undeformed state, or a laterally-deformed state. In practice, buckling is characterized by a sudden failure of a structural member subjected to high compressive stress, where the actual compressive stress at the point of failure is less than the ultimate compressive stresses that the material is capable of withstanding. Failure occurs in a distinct direction compared to the direction of the applied load.

To evaluate the behaviour of a slender structure which might lose its stability according to the previous definition, three characteristic ranges of the load deformation behaviour should be considered:
– the pre-critical range , i.e. $P \in (0, Pcr]$ defining the domain of *Structural stability*;
– the critical point (bifurcation of equilibrium), $P = Pcr$;
– the post-critical range, i.e. $P > Pcr$ the *Structural instability* domain.
Since metal structures, steel in particular, are slender, they are most prone to instability problems; hence the research on steel structures focussed on stability.

Although the stability of bars was first studied over 250 years ago (Euler's paper was published in 1744), adequate solutions are still not available for many problems in structural stability. So much has been and is being studied and written in the field of structural stability, that one may well wonder why, after such intellectual and financial efforts, there are no definite solutions to these problems.
Numerical facilities and advanced FE codes make it possibly today to calculate and/or simulate accurately the behaviour of complex structures. However, for slender structures highly sensitive to buckling, there are still difficulties for a reliable evaluation of its stability.

The topics of the papers included in this volume are diverse enough, tackling stability problems of steel structures with thin and tick walled bar members, open and hollow sections, plated structures and curved sandwich panels. There are theoretical, numerical and experimental approaches and combinations of them used in solving stability problems. The 12 papers have been framed into two parts:

Part I: Theoretical background, numerical and experimental advanced studies – 7 papers;
Part II: Design codification oriented studies – 5 papers.

36 authors from 11 European Countries have contributed with their research works to this Special Issue of the Romanian Journal of Technical Sciences. We are expressing our gratitude to all of them.
We are also grateful to the reviewers for the time and effort they spent evaluating the papers.
Thanks are also due to Dr. Luigi VLADAREANU and Dr. Dan DUMITRU of Institute of Solid Mechanics of the Romanian Academy, Bucharest, for the editorial work.
The guest editors hope that this special issue gives an overview of current research activities contributing to the stability and nonlinear analysis of steel structures.

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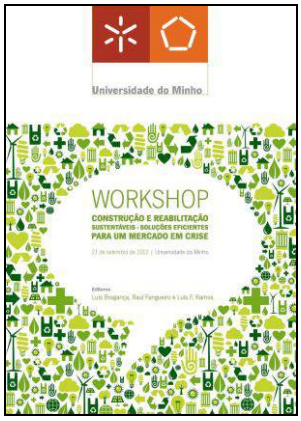
Workshop Construção e Reabilitação Sustentáveis

Soluções Eficientes para um Mercado em Crise, Guimarães, 21 September, 2012



Editors: Luís Bragança, Raul Fangueiro, Luís F. Ramos

Publisher: University of Minho

ISBN: 978-989-96543-5-8

Year: 2012

Editions and print run number per edition: 1st edition | 50 prints

Foreword

Currently, the Construction Industry is investing on conservation and sustainable rehabilitation of built heritage through innovation, research and development. For the sector is of prime importance the modernization and to increased competitiveness of technicians, implying the availability of senior specialist with postgraduate training that fits the profile for a Sector subjected to strong international competition and knowledge-intensive .

In this context, it is desirable that the Sector's players acquire advanced knowledge and skills in civil engineering, in particular as regards the designing, developing new products, processes and building systems sustainable and technologically advanced, ensuring the sustainability of construction and/or rehabilitation of buildings throughout their life cycle.

The MSc course in Sustainable Construction and Rehabilitation has produced relevant knowledge in these areas, mainly through the work of thesis undertaken by students in areas of high technical and scientific relevance, such as advanced materials, energy rehabilitation, rehabilitation, low-cost housing, practical sustainable urban regeneration, among others.

This Workshop on Sustainable Construction and Rehabilitation - Solutions for an Efficient Market in Crisis, aims to be a meeting place for those interested in these topics, taking as a time of sharing ideas, having as background the presentation of some works produced under this master program.

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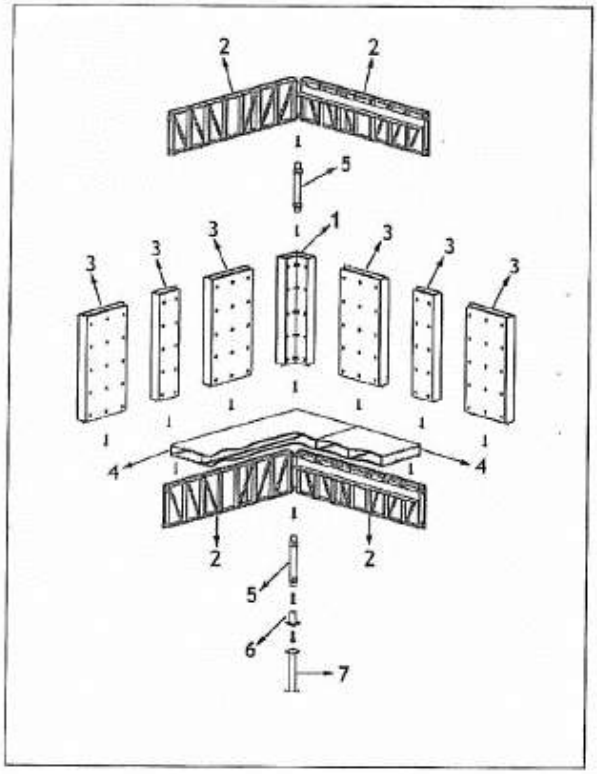
Patents

Epígrafe ou Título: PROCESSO CONSTRUTIVO MODULAR

Resumo:

O PRESENTE INVENTO DIZ RESPEITO A UM PROCESSO CONSTRUTIVO ATRAVÉS DE TRÊS TIPOS DE COMPONENTES ESTRUTURAIS INDICATIVA MAS NÃO LIMITATIVAMENTE EM AÇO: COMPONENTES DE BASE, VERTICAIS (1), HORIZONTAIS (2), COMPONENTES INTERMÉDIAS, VERTICAIS (3) E HORIZONTAIS (4) E UM PILAR DE UNIÃO (5), SENDO QUE AS COMPONENTES DE BASE SE UNEM ENTRE SI ATRAVÉS DO DITO PILAR, PODENDO ESTE SER LIGADO POR UM FIXADOR (6) A UMA ESTACA METÁLICA (7) CRAVADA NO SOLO. O PROCESSO CONSTRUTIVO MODULAR PROCEDE À AMARRAÇÃO DAS COMPONENTES DE BASE HORIZONTAL (2), SOBRE AS QUAIS ASSENTAM AS COMPONENTES INTERMÉDIAS HORIZONTAIS (4). ENTRE DUAS COMPONENTES DE BASE HORIZONTAIS SÃO COLOCADOS AS COMPONENTES DE BASE VERTICAIS (1) E, ENTRE ESTAS, AS COMPONENTES INTERMÉDIAS VERTICAIS (3). TODAS AS COMPONENTES TÊM DIMENSÕES PREVIAMENTE PADRONIZADAS, CONSTRUÍDAS A PARTIR DE UMA UNIDADE CONCEPTUAL MÍNIMA DE 600 MM POR 600 MM QUE FORMA UMA GRELHA QUE SERVE DE BASE CONSTRUTIVA A TODOS OS ELEMENTOS QUE COMPÕEM CADA MÓDULO. OU SEJA, TODOS OS MÓDULOS E RESPECTIVAS COMPONENTES TERÃO DIMENSÕES MÚLTIPLAS DESTA UNIDADE.

Figura publicada no BPI



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[Continued on next page]

(54) Title: TUBE-JACK SYSTEM AND METHOD FOR TESTING IRREGULAR MASONRY WALLS

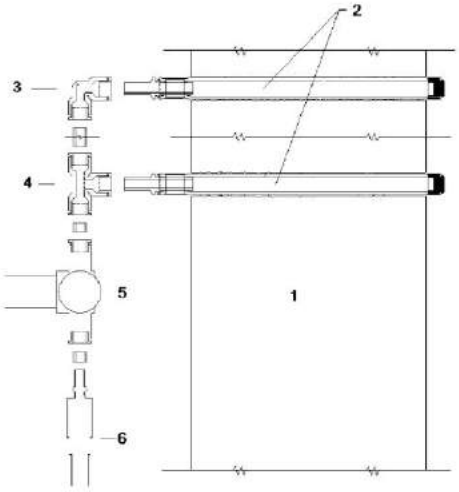

Fig. 13

(57) Abstract: System and method to analyze the pressure (or stresses), the deformability (Elastic moduli) and strength of masonry or adobe structural elements (1). The system comprises a number of tube-jacks (2), expandable tubular elements, connected in parallel, with a number of displacement transducers measuring the displacement of the masonry near the line of the tube-jacks, that when inserted into holes drilled in a stressed masonry element or wall (1), and inflated with fluid, through suitable connectors (3, 4, 6) to a pressure generator, expand to the size of the holes, and provide the necessary stress and displacement measurements, together a pressure gauge (5), to calculate the existing local compressive stress, the deformability and whenever possible, the strength of the masonry. Application includes historical and heritage constructions containing masonry or adobe structural elements with large and irregular stone units and nonlinear mortar joints.

WO 2012/042510 A1