ICIST

Instituto de Engenharia de Estruturas, Território e Construção

Concluded and Ongoing
PhD Theses

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Prof. Jorge de Brito

Instituto de Engenharia de Estruturas, Território e Construção (ICIST) is a research unit within Instituto Superior Técnico (IST), funded by Fundação para a Ciência e a Tecnologia (FCT), the Portuguese governmental research agency. With its current (2011) 95 PhD and 83 non-PhD members, it is the largest university-based research centre in the fields of Civil Engineering in Portugal.

ICIST has the purpose of developing scientific and technological research, promoting innovation and development, scientific dissemination and consultancy in the areas of its Research Groups:
- Earthquake Engineering and Seismology (group 1);
- Mechanics, Modelling and Analysis of Structures (group 2);
- Studies in Construction (group 3);
- Structural Design and Geotechnics (group 4);
- Information and Design Support Systems (group 5); and
- Architecture (group 6).

The main objective of ICIST researchers is to carry out the research needed for the advancement of the areas of their expertise. The centre supports activities such as the publication in scientific journals, the supervision of PhD and MSc theses, the participation in technical committees, the promotion of joint publications with foreign researchers, the participation and organisation of technical and scientific meetings, and the participation and coordination of European and national scientific and technological projects.

In 2007 the multiple activities of ICIST members have earned the centre the rating of Very Good. Since then, the centre has grown in members, and most particularly in scientific productivity indicators. A total of 212 papers published in international leading peer-review journals (189 ISI and 23 Scopus), 53 completed PhD theses (and 94 ongoing as of 2011), more than 3 M€ in funding for scientific projects and more than 2 M€ in consultancy testify the R&D work developed at ICIST in the 2007-2010 period only.

ICIST members have a significant involvement in national and international scientific and technological projects. This document lists the twenty projects with competitive funding which have been developed during 2011 and been coordinated by ICIST members (projects with the participation of ICIST members but coordinated by others were not included).

I am sure the list reflects the diversity of the R&D work currently developed at the Institute and the commitment of its members with the scientific and technological activity.

Jorge de Brito
President of ICIST

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Concluded PhD Theses (2007-2011)

Geographic Modelling of Location Problems

Alexandre Bacelar Gonçalves

SUPERVISORS: João Matos (IST-ICIST)

KEY WORDS: Location Problems, Geographic Modelling, Solution Analysis, Optimization, Solving Methods for Location Problems, Optimality and Cost Differences

INTRODUCTION: This thesis addresses location problems. A generic model for these problems is presented, identifying the required components to allow a formal description of a problem that asks for the location of points, lines or areas. The model covers both overlay problems, solved by spatial analysis operators, and optimization problems, studied in the Location Theory field.

Reviews of the most common location problems and the corresponding exact and heuristic solving methods are presented.

Also covered are the aspects that concern the conception of a geographic model, which may result on distinct representations of phenomena and therefore influence the solutions of location problems. The geographic modelling of the constituent parts of the generic model for location problems is focused.

Some indices for the sensitivity analysis of location problems are devised, being able to express the effects of considering different solving methods or base spatial data in problem results. These measures are illustrated in two case studies, implemented on a geographical information system: the first is the maximum covering problem for the distribution of observers over an elevation model, and the second concerns the least-cost path for road building.
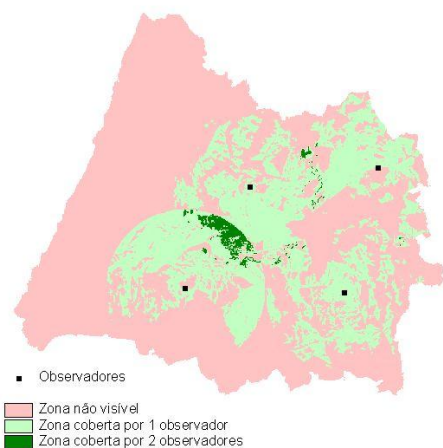
Example of solution for a maximum covering problem (maximization of viewshed area)
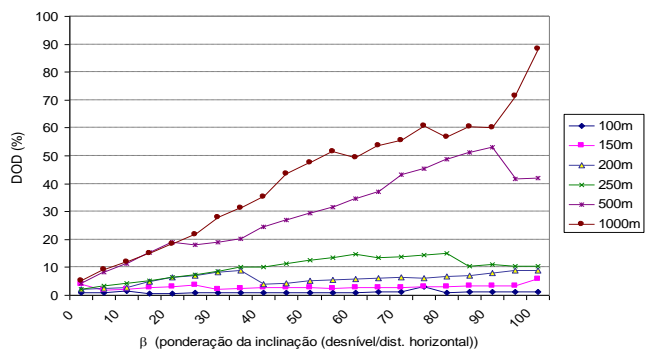
Differences in Optimality from Data (DOD) of least-cost path solutions for a road location problem in East Timor, including slope as a cost, for several raster resolutions

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Numerical Modelling of Wave Breaking. Integrated System for Wave Propagation Modelling

Ana Catarina Coelho Rosa Zózimo

SUPERVISORS: Alexandre Gonçalves (IST–ICIST), Juana Fortes (LNEC)

KEY WORDS: Non-linear time dependent mild slope equation, numerical modeling of wave breaking, Geographical information systems, integrated system, geographical variability, harbors and coastal zones

INTRODUCTION: This dissertation is divided into two main parts. The first is dedicated to the development of a new numerical model for the propagation of weakly non linear waves including energy dissipation due to wave breaking, while the second concerns the development of an integrated system for wave modeling in harbors and coastal zones to enable the simplified use of numerical wave models and to help in the decision making process (in current and emergency situations).

In the first part, the equations given by Beji and Nadaoka (1997a,b) are extended in order to account for energy dissipation due to wave breaking. This is accomplished by considering the Reynolds stresses in the momentum equation without dissipation and by deriving a new time dependent mild slope equation. The numerical model within this thesis is applied to three physical model tests, comprising both constant slope beaches and a bar-trough profile. The integrated system for wave modeling, GUIOMAR, its structure and interfaces are presented in the second part. The GUIOMAR system enables the simplified use of wave propagation models, including the construction, manipulation and visualization of data and results. The characteristics contribute to the establishment of this system as a tool for the decision making process in coastal engineering studies.

The influence of the potential geographical variabilities in the wave models are assessed, namely those associated with scale and resolution of bathymetric data, interpolation methods and subjectivity of coastline definition. From the analysis of the numerical wave models results, it was noticed that for any wave modeling study a great attention must be given to both the bathymetric data and the choice of interpolators with their respective parameters.

Some suggestions/recommendations for a future use of the GUIOMAR system are outlined regarding the use of interpolation methods.
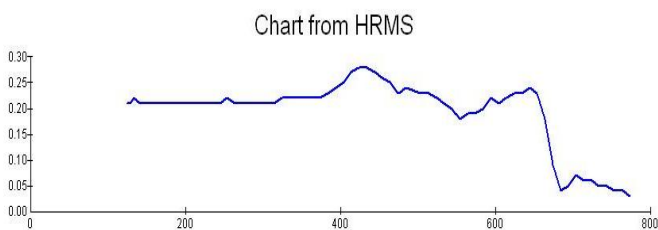
Results of the FUNWAVE model (wave heights) for a profile using GUIOMAR system
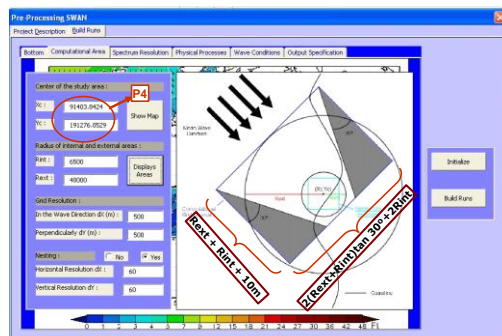
Computational area" tab in the SWAN model form, to define the meshes used by the model

CONTACTS: Ana Zózimo – catarina.zozimo@gmail.com - Concluded 29/11/2010

The Transformation between GNSS Geometric Heights and Gravity Heights in Surveying Applications

Ana Paula Martins Falcão Flôr

SUPERVISORS: João Casaca (LNEC), João Matos (ICIST-IST)

INTRODUCTION: This thesis presents and discusses expedite solutions to transform GNSS geometric heights into gravitic heights in the surveying practice framework.

A synthesis of the main concepts related with the definition of geopotential, dynamic, orthometric, normal and geometric heights is presented. The altimetric relations between the distinct types of height are described using the geoid undulation and the height anomaly. A reference to the classic methods for their computation is included, and the spatial prediction method is identified as the most efficient in the surveying context of this study.

Several statistical criteria are identified in order to support the choice of a function that best describes a trend, avoiding the overfitting. The results of the application of both prediction and prediction with external trend to real data of geoid undulation and height anomaly are assessed. The results support the applicability of the presented method to predict geoid undulation and height anomaly values. Best results were achieved using the residual prediction method with external trend.

The presented methodology is valid and useful in the transformation from geometric heights to physical heights in surveying applications
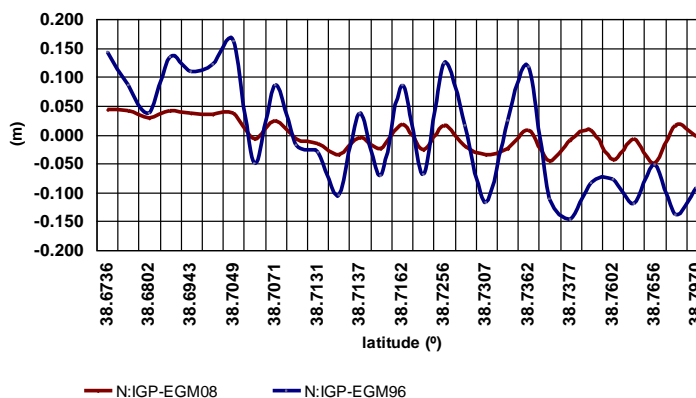
Differences in geoid undulation between the IGP-EGM08 and IGP-EGM96 models, according to the latitude

CONTACTS: Ana Paula Falcão Flôr; afalcao@civil.ist.utl.pt – Concluded 29/07/2010

Development of a Method for the Dynamic Characterisation Of Daylighting in Mediterranean Climates

António José Costa dos Santos

SUPERVISORS: António Moret Rodrigues (IST-ICIST); Licínio Catarino de Carvalho (Univ. of Algarve); Carlos Alberto Pina dos Santos (LNEC)

KEY WORDS: Building Physics, Daylighting, Visual Comfort, Behavioural Models, Energy Efficiency

INTRODUCTION The traditional methods of calculation of daylighting in buildings and the metrics used for its quantification (such as daylight factor, for example) have limitations that do not allow to take into account, effectively and realistically the consequences of the dynamic characteristics of natural light and in particular those related to its energy-related impacts and the influence of the occupants of the buildings in the final daylighting performance of the buildings.

The study proposes an integrated method for characterization and realistic prediction of the dynamic performance of daylighting. The method takes into account: i) the characteristics of the luminous climate in the southern European regions, where non-overcast sky conditions prevail; ii) the guarantee of an adequate indoor visual environment and minimization of visual discomfort; iii) the energy-related impacts of daylighting; iv) the influence of environmental management systems and their control strategies in the final daylighting conditions and energy use and v) the expectations, preferences, attitudes and behaviours of individuals towards their indoor environmental conditions and control systems at their disposal.

The study included results from a Post-Occupancy Evaluation, based on formal surveys, informal interviews, on-site daylighting measurements, and daylight characterisation of shading devices on test-cells. A behavioural model was also proposed for describing the relevant relationships for an interdisciplinary approach (subjective/objective) that allows the definition of typical-behavioural patterns.
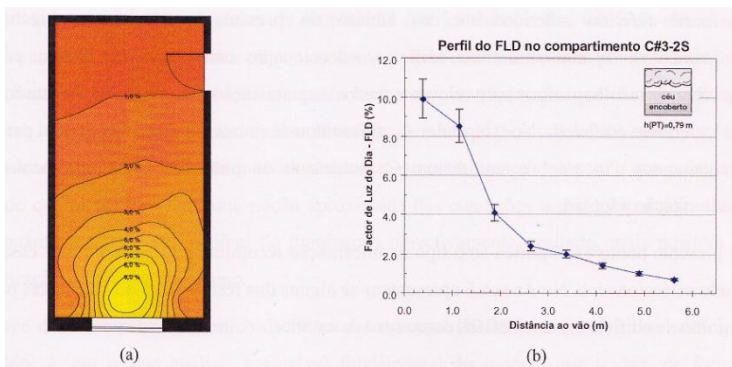
Daylight Factor experimental results: a) view at work level
b) profile normal to the window plane.
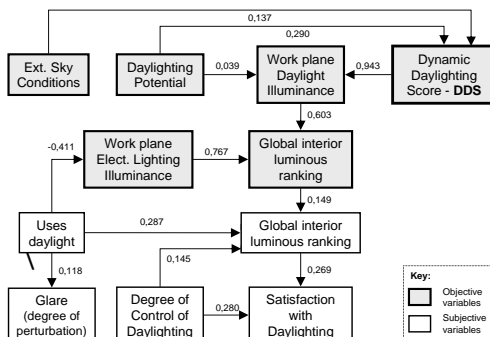
Diagram of the structural equation model obtained for describing the relevant relationships for an interdisciplinary approach (subjective/objective) that allows the definition of typical-behavioural patterns.

Building Deconstruction: An Architectural Perspective

António José Damas da Costa Lobato dos Santos

INTRODUCTION: The current rate of resource consumption in construction activities is considered unsustainable, therefore strategies for resource usage efficiency in current and future stock of buildings, must be investigated, including building materials reuse. Building Deconstruction corresponds to the careful disassembly of buildings upon ending their service lives to recover the maximum of serviceable components for reuse, thereby reducing the volume of landfilled material and consumption of virgin resources for new construction or reconstruction. Promotion of building materials reuse, as well as provision of the possibility for future reuse of buildings, depends on decisions made at the design stage, a moment usually concerned with other priorities. The adoption of building design principles with greater consideration for preservation of material resources rests upon the demonstration of its advantages (economic and environmental) and the compatibility of such an approach with other design priorities (aesthetical and technical). This study presents international examples of building deconstruction and material reuse, considering technical, economical and policy aspects, analyses its applicability in the Portuguese context and includes methodologies (existing and proposed) for evaluation of different building material reuse options both during design and after construction, with the explicit aim of facilitating the mainstreaming of this concept.

Figure 2: The "3 Rs" of Reuse (Guy & Williams, 2003)

Figure 1: Dismantling techniques as a function of reversibility
of connections and probability of reuse (Santos, 2010)

CONTACTS: António Lobato dos Santos – Concluded 3/11/2010

Method for Buildings' Maintenance Condition Assessment. Analysis and Contributions for its Improvement

António José Dâmaso Santos Matos Vilhena

SUPERVISORS: João António de Oliveira Pedro (LNEC); Jorge de Brito (IST-ICIST)

KEY WORDS: assessment methods, maintenance condition, improvement, defects, buildings, proposals, improvement, Portugal

INTRODUCTION: The Portuguese method for buildings' condition assessment (MAEC) allows determining the condition of buildings and the presence of basic infrastructure, based on visual inspections, carried out by qualified surveyors.

MAEC was implemented in November 2006. Since then more than 30,000 rented units were inspected with it.

Thus it was considered convenient to develop a study that analyzes the performance of MAEC in its period of application. An analysis of the results of MAEC inspections, completed between January 2007 and May 2010, was performed, and the opinion of MAEC main actors was gathered. A comparative study of MAEC with 16 other methods that assess buildings condition was performed.

Based on the results of the analysis, two types of improvement proposals for MAEC were developed: (i) proposals to simplify the application of MAEC and increase the level of information collected and accuracy of results, and (ii) proposals to apply MAEC within new scopes beyond those for which it was originally conceived.

The general conclusion is that MAEC complies with the main purposes for which it was designed. However, it is possible to introduce some improvements that will contribute to a better application of the method.

Detachment of the concrete cover and corrosion of reinforcement in beam

Survey under the experimental application of the MAEC

CONTACTS: António Vilhena – Concluded 23/11/2011

Social e-Business: A New Vision for Construction e-Procurement Platforms

António Morais Aguiar da Costa

SUPERVISORS: Luís Valadares Tavares (IST), José Antunes Ferreira (IST)

KEY WORDS: e-procurement, social e-business, social networks, supply chain management, BIM, multicriteria evaluation, past performance, future performance, game theory, pilot case

INTRODUCTION: E-procurement platforms generate positive impacts and raise interesting opportunities for the construction industry. However, various challenges must be faced when designing and managing these systems to attract new users, potentiate e-procurement networks and promote innovative procurement and working systems.

To overcome these challenges, a new vision to e-procurement platforms for construction is proposed. This new vision is called Social e-business; it recognizes the role of multicriteria evaluation instruments, it emphasizes the strategic importance of relationship-based approaches to procurement and assumes the increasing relevance of Information and Communication Technologies, such as BIM and web-based collaborative platforms, in construction projects performance. This vision exploits the benefits of online social networks to create a collaborative, integrated and interoperable space where social capital is potentiated and supply chain management assumes a central role. One feature that contributes to this inter-organizational perspective is the Satellite network model proposed, which promotes supply chain dematerialization and collaboration in a project-based environment.

This innovative vision for e-procurement platforms has been implemented in a platform prototype developed throughout the research, which has been tested in a pilot case study focusing a construction project. Finally, the particular case of Social e-business vision implementation in the public sector has also been analysed.
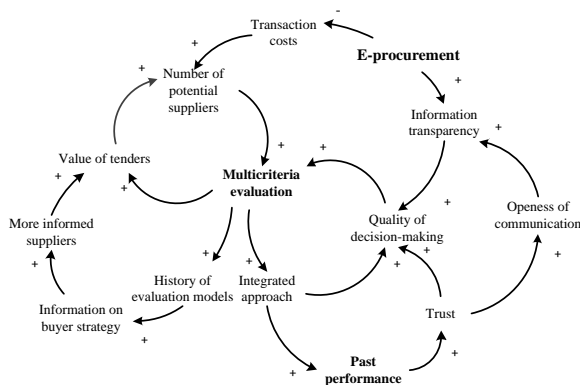
Multicriteria evaluation and past performance in e-procurement
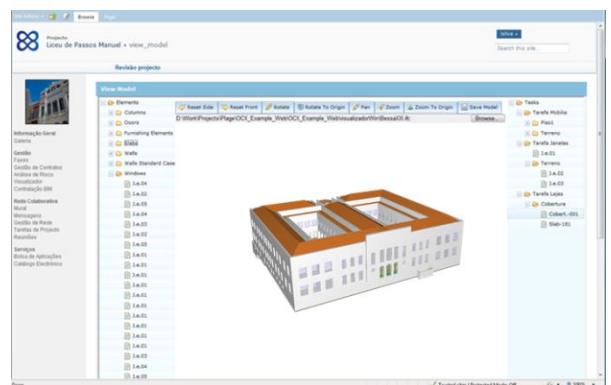
PLAGE platform interface integrating a BIM viewer

CONTACTS: António Aguiar da Costa; aguiar.costa@.ist.utl.pt – Concluded 19/12/2011

Geophysical Monitoring and Alert Levels for the Fogo Volcano, Cape Verde

Bruno Vicente Eberl de Faria

SUPERVISORS: João Fonseca (IST-ICIST)

INTRODUCTION: Both seismic and tilt activity recorded at Fogo Volcano (Cape Verde), between March 2001 and August 2003 is analyzed and a baseline is established. The seismic activity is marked by volcano-tectonic and volcanic (hybrids, cigar-shaped and long-period) events. The hypocentral relocation of the volcanic-tectonics and the focal mechanism solutions show that they are produced by the shearing between the less consolidated material and fossil dikes; the stress field being produced by the weight of the volcano edifice. The volcanic events represent the main seismic activity recorded. Their proprieties and the focal-depth close to water table suggest that these events were produced by hydrothermal activity.

The epicenters in vicinity of Brava are correlated to seamounts, therefore are interpreted as the result of submarine eruptive activity. As the tilt signals are controlled mainly by the thermo-alstic effect, the confidence-intervals on a time base of four days were adopted to monitor these signals. The alert-levels table were established based on the geological settings, on the established baseline and on the computed deformation pattern.

It was concluded that five levels of alert are necessary, including the trivial one. The most vulnerable regions are identified and it is proposed some civil protection preventive measures.
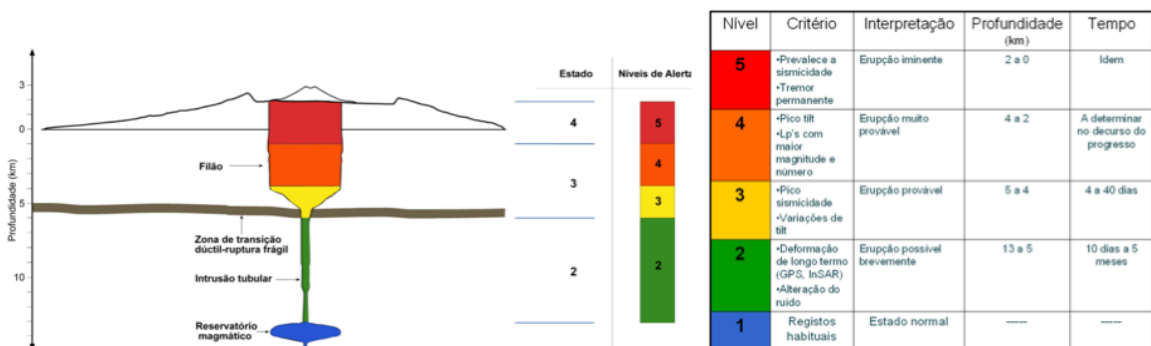
Schematic model of the eruptive mechanism of Fogo volcano, and associated alert level table. From Faria (2010).

CONTACTS: Bruno Faria– Concluded 05/2010

Analysis and Design of Prefabricated Hollow Core Slabs

Carlos António Menegazzo Araújo

SUPERVISORS: Daniel Domingues Loriggio (Federal Univ. of Santa Catarina, Brazil); José Câmara (IST-ICIST)

INTRODUCTION: The focus of this thesis is the contribution to the structural design of hollow core slabs. The development of building techniques of hollow cores slabs allowed its wide use in different types of structure, although some characteristics of prefabricated elements still cause uncertainties in the scientific community. For the analysis of these types of slabs it is fundamental to evaluate the time effects of concrete (creep and shrinkage) and steel relaxation on the stress distributions at section and structural levels. This study evaluated precast systems, where isostatic slabs are joined to form a continuous structure with composite cross section. The stress distribution and deformations obtained at different stages of construction process and of its life time are analyzed. The basis of the numerical model adopted on this thesis, based on the general aging coefficient method, is summarized. In this context the effects of non uniform shrinkage are discussed. The software PROTENLAJE, suitable for analysis, design and verification of bi-supported and continuity pretensioned members on the service and ultimate limited stats, was used and expanded in this study.

The shear strength and failure mechanisms in the region of support are also unaswered questions in the design of these slabs, since the large proportion of voids in cross sections without shear reinforcement, the lengths of support usually small, the anchorage of strands and the dispersion of prestressing force. To investigate these issues, this thesis presents nonlinear numerical analysis of hollow cores slabs subjected to bending moment and shear, considering the bond between the strand and concrete. The models generated with the commercial software ATENA are discussed and compared with experimental results, clarifying the points raised.

The current design methods for hollow core shear resistance are derived from experimental results and elastic theories that are not usually directly related to the specific behavior of these slabs.

Moreover, the manuals about this subject do not discuss the anchorage failure. Although it is not common in this type of slab, it may influence the shear strength. In this thesis, the anchorage failure of strands is considered with the concepts from Eurocode 2 and an analytical methodology for shear design based on the modified compression field theory (MCFT) and the safety concepts of Eurocode 2 is properly presented and evaluated with experimental data available in the literature. It proved to have a good accuracy and is simple enough for use in design. Comparisons with international codes are also presented. Verification of anchorage failure is regarded with the concepts of Eurocode 2, consistent with the proposed methodology.
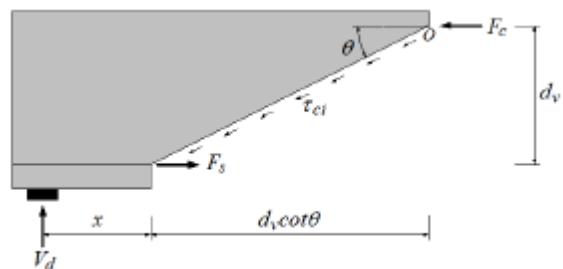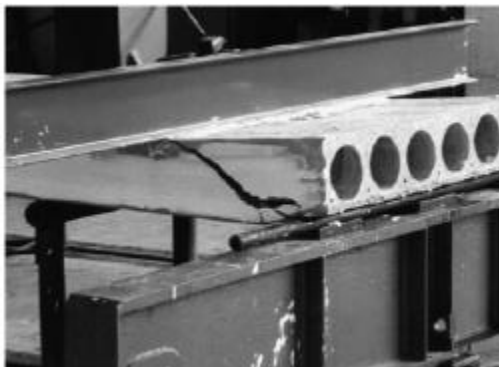
Shear resistance mechanims and design

Essays on Infrastructure Public-Private Partnerships:
Decision, Development and Management

Carlos Paulo Oliveira da Silva Cruz

SUPERVISORS: Rui Domingos Ribeiro Cunha Marques (CEG – IST)

KEY WORDS: Bayesian Networks; Concessions; Contract Management; Econometric Analysis; Flexibility; Infrastructure provision; Public-private Partnerships; Public Sector Comparator; Real Options Analysis; Renegotiations.

INTRODUCTION: The economic development and social welfare depend on the existence of effective and efficient infrastructure systems (health, energy, transportation, water, etc.). Nevertheless, developing and operating these systems brings an enormous financial effort by Governments, increasing the burden on the public budget.

Therefore, most countries have chosen to develop and manage their infrastructure networks, under Public-Private Partnership arrangements, following a worldwide trend of increasing private sector participation in the delivery of infrastructure and public services. The private sector is eager to invest, and Governments need the private sector expertise to manage and control cost and time overruns.

However, empirical evidence shows some pitfalls in the use of these arrangements. This research explores the several models for private sector participation in infrastructure delivery, in several sectors: energy, transportation (roads, airports, ports), and health, using benchmarks and case study analysis. After this characterisation, the research focuses on three key areas for improving these models: Public Sector Comparator – developing a Bayesian network (decision tree) able to improve the robustness of the calculation; Renegotiations – an econometric model was developed to understand the main determinants; and Flexible Contracts – identifying flexible options and assessing, through a real options model, the potential for economic gains.
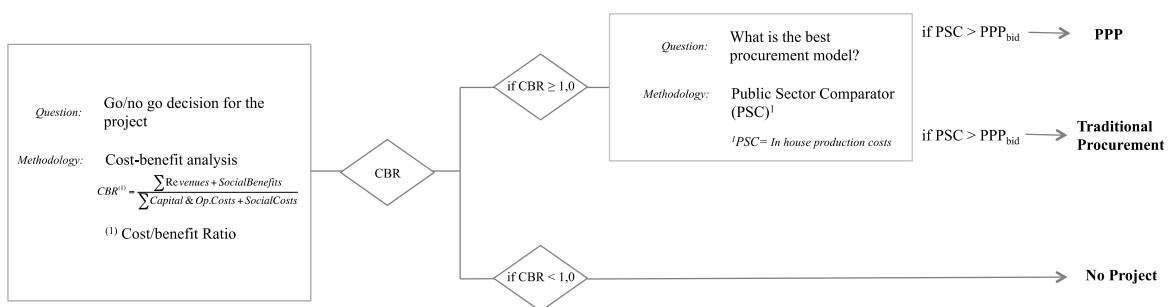
Decision chain of an infrastructure investment project

CONTACTS: Carlos da Silva Cruz; ccruz@civil.ist.utl.pt – Concluded 16/12/2011

Computer-Aided Building Spatial Layout

Francisco Afonso Severino Regateiro

SUPERVISORS: João Bento (IST-ICIST)

KEY WORDS: Computer-Aided Architectural Design; Constraint Satisfaction; Generative Systems; Relational Algebras; Spatial Organization; Spatial Reasoning.

INTRODUCTION: A building construction encompasses several design phases, until all necessary specifications for edification are finished. Any design process starts with the definition of problem requirements and closes with the definition of solution characteristics. In practice, these actions can be mixed together. There is not a universal problem solving approach in architectural preliminary design. Typically, there is a search process for satisfactory solutions, based on uncertain information, iterative evaluation of alternatives, and objective, as well as subjective, evaluation factors.

The main goal of this thesis is to develop floor plan organization support, taken as an architectural preliminary design problem.

We developed a knowledge representation scheme and algorithms, which allow qualitative and quantitative input requirements specification, its consistency validation, implicit data deduction, precise solutions determination, and explanatory information about impossibilities derived from the specification.

The main achievement is the development of constraint satisfaction and relational algebras techniques applied to design support. In order to validate it, we developed a research prototype and a methodology, thus contributing to the furthering of design support tools for architectural design.
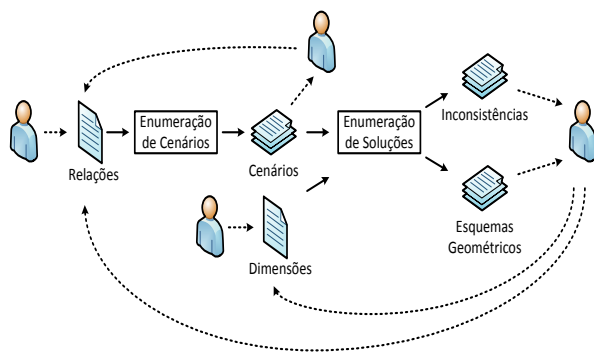
The problem solving process
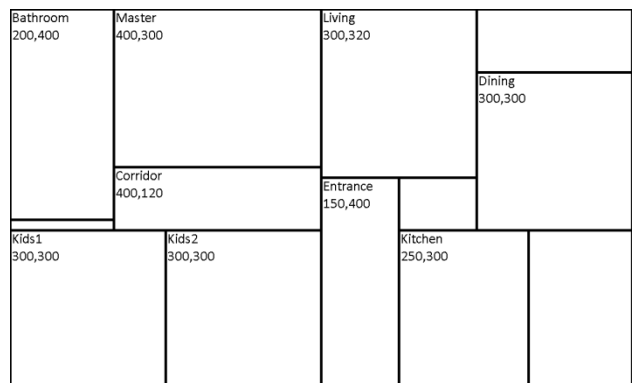
One solution generated by the prototype for a case study

CONTACTS: Francisco Regateiro; fasr@civil.ist.utl.pt – Concluded 20/01/2010

Methodology For in Service Performance Assessment of Rendering Façades for Predictive Maintenance

Inês dos Santos Flores Barbosa Colen

SUPERVISORS: Jorge de Brito (IST-ICIST); Vasco Peixoto de Freitas (FEUP).

KEY WORDS: In-service performance; Inspection; Predictive maintenance; In- service parameters; In-situ tests; Criteria.

INTRODUCTION: Proactive maintenance is crucial to guarantee an adequate in-service performance of buildings' elements and fulfill the users' needs, during the expected service life. However, the occurrence of these maintenance actions has not been a current issue in buildings (specially in housing buildings), leading to several problems such as: risks for users' safety, urgent interventions with additional costs, stoppage in normal operation of buildings, among others.

The main issues that can be pointed out as the reasons of this present scenario are: deficient conditions for in-service diagnosis (in terms of human, technical and economical resources), absence of criteria and decision-making methodologies, and also absence of requirements in current codes and governmental support. In this sense, the near future publication of the General Buildings Code (RGE) can be an important turning-point, since this code already includes the requirements of periodic inspections and the elaboration of inspection and maintenance manuals for buildings.

The thesis intends to develop a methodology to be applied in rendering of current buildings' façades (with cement-based renders, mixed on-site or pre-mixed in a factory), in order to improve inspections' diagnosis during service life. Therefore, a set of in-service parameters (visual observation and measurements) are proposed and their methods of assessment are also discussed (based on visual inspections, auxiliary techniques, in-situ and laboratorial testing). Finally, assessment criteria are also proposed to allow the application of the previous parameters in in-service performance assessment of renders applied in façades and also to help the choice of predictive maintenance actions (actions that are the result of inspection's diagnosis).
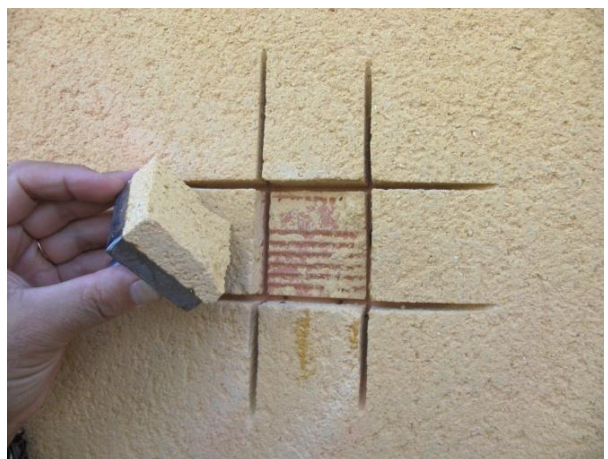
In-situ testing for renders' performance evaluation:
cracks measurement (left) and adherence pull-off test (right)

CONTACTS: Inês Flores-Colen; ines@civil.ist.utl.pt – Concluded 06/07/2009

GFRP Pultruded Profiles in Civil Engineering: Hybrid Solutions, Bonded Connections and Fire Behaviour

João Pedro Ramôa Ribeiro Correia

SUPERVISORS: Fernando Branco (IST-ICIST); João Gomes Ferreira (IST-ICIST); Thomas Keller (CCLAB/EPFL, Switzerland)

KEY WORDS: Fiber reinforced polymers (FRP), Glass fibre reinforced polymer (GFRP) pultruded profiles, GFRP-concrete hybrid beams, Adhesive bonding, Fire behaviour, Fire protection systems

INTRODUCTION: The objective of this thesis was to study the viability of the structural use of GFRP profiles in floors of buildings. The research was conducted along the three following axes: (i) development of GFRP-concrete hybrid beams for floors; (ii) behaviour of adhesively bonded connections between GFRP profiles; (iii) fire behaviour of GFRP profiles and development of fire protection systems.

Regarding the development of floors with GFRP-concrete hybrid beams, an hybrid solution was proposed, combining GFRP profiles and concrete elements, with two alternative shear connection systems: steel bolts and an adhesive layer. The experimental programme included shear connection tests, flexural tests on hybrid beams and tests on supports. Design equations were derived and numerical models were developed.

In what concerns the behaviour of adhesively bonded connections, experimental investigations were performed on double lap joints made of GFRP adherends and epoxy adhesive layers, in order to study the influence of different geometric parameters on the joint behaviour. Numerical models of the joints were developed and a probabilistic method was developed to predict the strength of adhesively bonded joints made of GFRP adherends.

With regard to the fire behaviour of GFRP profiles, DMA and DSC/TGA experiments were first carried out. Subsequently, fire resistance tests were performed on loaded GFRP pultruded beams under a fire situation, either unprotected or protected with different fire protection systems, in order to determine the thermal response, the mechanical response, the failure modes and the fire resistance of the different systems. Finally, the fire reaction properties of the GFRP material and the effect of using the different fire protection systems on those properties were evaluated by means of cone calorimeter tests.

Flexural test on a 2-span GFRP-concrete hybrid beam.

CONTACTS: João Correia; joao.correia@civil.ist.utl.pt – Concluded: 23/01/2008

Application of Neural Networks in Seismic Engineering

Joaquim Luís Ramos Dias

SUPERVISOR: João Bento (IST-ICIST)

KEY WORDS: Artificial Neural Networks, Machine learning, Artificial Intelligence, Hysteretic behavior models, Building Structures, Seismic engineering

INTRODUCTION: The present work studies the application of artificial neural networks to the non-linear two-dimensional dynamic analysis of reinforced concrete building structures, with the main purpose of reducing its computational effort.

An introduction to artificial neural networks is presented, with emphasis on the type of networks used — the multilayer feed-forward networks. A survey of the usual modeling of seismic behavior of reinforced concrete building structures is also presented, as well as a short survey of the structural response evaluation based on damage indices.

The networks were trained over a set of examples that were numerically produced with the intent of simulating the real tests usually done for characterizing the hysteretic behavior of reinforced concrete elements. The issues related to the production of the training examples and the production of the neural networks are presented, and an evaluation of the networks performance is done. Also, the adaptation and inclusion of the networks in the more general modeling of the hysteretic behavior is described.

Finally, the performance of the developed "neural" model, when included in the global modeling of the seismic behavior, is evaluated. For that, seismic analyses were done over a set of building structures, chosen to represent the most common situations.

CONTACTS: Joaquim Dias; jdias@civil.ist.utl.pt – Concluded: 6/2/2008

Characterization of Structural Lightweight Expanded Clay Aggregate Concrete

José Alexandre de Brito Aleixo Bogas

SUPERVISORS: Augusto Martins Gomes (IST-ICIST)

KEY WORDS: Lightweight aggregate, lightweight concrete, characterization, formulation, bonding, shrinkage, self-compacting concrete, durability, service life predictions, chloride attack, carbonation, probabilistic analysis

INTRODUCTION The main goal of the present work is to formulate, characterize and evaluate lightweight aggregate concrete (LWAC) made with expanded clay aggregates available in Portugal.

Firstly, lightweight aggregates are characterized by their geometrical, compositional, microstructural, physical and mechanical properties. A simplified methodology is proposed to estimate the aggregates absorption in fresh concrete.

Secondly, the main physical and mechanical properties of LWAC, namely workability, density, compressive, tensile and shear strength, steel-concrete and concrete-concrete bonding, modulus of elasticity and shrinkage, are studied for different compositions. A simplified mix design methodology is proposed, applicable to different types of aggregate. Non-destructive ultra-sound tests are applied to assess the LWAC quality and strength capacity.

Moreover, a study has been conducted with the purpose of producing self-compacting LWAC and of performing its mechanical characterization and durability analysis.

Finally, LWAC durability is evaluated concerning the main deteriorating mechanisms in concrete structures, such as carbonation, chlorides attack and freezing and thawing action. An extensive experimental campaign with laboratory and in-situ field tests is performed. Life-time predictions are made taking into account semi-probabilistic analyses proposed in standard documents, as well as probabilistic analyses based on Monte Carlo numerical simulations. Based on this study some measures to achieve high performance lightweight concrete are also suggested.

Characterization of lightweight aggregates and structural lightweight concretes
Mechanical and durability performance
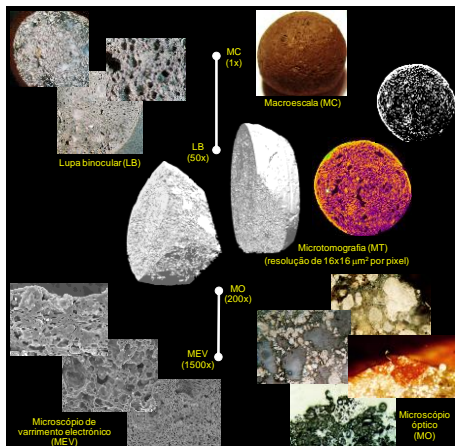
Comprehensive experimental work involving different observation scales - optical microscopy (OM), scanning electron microscopy (SEM), mercury porosimetry (MP) and X-Ray microtomography (abbreviated μ-CT)

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23

Refined Three-dimensional Seismic Analysis of Reinforced Concrete Structures

Luís André Marcos Mendes

SUPERVISORS: Ema Coelho (LNEC); Luís Castro (IST-ICIST)

KEY WORDS: Reinforced Concrete; Seismic Response Simulation; Incremental Dynamic Analyses; Inelastic Behaviour; Concrete-Steel Bond; Substructuring

INTRODUCTION: This thesis focuses on the development of advanced numerical models for the simulation of reinforced concrete structures under earthquake loading.

The main motivation for this work is the necessity felt to have a complementary, reliable and practical numerical tool to predict, follow and extend the experimental research developed in large-scale seismic testing facilities.

To contribute to this challenging goal, the methodology adopted is based on using refined three-dimensional meshes, the conventional Finite Element Method and a suitable time-integration scheme. The research presents three main axes: Firstly, to combine adequate constitutive relations to model the reinforced concrete response, which led to using continuum damage models for the concrete and global behaviour models for the reinforcing steel. Secondly, the concrete-steel interfaces were simulated by using zero-thickness interface elements and an original semi-analytical model defined at the reinforcement scale. Finally, the computational performance is enhanced by taking advantage of concurrent computations, using advanced substructuring techniques and reducing the problem size by using an innovative proposal of hybrid discretization.

The results obtained demonstrate that the proposed models are robust, accurate and present many advantages when compared to other approaches like static nonlinear analyses and modelling with

fiber and phenomenological models.
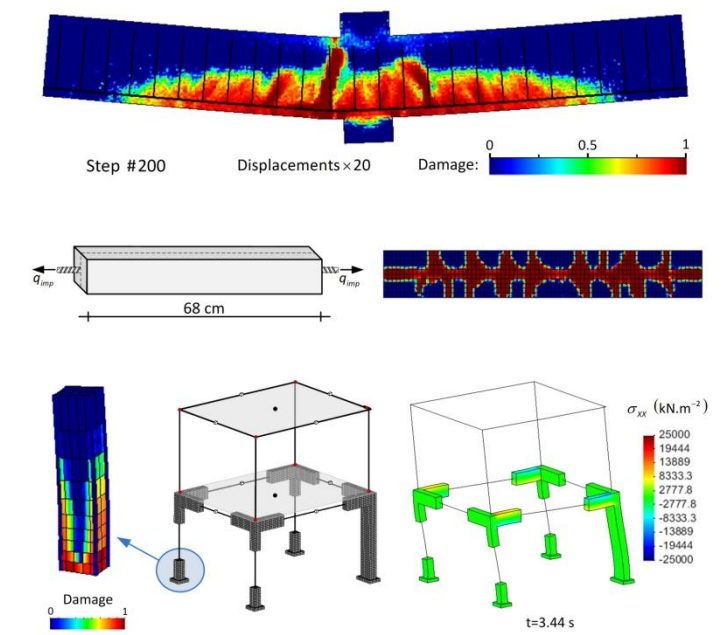
Figure 1: Examples of the analyses presented in the thesis: i) RC beam test (concrete damage model and steel model validation); ii) RC tie test (CSI bond model validation), and iii) Substructured structural analysis (Primal method).

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Thermal Performance of Double Skin Façades. Numerical Modelling and Experimental Analysis.

Maria da Glória de Almeida Gomes

SUPERVISORS: António Moret Rodrigues (IST-ICIST)

KEY WORDS: Double skin facades; Thermal performance; Venetian blinds; Experimental tests; Numerical modelling; CFD (Computational Fluid Dynamics) simulations.

INTRODUCTION: Double skin facades are characterized by having at least two transparent glazed panes, between the interior occupied space and the exterior environment, separated by an air cavity that can be ventilated.

This work focuses on the study of the thermal performance of double skin facades, particularly in Mediterranean climates, by means of experimental testing and numerical modelling.

A numerical model, which calculates heat and mass transfer and solar-optical properties of the system with or without shading devices, was developed. Special attention was paid to venetian blind's modelling, that included CFD simulations.

Moreover, some experimental tests were carried out in an outdoor test cell and in three post-occupancy buildings. These measurements allowed detailed insight into the facade behaviour, and provided data to calibrate the numerical model. A set of wind tunnel tests was also performed to analyse the wind effect on double skin facades.

Finally, the influence of different parameters on facade thermal performance was investigated through a parametric study. The results indicate that system performance is particularly sensitive to solar radiation, type of glazing and shading devices and air gap's geometry and ventilation. Some recommendations for the design and implementation of this technology in Mediterranean climates were also presented.

Test cell experiments of double skin façade with roller and venetian blinds.
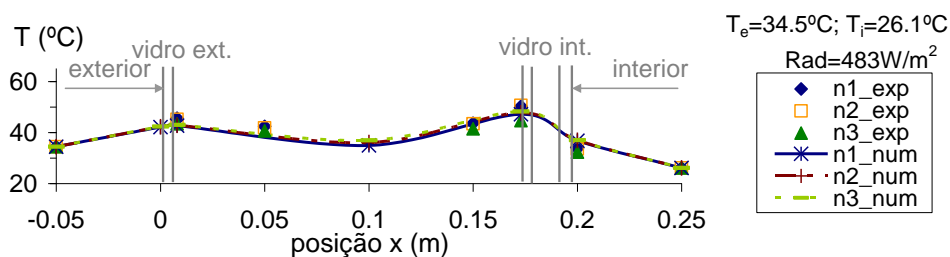
Comparison between experimental and numerical temperature profiles at three different heights.

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Treatment and Consolidation of Degraded Pine Timber In Structural Elements From Antique Buildings

Maria Dulce e Silva Franco Henriques

SUPERVISORS: Jorge de Brito (IST-ICIST)

KEY WORDS: wood, rot fungi, conservation, old buildings, consolidation, treatment, mechanical performance, structural elements

INTRODUCTION: This research work concerns the conservation of timber structural elements from antique buildings moderately degraded by fungi. The compatibility between preservative treatment and consolidation by impregnation products, applied sequentially, was studied. The process evaluation was done taking into account the overall mechanical performance of the timber and the products applied, through physical-chemical destructive and non-destructive laboratory tests and in-situ non-destructive mechanical tests. Commercially available products were applied to the most currently found timber species in old buildings in the Lisbon region: Maritime pine and Scots pine. The project involved the mechanical study of new and old timber, degraded and non-degraded; the development of a method to measure the in depth penetration of treatment products; the evaluation of the consolidating capacity of degraded timber by fluid polymeric products; the evaluation of their combined action, with and without artificial ageing.

A possible solution was developed to be applied to degraded wood that still has bearing capacity thus avoiding an eventual total removal.

MAIN OBJECTIVES: Mechanical evaluation of wood degraded by fungi consolidated with polymeric fluid products; study the compatibility between preservative treatment and consolidation, applied sequentially with and without artificial ageing; evaluation of their combined action applied to an antique buil-ding, for non-destructive methods; mechanical study of new and old timber, degraded and non-degraded; development of a method to measure the in depth penetration of treatment products;

EXPERIMENTAL RESULTS: The results obtained showed significant increases in mechanical strength of decayed wood, following preservative treatment and consolidation. The results also showed good compatibility of some pairs of products. The process of timber treatment and consolidation developed promotes resistance to rot fungi and, simultaneously, some recovery of mechanical strength, giving it the ability to continue in service.

CONTACTS: Maria Dulce Henriques - mfhenriques@dec.isel.ipl.pt; 966142404 – Concluded 24/11/2011

Mineral Air Lime Binders. The Influence of Slaking Processes and Curing Time on Their Quality

Maria Goreti Lopes Batista Margalha

SUPERVISORS: Maria do Rosário da Silva Veiga (LNEC); Jorge de Brito (IST-ICIST)

KEY WORDS: Mortar, air lime binders, lime putty, quick lime slaked with sand / "hot lime process", slaking time, traditional kilns

INTRODUCTION: Lime putties have been used to make mortars for many centuries and even today well-preserved examples can be found that bear witness to their quality and durability. As a result of the widespread introduction of cement during the 20th century, knowledge that had been handed down from generation to generation has been lost. The failure of many applications of renders with hydraulic binders has made it necessary to relearn how to use air lime binders.

During this investigation, the physical and microstructural alterations were assessed using hydrated lime putties. The influence of the lime's maturity, when used in mortars, was studied using two distinct processes: the quick lime was slaked with sand, which remained damp during the laboratory test stages; lime putty with different curing times was added. In addition, mortars were prepared using traditional dry hydrated limes, black and white limes; and hydraulic mortars, with NHL Z-3.5 hydraulic lime, and mortars with percentages of 33% and 50% cement in relation to the dry hydrated lime. In general the mortars were assessed in terms of their rheological, mechanical and microstructural behaviour and their response to water. The study was complemented with practical applications on site.

It was concluded that physical and microstructural alterations occur in the lime putties due to the effect of ageing. A reduction in the particle size of the portlandite crystals and a reorganisation of the internal structure occur. The percentage of free water decreases over time but the limes maintain a considerable capacity for water retention, and the physical forces connecting the particles remain high, which is the reason for the good rheological behaviour of mortars made using this binder. Thus, the characteristics of the mortars assessed benefited from the increase in the maturation time. The mortars with dry hydrated lime and cement developed high compressive strength, low permeability to water vapour and an increase in their sulphate content. The rheological behaviour of the mortars made with hydraulic lime and dry hydrated lime was poorer than that of the mortars made with lime putty.
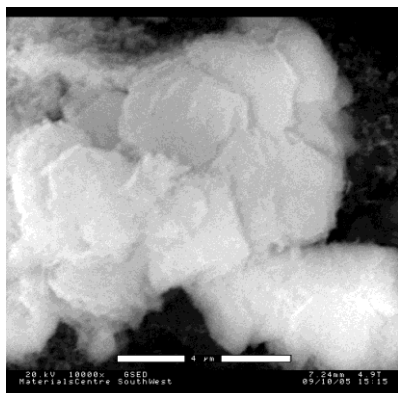
ESEM image of a lime putty after 8 months of hydratation (10000x)
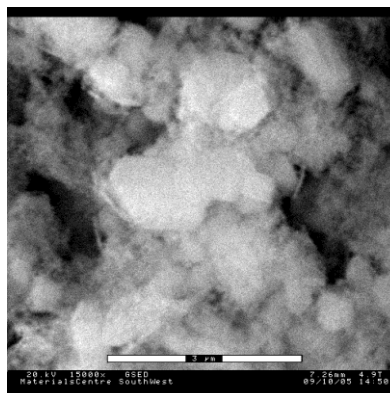
ESEM image of a lime putty with 5 years of hydratation (10000x)

CONTACTS: Maria Goreti Margalha – Concluded 19/01/2010

Hydro-mechanical Behaviour of Compacted Marls

Maria Rafaela Pinheiro Cardoso

SUPERVISORS: Emanuel Maranha das Neves (IST-ICIST), Eduardo E. Alonso (UPC, Barcelona, Spain)

KEY WORDS: constitutive model, unsaturated soils, hydro-mechanical behaviour, degradation, embankments, compacted soft rocks

INTRODUCTION: The degradation of the hydro-mechanical properties of marls occurs when they are exposed to atmospheric actions. Important deformations can occur in embankments and other earth structures built with this material, which can have negative impacts in their performance during service.

Compacted marls are a set of fragments of marl named macrostructure. The marl has its own structure, which is named microstructure. The degradation of the fragments has strong effects on global behaviour therefore, besides the study of the compacted material, it is necessary to study the hydro-mechanical behaviour of the rock.

Experimental tests on rock samples were performed to investigate their hydro-mechanical behaviour. Suction cycles (wetting and drying) were applied to simulate physical degradation. Hydro-mechanical coupled analysis using Code Bright and an unsaturated constitutive model for structured materials were used to reproduce the oedometer tests performed.

Laboratorial tests on compacted samples were also performed to the end of characterizing the hydro-mechanical behaviour of this material. Loading paths involving cycles of suction and stress were applied. Strong structural changes were measured in the level of the micro and the macrostructure.

The information collected in the experimental study allowed the development of a constitutive model for the compacted material. The model can reproduce the behaviour observed in the laboratorial tests. After being implemented in a finite element code, the model can be used in the simulation of the behaviour of embankments built of marls.

Compacted marls under 1000kPa
(w=2%, s=230MPa)

Compacted marls loaded full saturated until 1000kPa

Oedometer tests performed under different suctions showing the physical degradation of the fragments
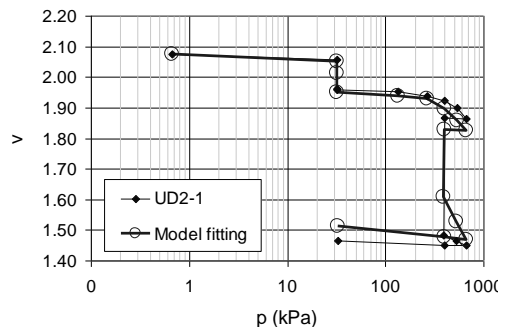
Experimental and numerical results found using a constitutive model for unsaturated double structured materials incorporating damage

porosity distribution at the end
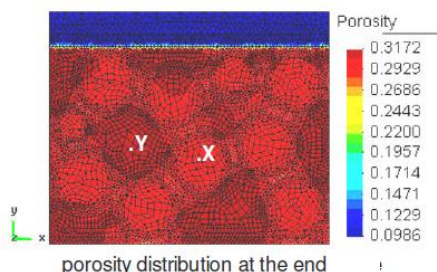
Simulation of the degradation using program Code Bright

CONTACTS: Rafaela Cardoso – rafaela@civil.ist.utl.pt Concluded 8/7/2009

Static and Dynamic Analysis of Concrete Structures using Damage Mechanics

Mário Rui Tiago Arruda

SUPERVISORS: Luís Castro (IST-ICIST)

KEY WORDS: s Finite Elements, Hybrid Mixed Stress Models, Static Analysis, Dynamic Analysis, Non-Linear Analysis, Frame Element, Plane Elasticity problems, Damage Mechanics, Concrete Structures, Reinforced Concrete Structures.

INTRODUCTION: This work presents a study on the static and dynamic non-linear analysis of two-dimensional plain concrete structures and plane frame reinforced concrete structures. To model the physically non-linear behaviour of concrete, continuum damage models allowing for the consideration of permanent strains and hysteretic loops are used. For the steel reinforcement bars, the classical plasticity theory is used with hardening and plastic strains. To discretize the space domain two types of non-conventional finite elements are used: the hybrid mixed stress element for the case of the frame element, and the 4 field hybrid mixed stress element for the plane element. For the time domain discretization, a novel approach in which a mixed element is designed considering independent approximations for displacements, velocities and accelerations is tested and assessed. The main objective of this study is to develop a robust and computationally competitive finite element method for the physically non-linear analysis of concrete structures. For time integration procedures, the main goal is to adopt a numerical

technique that may be more effective than the classical Newmark family methods.

To validate the model and to illustrate its potential, several numerical tests are presented and discussed. The results obtained are directly compared to experimental results and to

conventional finite element numerical solutions present in the literature.
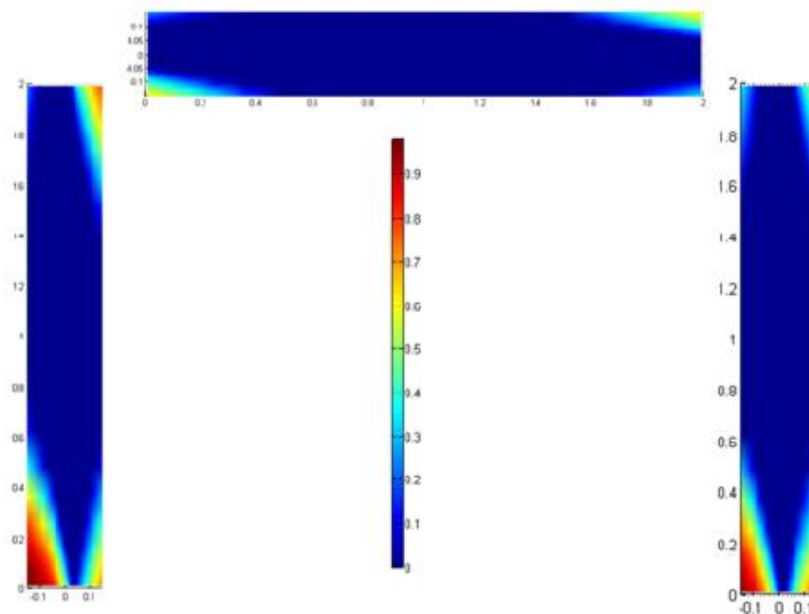
Figure 7.60 – Tension damage at time step 0.1 seconds for discretization D.

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Adaptive Stress Field Models for Structural Concrete

Miguel Filipe Passos Sério Lourenço

SUPERVISORS: João Carlos de Almeida (IST-ICIST); Karl-Heinz Reineck (Univ. Stuttgart, Germany)

KEY WORDS: Structural Concrete, Discontinuity Regions, Stress Field Models, Adaptive Structures, Nonlinear Analysis, Design Models

INTRODUCTION: Stress Field Models are commonly recognized as a powerful tool for the development of design methods for structural concrete. They allow a rational understanding of structural behaviour by relying on the idea of following the flow of forces throughout any given region. This potential is explored herein by reviewing the theoretical basis for the design, further extended to the analysis of nodal regions. New insights are thus provided and some rules of thumb are supported by a reliable methodology.

Despite of all its unquestionable advantages, the stress field method is not widely disseminated due to several practical constraints. One of the aspects frequently mentioned is the non-uniqueness of suitable models, which arises the discussion on the validity of models, mainly concerning ductility and service behaviour.

A new methodology for nonlinear analysis and design of structural concrete discontinuity regions, entitled *Adaptive Stress Field Models*, is developed, as a contribution to overcome the aforementioned limitations. The proposed technique is based in Stress Field Models, alongside with the application of Adaptive Structures concepts. To extend the application to discontinuity regions under cyclic loads, constitutive relationships for elements subject to reversal loading are also presented.

The numerical results obtained by the proposed technique are compared with monotonic and pseudo-dynamic tests, as well as other numerical analysis of several discontinuity regions.

The presented research on model assessment topics can be considered the most relevant practical application of the developed procedures. Several models for representative discontinuity regions are studied, providing guidance for adequate modelling, designing and detailing for most practical situations.
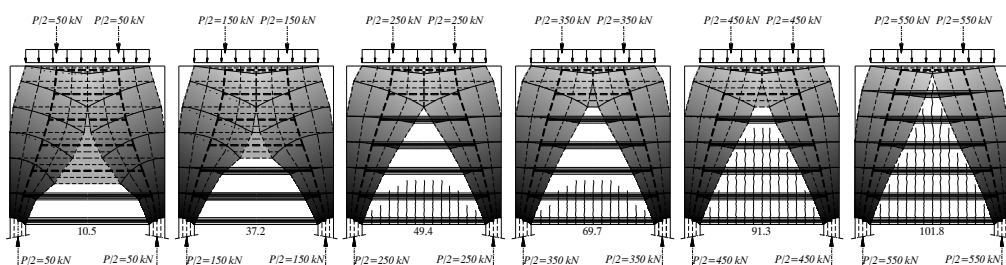
WT2 adaptive stress field model for several load steps
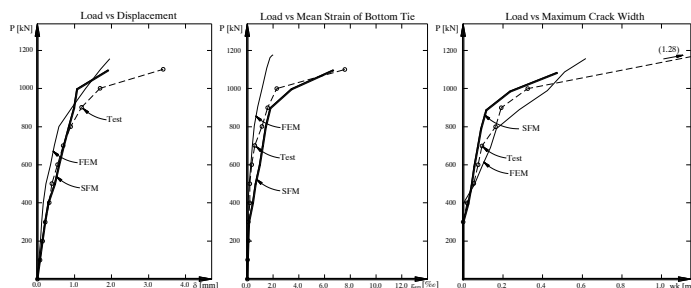
Test, nonlinear finite element and adaptive stress field results for *WT2*

CONTACTS: Miguel Lourenço; Concluded 19/2/2012

Friction-induced Dynamic Instabilities and Solution (Non-)uniqueness In Contact Mechanics

Mohamed Ali El-Sayed Mohamed Agwa

SUPERVISIOR: António Pinto da Costa (IST-ICIST)

KEY WORDS: Coulomb Friction; Solution Multiplicity; Directional and Flutter Instabilities; Orthotropic Behavior; Finite Elements; Parallel Computing

INTRODUCTION: The work deals with two important issues arising in frictional contact problems: (*i*) the occurrence of more than one solution, with an emphasis on the quasi-static incremental problem, and (*ii*) the occurrence of dynamic instabilities of the divergence (directional instability) and flutter types. The conditions for the existence of multiple solutions to the quasi-static incremental problem, with an intrinsic combinatorial character, are numerically tested and compared for several criteria. The appropriate conditions under which friction-induced instabilities may occur are computed by the search of smooth dynamic solutions, beginning arbitrarily close to an equilibrium state or a steady sliding state, that take the system away from equilibrium in an exponential oscillatory (flutter) or non-oscillatory (divergence) way. Dynamic instabilities of the divergence type are investigated both in analytic and discrete models of nonhomogeneous or non-isotropic infinite layers or hollow cylinders, respectively with flat and curved frictional interfaces. Instabilities of the flutter type in infinite layers, hollow cylinders or orthotropic half-spaces with a frictional interface are computed. The thresholds of the coefficient of friction for flutter in orthotropic media can be considerably smaller than in the isotropic case. The eigenvalues' loci as a function of the coefficient of friction may be significantly different from the isotropic case. Dynamic consequences of divergence or flutter instabilities are also illustrated and discussed.

MAIN OBJECTIVES: The *reliable simulation* of frictional contact systems depends on the precise conditions for which (1) instabilities or bifurcations occur, (2) algorithms do not converge or (3) the basic problem behind a phenomenon does not have a solution or exhibits multiple solutions.
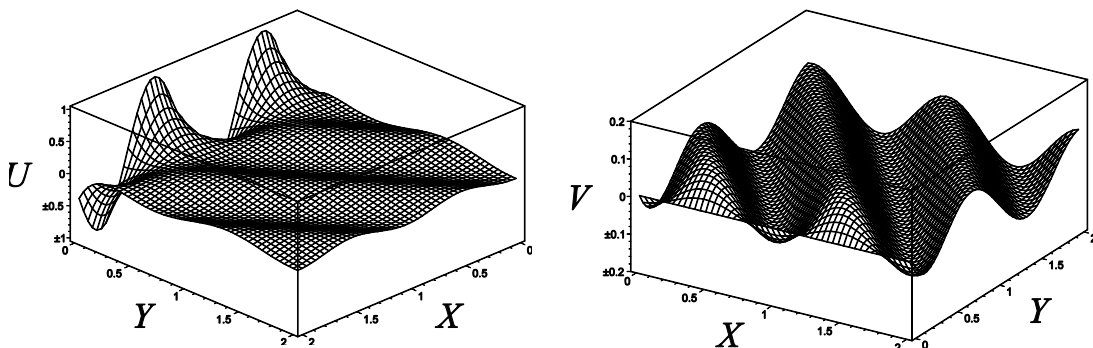
Flutter instability of an elastic orthotropic solid near a frictional interface

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Concluded 06/2011

Knowledge Management at the Construction Company

Paulo José Simões Vaz Serra

SUPERVISORS: Francisco Loforte Ribeiro (IST-ICIST); Diogo Manuel Vaz Pinto Mendes

INTRODUCTION: In an increasingly global world, with great mobility, companies must be in permanent alert and seeking for new solutions in order to be more competitive, more innovative, reduce costs and response times. Valuing knowledge as an asset of the organization, identifying, capturing, disseminating and reusing it, has thus become a priority. However, the ways to manage that knowledge are not consensual.

Using the case study research method and by collecting data through interviews of the companies in the sector AEC - Architecture, Engineering and Construction and other sectors with more experience in the knowledge management, the answers were evaluated and compared to determinate the better way to perform knowledge management in a construction company, as a competitive advantage to support process improvement and motivation of decisions by previous experiences.

A system called *SIPCEC* – Knowledge Sharing System in Construction Company has been created, to be used by companies as an initial phase of their knowledge management process. The system was tested and validated at two construction sites in a Portuguese company. Its efficiency has been verified and validated, showing effective sharing of knowledge generated by the experience at the construction phase.
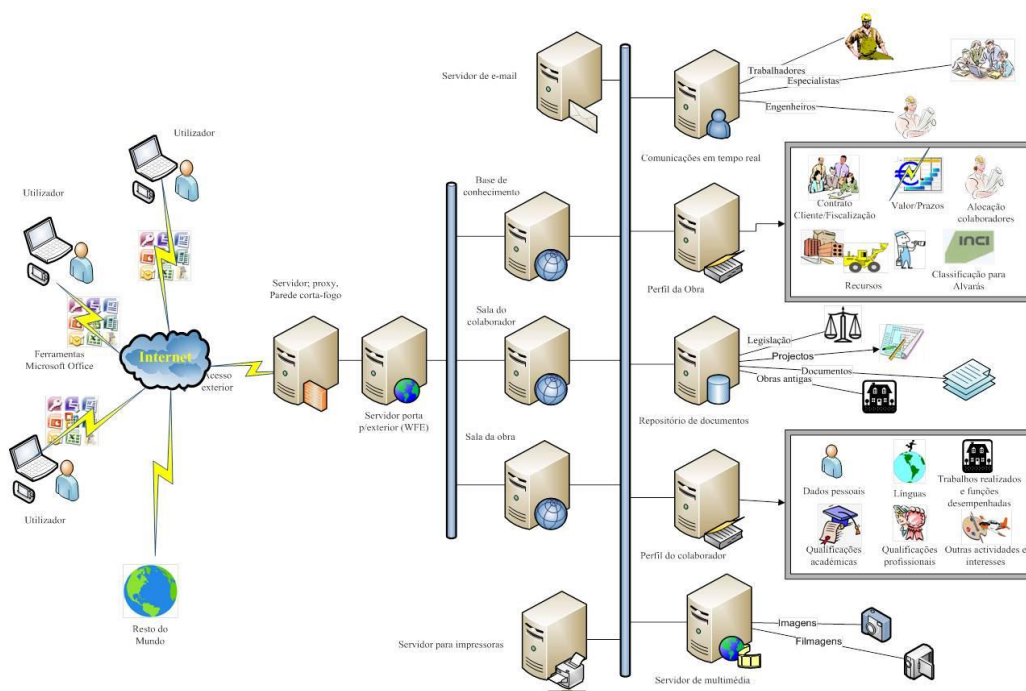
Service Life of Buildings: Methodology for Service Life Prediction of Building Components. Application to External Cement-renders

Pedro Manuel dos Santos Lima Gaspar

INTRODUCTION: This research work presents and discusses a methodology for service life prediction of building elements, based on field-work assessment of buildings in real-life service conditions. The methodology proposed includes the identification, classification and quantification of the condition of defects, which can be collected on Degradation Atlases to be used as reference data for field-work. The results thus obtained are combined into degradation indicators from which can be derived the overall degradation level over time, for the element assessed. Such degradation models result from statistical regression lines from the data collected (referred to as graphic method) and provide durability information for building elements, such as: degradation patterns, upper and lower performance limits, minimum reference performance levels, reference service life, condition groups, probabilistic condition curves and variation indexes related to durability factors, for the samples analyzed. These data can also be used to quantify durability factors within factorial methods.

The methodology is exemplified through its application to external cement-renders, by which a model is proposed for the durability of this material as well as numerical durability factors to be used within factorial methods.

A Buildings Management System (Buildingslife). Application of Deterministic and Stochastic Models With Genetic Algorithms to Building Façades

Pedro Miguel Dias Vaz Paulo

SUPERVISORS: Fernando Branco; (IST-ICIST) Jorge de Brito (IST-ICIST)

INTRODUCTION: This research is concerning Building Management System (BdMS) to help a building's owner or manager by finding the best maintenance option (time frame and appropriate technique), and to help the designer to choose the best constructive solutions and materials for the owner's needs, based on the known exterior effects, such as ambient and environmental conditions. The web software developed, called BuildingsLife, allows the user to enter information or files related to the building and street characteristics, materials, defects, maintenance, degradation agents and levels, and with queries it is also possible to obtain specific reports or statistics for data analysis. Also, with mathematical and computational models the BuildingsLife can estimate several degradation agents or quantify degradation such as, PhotoColour, PhotoMeasure, water retention analysis, solar exposure time, solar radiation and surface roughness are also analyzed, as well as meteorological data.

To characterize environmental agents, which influences the façades durability, twenty-two degradation agents were characterized: sun-air temperature, degree day, global radiation, solar UV index, sun hours, wind-driven rain, water retention index, time of wetness, biological index, wind, carbon monoxide, mono-nitrogen oxides (NOx), volatile organic compounds (VOC), hourly mean traffic, street vehicle occupancy, street classification, local classification, acid rain, nitrate salts, nitrite salts, chloride salts and sulfate salts. Their quantification was based on numerical and experimental models capable of estimating the effects on each building façade. The approach is mainly micro-scale (building level) and if this is impossible, the next level, local scale, is considered.

Also, it was classified several material properties to analyze their durability for each criterion range. Material properties were grouped in discrete or continuous modes to represent the material property. They were defined according to experience and literature references to achieve total characterization.

The façades degradation were quantified using ratings to avoid specialists interpretation errors. To simplify the degradation quantification a methodology was defined to characterize each defect according to a 6-state degradation classification, where 0 is the best condition and 6 is the worst. Quantification was direct or adapted, supported by standards for the use of universal criteria. To predict the building façades service life it was used deterministic (Gompertz curve) and stochastic (Markov chains) models and validate their results with real degradation rates.

As final result it was used genetic algorithm applied to Markov Chains to estimate the best maintenance plan. This simulation compares different maintenance plans actions. The best maintenance plan can be characterized as the plan offering the lowest global cost over a certain analysis period which allows an acceptable degradation level, as established by the building manager.
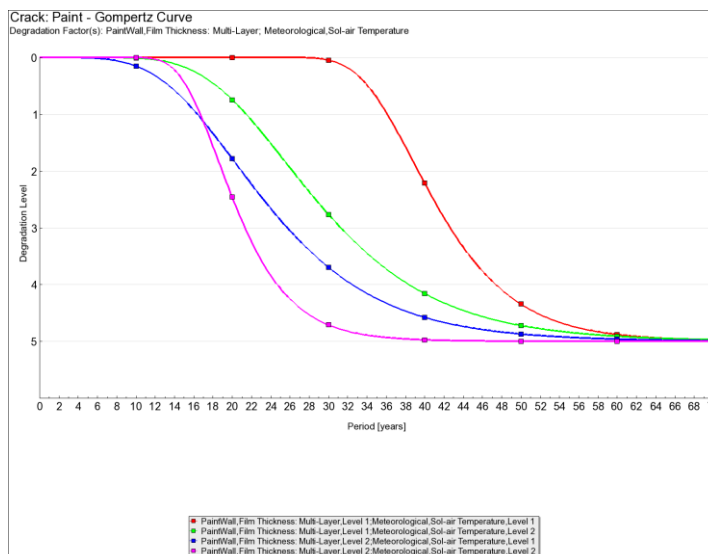
Gompertz curve for paint cracking and the multi-layer film thickness and sol-air temperature factors

CONTACTS: Pedro Paulo; ppaulo@civil.ist.utl.pt – Concluded 16/12/2009

Numerical Modelling of The Seismic Response of The Ground and Circular Tunnels

Rui Pedro Carrilho Gomes

SUPERVISORS: Carlos Sousa Oliveira (IST-ICIST); Jaime Santos (IST-ICIST)

KEY WORDS: Local seismic response; Artificial time histories; Recorded time histories; Selection of time histories for numerical analysis; Numerical modelling; Elastoplastic constitutive law; Soil behaviour under cyclic loading; Seismic behaviour of tunnels; Permanent displacement; Eurocode 8.

INTRODUCTION: The present work is oriented to improve the knowledge concerning the local seismic response assessment. The main factors analysed are: (i) the type and characteristics of the time histories, (ii) the ground profile, (iii) the soil properties, and (iv) the method of analysis.

The main advantages and limitations of several types of time histories are described. The record time histories are selected from a strong-motion database, according to the seismic scenarios defined for Portugal. Also spectrum-compatible time histories are generated and selected, using as reference the response spectra defined in the Portuguese code.

The main characteristics of the soil cyclic behaviour are referred. The viscoelastic law and the Hujeux elastoplastic law are described. The Hujeux law is used to simulate the cyclic behaviour of Toyoura sand and St.ª Iria da Azóia clay for simple shear loading.

The assessment of the local seismic response is done by the following methods: (i) finite element method with the Hujeux law built-in, and (ii) the linear equivalent method, implemented by both probabilistic and deterministic approach.

The local seismic response computed for Toyoura sand and St.ª Iria da Azóia clay and with the selected time histories allow: (i) to identify the main factors that affect the response, (ii) to analyse the rules defined in Eurocode 8 to select time histories and (iii) to compare the average local seismic response with the elastic response spectra defined in Eurocode 8 for different ground types.

The seismic behaviour of the cross section of a circular tunnel is evaluated. The influence of the delay between excavation and lining installation, the lining thickness, the soil properties and stratification of the ground is analysed.
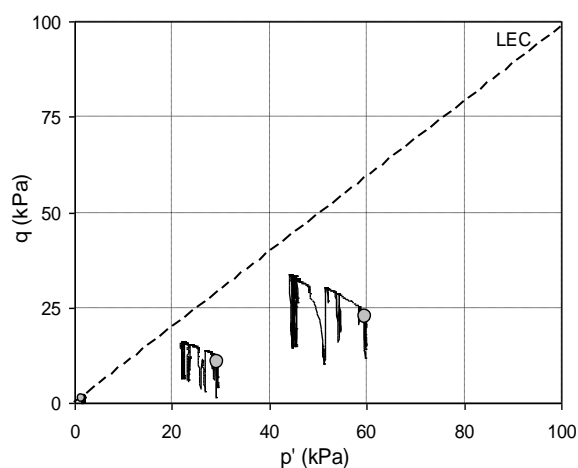
Stress path during seismic loading.

CONTACTS: Rui Gomes; ruigomes@civil.ist.utl.pt – Concluded 18/12/2009

Salt Crystallization in Plastered or Rendered Walls

Teresa Cláudio Diaz Gonçalves

SUPERVISORS: José Delgado Rodrigues (LNEC); Fernando Branco (IST-ICIST)

INTRODUCTION: This thesis was aimed at understanding the behaviour of plasters and renders on salt-loaded walls. The current state-of-the-art and state-of-the-practice were accessed focusing particularly on old plastered/rendered buildings and their conservation practice in Portugal. Afterwards, experimental work was carried out aiming at answering the identified questions. Two laboratory techniques, for relative humidity control with salt solutions and for salt content

determination by hygroscopic moisture content measurements, were investigated. Drying of salt-loaded materials was studied by means of drying experiments monitored using a magnetic resonance imaging (MRI) technique. The behaviour of plasters and renders in relation to salt crystallization was then accessed by means of crystallization tests and MRI-monitored drying tests. Most drying and crystallization tests were carried out on specimens composed by a plaster or render applied on a given substrate. Finally, the study of five old buildings in Portugal provided an insight into practice-related salt decay features.

On the basis of this research, guidelines are proposed to select plasters and renders for saltloaded walls. Conclusions were also achieved on: (i) possibilities and limitations of the test methods, particularly salt crystallization tests, and diagnostic methodology used; (ii) salt decay processes, namely, influence of soluble salts on drying, mechanisms of salt-induced dampness and salt distribution in masonry; (iii) reasons for sodium chloride being typically much less damaging than sodium sulfate in laboratory tests; (iv) influence of factors such as the type of salt, kind of substrate material or presence of a paint layer on the behaviour of plasters and renders; (v) factors that can account for a worsening of salt damage after restoration interventions; (vi) field or application conditions that favour salt damage.

Two typical salt-damage patterns. Left: efflorescence and damage to paint, temporary exhibition gallery, south wing of Alcobaça Monastery, 2002. Right: sanding of lime plaster and of the lime bedding mortar leading to masonry disintegration, Paulistas tide-mill, Corroios, 2004.

CONTACTS: Teresa Gonçalves - teresag@lnec.pt – Concluded 17/7/2007

Seismic Tomography of the Mozambique Rift

Ana Domingues

SUPERVISORS: João Fonseca (IST-ICIST)

KEY WORDS: African Rift, seismic tomography, seismic network

INTRODUCTION:

1) A comparative analysis of different forward modeling techniques: full ray theory; Born scattering; and the spectral element method. Selection of the forward modeling technique to be used for tomographic inversion of the data.

2) A comparative analysis of different inversion algorithms to derive the 3-D velocity structure of the crust and upper mantle under the target area. Selection of a suitable technique for the dataset.

3) Implementation of the selected combination of forward and inverse techniques. Tomographic inversion of the dataset.
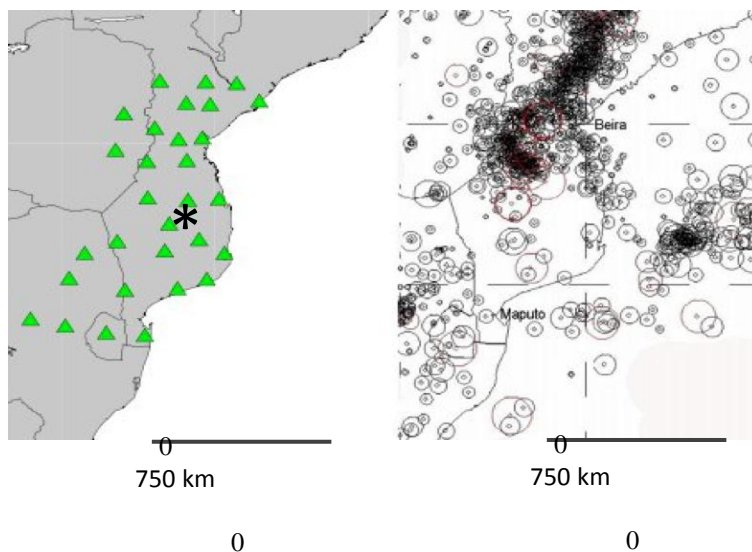
Layout of the MOZART seismic network, used for this Ph.D. project (left), and seismicity of Central and Southern Mozambique (source: NEIC)

Statistical Modeling Of Service Life Prediction Of Building Facades

Ana Filipa Ferreira da Silva

SUPERVISORS: Pedro Gaspar; Jorge de Brito (IST-ICIST)

KEY WORDS: service life prediction; advanced statistical tools, building facades

INTRODUCTION:

In this study are develop different methods for service live prediction of building facades. The service life prediction methodologies are define using many advanced statistical tools, who allow to ally the study of degradation of building's facades in real conditions (the study cases are analyze in an extensive field work) with mathematical models. The mathematical models can be use to estimate the durability and service life of building's facades, integrating a risk analysis.

The definition of these methodologies are very important in nowadays because allows the definition of an adequate and optimized maintenance strategy, avoiding the situations of urgent replacements of buildings facades and the elevated costs associated with that.

The different methodologies are exemplified through its application to external cement renders, natural stone claddings, adhesive ceramic tiling systems and external paint finishes (on rendered facades).

MAIN OBJECTIVES:

The main objective of this study is establishing service life prediction models using the advanced statistical tools. The statistical tools that will be use are: simple linear and non-linear regression; multiple linear and non-linear regression; artificial neural networks; Markov chains; ROC curves; logistic regression; non parametric tests; Monte Carlo simulation; evidence theory; fuzzy logic; and others.

The methodologies proposed in the study will be validated with 1000 cases of natural stone claddings and apply to the others types of building facades.

The analysis of different statistical methods will allow understanding what method is more efficient for service life prediction of the various types of building facades analyzed.

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High-performance Sustainable Solutions For The Renovations Of Commercial Areas

Ana Sofia Santos Ferreira

SUPERVISORS: Manuel Duarte Pinheiro (IST); Jorge de Brito (IST-ICIST)

KEY WORDS: Sustainability, retail buildings, high-performance building solutions, retrofit of buildings

INTRODUCTION: Retail buildings are responsible for up to 20 % of the energy consumption in the commercial sector which makes them an important focus for the implementation of high-performance building solutions. This is furthermore important in the retrofit of existing buildings, as new construction has a greater environmental impact that needs to be restrained.

The thesis analyses what retail companies – like Wal-Mart, Carrefour, Metro AG - are doing to increase sustainability in their buildings and presents a case study of which solutions were used in the retrofitting of a store.

Lessons learned from retailers are contributive as they can usually be adapted by their peers or by other commercial buildings, provide opportunity for the optimization and affordability of new technologies and can have a broaden influence not only in the upstream construction industry but also in society, as the retail sector is becoming potential the greatest purveyor of culture.

MAIN OBJECTIVES: The thesis will have as main objectives the development of a methodology that can be applied to existing retail buildings regarding their environmental performance as well as the proposal of high-performance sustainable solutions which can be used when retrofitting commercial buildings, having into consideration the specificity of their life span.

EXPERIMENTAL RESULTS: The thesis will propose a framework that identifies and correlates the available high-performance sustainable solutions with its possibility of use in the retrofit of existing commercial buildings once the building's environmental performance has been assessed. The framework will then be tested on a case study – following up the retrofit of a given commercial building – and results will be evaluated and transposed into the framework.

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Non-linear Monotonic and Cyclic Behaviour of Cold-formed Steel Members And Frames

Ângela Neves

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KEY WORDS: Cold-formed steel; non-linear behavior, monotonic loading, cyclic loading

INTRODUCTION: The work aims to analyze the structural behavior and estimate the ultimate strength of structural elements and lightweight steel frames by examining their susceptibility to either monotonic or cyclic actions. It is intended to evaluate several design methodologies for metallic structures in existing codes of practice and to evaluate the load bearing capacity and ductility of such metallic structural elements and frames subjected to cyclical actions. There is also the aim of proposing new methodologies for the design and safety checking of cold-formed steel members submitted to cyclic actions. In particular, the assessment of ductility of class 4 cross-sections is an issue of great relevance for LSF (Light Steel Framing) houses located in seismic areas.

MAIN OBJECTIVES: The main objectives of this work are to investigate the nonlinear monotonic and cyclic behavior of lightweight elements and steel structural systems. It is intended to evaluate the accuracy of estimates obtained through the design rules of the EC3-1-3 and other design codes of lightweight steel structures, proposing alternative methods if necessary. The first part of this investigation concerns the use of numerical models (shell finite elements) to assess the nonlinear behavior of thin-walled beams and frames. The second part of this investigation concerns an experimental program, including a set of cold-formed steel beams subjected to monotonic and cyclic actions.

EXPERIMENTAL RESULTS: Planning and performing a set of tests of cold-formed steel beams under monotonic and cyclic actions. These results will be used to validate the numerical models and assess the ductility of beams with class 4 cross-sections, thus paving the way to clarify their suitability for structures in seismic areas.
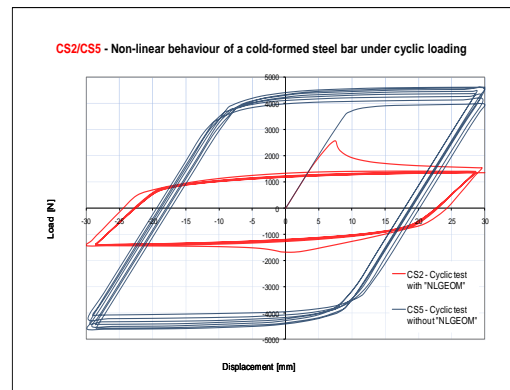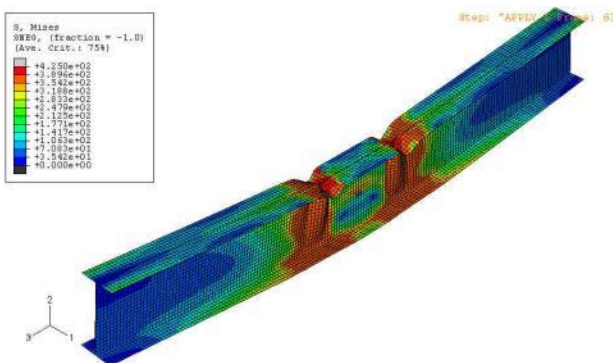
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Procurement of Construction Projects: Analysis of Traditional and Non-traditional Models and Contribution to Their Improvement

António Manuel Gardete Mendes Cabaço

SUPERVISORS: Armando da Costa Manso (LNEC); Jorge de Brito (IST-ICIST)

KEY WORDS: procurement models, construction projects, public construction works, public-private partnerships, tendering procedures, public contract code, contracts, specifications, construction project management, tender evaluation

INTRODUCTION: This research analyses and defines different procurement models to apply in public construction projects, as a way of addressing some of the identified needs arising from the recent publication of the *Códigos dos Contratos Públicos* (Public Contract Code) and the recent contracts in Public-Private Partnerships (PPP). Relevance is given to the technical and construction issues and how these can and should be considered by Public Procurement Entities in the stages of preparation of contracts. Some tools and some procedures are also proposed to be used by those entities under the public procurement models defined in the legislation.

The study was based on a diverse range of construction projects undertaken in the last decade in Portugal, subject to contract research conducted at the National Laboratory of Civil Engineering (LNEC), in which the main critical aspects related to contracting and management were analysed. The models and contracting procedures developed in this work were applied in some of these projects, and the results contributed to the benchmarking and validation of these models. This study contributes to the clarification and reinforcement of the tendering procedures for the implementation of public construction projects, whether traditional procurement & contract models or non-traditional ones in PPP formats are adopted.

MAIN OBJECTIVES: This research work aims to define methodological approaches to procurement models within construction projects, both traditional and non-traditional, by analysing the critical aspects and by defining procedures to ensure the fulfilment of the legal requirements and the safeguarding of the public interest. The study aims also to give a response to some needs identified within the construction sector mainly due to the introduction of new procurement models and new tendering procedures resulting from the recently publication of the *CCP* (Public Contract Code) and the usage of PPP's.

EXPERIMENTAL RESULTS: 80 case studies of construction projects were considered for this research. They allowed the definition and validation of proposals models, proposals evaluation models, negotiation models, and the definition of the role of the stakeholders within traditional and non-traditional procurement. The main critical aspects of the construction projects procurement and contracting were also addressed and contributions for their improvement were presented.

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Reliability Assessment of the Direct Displacement Based Design Methodology

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KEY WORDS: Displacement-based seismic design, Reinforced Concrete Structures

INTRODUCTION: The Ph.D. aims at investigating a complete seismic design approach based on performance criteria, which results in structures that achieve a specified deformation state under the design level earthquake. The method subject to study requires little or no iteration to design a structure that achieves specified displacements, and thus is known as Direct Displacement-Based Design (DDBD). It represents the structure by a SDOF substitute structure characterized by the secant stiffness and by equivalent viscous damping representing the combined effects of elastic and hysteretic damping. In this context, special emphasis will be put on the definition of the equivalent viscous damping, as it is generally stated that an accurate evaluation of this equivalent viscous damping is a crucial step in the DDBD methodology. The reliability of the DDBD methodology will also be assessed for frame and dual wall-frame buildings by means of non-linear time history analyses (NLTHA).
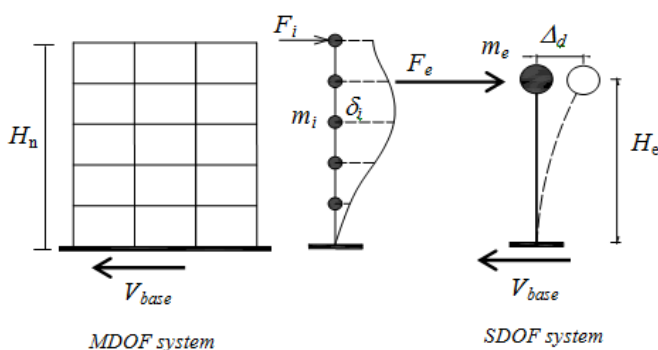
Simplified model of a multi-storey building
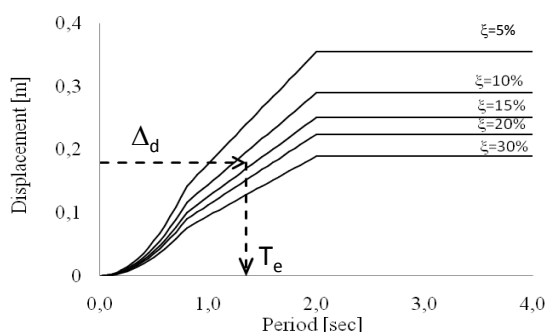
Design Displacement Spectrum

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Decoding Alberti's De Re Aedificatoria: A Computational Approach

Bruno Figueiredo

SUPERVISORS: José Pinto Duarte (FAUTL-ICIST)

KEY WORDS: Leon Battista Alberti, generative design, shape grammars, transformations in design, design automation, rapid prototyping

INTRODUCTION: The thesis discusses the emergence of digital technologies in architecture, the integration of computational models in the design and analysis of architectural design, mainly as tools that integrate processes of historical research in architecture. The research will develop generative computational models for the scrutiny of the cultural impact of De Re Aedifciatori from Leon Battista Alberti (1485) in classical architecture in Portugal, particularly during the Counter-Reformation(XVI-XVII centuries). In this context, it will take as a case study creating a computer model to implement a form of generative grammar, which decodes the De re aedificatoria treatise and enables the understanding of the changes proposed in the formal organization of churches designed and built by Alberti, and its impact on the architectural culture of Renaissance in Portugal.

MAIN OBJECTIVES: The aim of this research it is to use an intelligent computational model for analyzing and understanding the impact of the *De Re Aedificatoria* in classical Architecture, using it as a tool to understand the implications of this theory both in Portugal and in the territories where it has been administratively.

EXPERIMENTAL RESULTS: Research has been focused on developing shape grammars of the temples as described on the *De Re Aedificatoria*. This task has been initiated by the reading of the Book 7 - *The Ornament of sacred buildings*, and uses a methodology of seven stages of knowledge of the shape grammars: (1) selection of parts of the text on which Alberti describes the various components of temples, (2) compiling the information, grouping it in order to allow the description and the definition of the components variables, (3) description and definition of the transformation rules of the various phases of the generative grammar, (4) implementation of the rules in computational models in a graphical integrated software – *grasshopper*, a 3D modeling program - *Rhino*, (5) the illustration of applying the rules to generate a corpus of solutions, (6) comparison of results obtained with the corpus of church buildings designed and built by Alberti, (7) and finally, the implementation of changes to the grammar that reflect the differences found in the previous task.
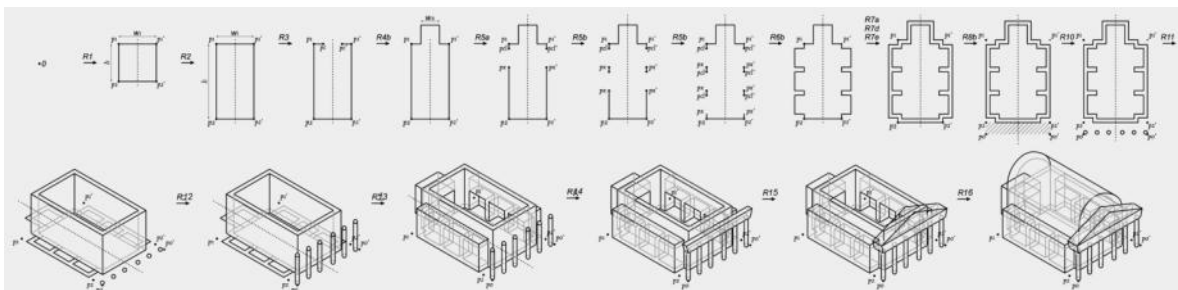
Example of application of rules for the generation of a quadrangular temple

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Adhesion of Repair and Plastering Mortars to Concrete Substrates

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SUPERVISOR: Eduardo S. Júlio (IST-ICIST)

KEY WORDS: Mortar, substrate, repair, surface

INTRODUCTION: Currently, there is a vast set of repairing and plastering mortars, with different constitutions, physical/chemical properties and mechanical behaviors. The adhesion of these materials to the concrete substrate is essential for the adequate behavior of the whole. Anomalies often take place because the compatibility between the applied product and the concrete substrate is not guaranteed. This is due, mainly, to the influence of parameters such as the texture of the substrate surface, the moisture of the substrate, and the differential stiffness and/or shrinkage, when submitted to temperature gradients and other type of actions.

This doctoral thesis aims to contribute to the study of adhesion of repairing and plastering mortars to concrete substrates. The study will focus primarily on the influence of the texture of the substrate surface and will include various types of repairing and plastering mortars. Traditional mortars, industrial mortars, ultra-high performance fiber-reinforced mortars, and alkali-activated mortars will be considered. Different types of concrete substrates will be used, e.g. current concrete, self-compacting concrete and lightweight concrete.

MAIN OBJECTIVES: The aims of this research work are: (i) to identify and characterize the constituents to be used in mortars, (ii) to develop different mixtures and curing conditions and to characterize mortars in both fresh and hardened states, (iii) to define and characterize different types of surface textures and methods to adequately produce these, and (iv) to study the influence of different parameters in the mortar-to-concrete strength. Both experimental and numerical work using the commercial software Abaqus is previewed.

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Seismic Assessment of Existing Buildings Using Nonlinear Static Procedures (NSPs) - A New 3D Pushover Procedure

Carlos Augusto de Almeida e Fernandes Bhatt

SUPERVISORS: Rita Bento (IST-ICIST); Rui Pinho (Univ. of Pavia, Italy)

KEY WORDS: Earthquake engineering, nonlinear analysis, 3D Pushover analysis, nonlinear static procedures, nonlinear dynamic analysis, existing reinforced concrete buildings asymmetric in plan, torsion, performance based design, seismic assessment, seismic codes.

INTRODUCTION: The good performance of Nonlinear Static Procedures (NSPs) on the seismic assessment of bridges and planar frames is nowadays generally recognized. However, the use of such methods in the case of real existing plan irregular structures has so far been studied by a limited number of authors. This fact limits the application of NSPs to assess current existing structures, the majority of which are irregular in plan. Existing studies on this topic usually focus on the evaluation of a single NSP. In order to obtain useful elements of comparison between different methodologies, the performance of four commonly employed nonlinear static procedures (CSM, N2, MPA and ACSM) is evaluated in this thesis. The appropriate variants of code-prescribed NSPs (CSM and N2) to be considered for subsequent evaluation were established as a preliminary study. An extension of CSM-FEMA440 to plan asymmetric buildings and a new 3D Pushover procedure are also proposed in this thesis. The case studies chosen are real existing reinforced concrete plan asymmetric buildings with different typologies. The accuracy of the NSPs is evaluated by comparison with nonlinear dynamic analyses for several levels of seismic intensity. The results obtained from the parametric studies showed that the Extended N2 method, the proposed Extended CSM-FEMA440 and the new 3D Pushover procedure exhibited the best performance on the analysed buildings, and seem to have potential to be incorporated in future seismic codes.
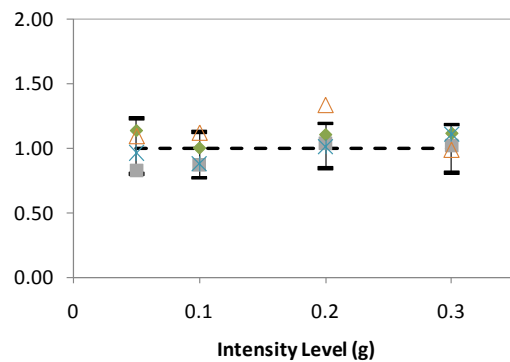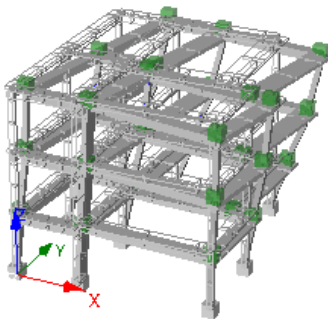
CSM FEMA440   ◆ Extended N2   ✳ MPA   △ ACSM   – ● – TH median   —●— TH mean ± standard deviation

left: SPEAR building: three storey reinforced concrete structure analyzed
right: Top displacement ratios in the SPEAR building for different seismic intensities

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Cohesive Fracture Analysis of Concrete Structures

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Catarina Isabel de Almeida Paulo

SUPERVISORS: Luís dos Santos Castro (IST-ICIST); João Teixeira de Freitas (IST-ICIST)

KEY WORDS: hybrid-mixed finite elements, cohesive fracture mechanics, damage mechanics, transition techniques.

INTRODUCTION: The work aims to assess and develop a robust and computationally competitive finite element formulation for the analysis of nonlinear concrete structures. More specifically, a hybrid-mixed finite element formulation for the analysis of fracture processes in concrete structures using discrete cohesive fracture models will be developed, implemented and fully tested.

The development of adequate transition techniques is also addressed, in order to model the transition from a fracture analysis based on continuum models (damage mechanics) to discrete models (cohesive fracture mechanics).

The most relevant feature of hybrid-mixed formulations is the capability to easily enrich the adopted approximation basis functions. It is therefore possible to model explicitly displacement field discontinuities and stress field singularities.

MAIN OBJECTIVES: Main objectives are the following:
 - Implementation of discrete cohesive fracture models using a hybrid-mixed finite element formulation;
 - Comparative performance analysis of the adopted cohesive fracture models;
 - Development of transition techniques to switch from a continuum to a discrete analysis of the fracture process;
 - Assessment and validation of the developed models through the analysis of plane elasticity benchmark problems, and numerical comparison of the obtained results with those provided by alternative well known formulations proposed in the literature.

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Ultra High Durability Concrete With Self Sensor Capacity

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SUPERVISORS: Eduardo S. Júlio (IST-ICIST)

KEY WORDS: Ultra high durability concrete, self sensor properties

INTRODUCTION: In the last few decades, there has been a growing interest in the use of fiber-reinforced concrete (FRC) for both new construction and rehabilitation of existing concrete structures. More recently, ultra high performance fiber-reinforced concrete (UHPFRC) appeared as one of the most promising types of FRC, presenting not only ultra-high compressive strength but also ultra-high durability, because of its ultra dense structure and thus highly reduced porosity. This PhD thesis aims to develop and characterize various types of ultra-high durability concrete (UHDC), including the development of a robust mixture design method based on experimental data. The ultimate goal is to replace the cover of concrete members by a UHDC protective layer. This is also intended to provide real-time structural health monitoring, by further develop the ability of the UHDC cover to be used as self-sensor or, if proven unviable, to develop alternatives using electronic devices.

MAIN OBJECTIVES: Main objectives are:
- To develop a robust mixture design method for ultra high durability concrete (UHDC)
- To characterize the properties of UHDC, especially durability
- To develop a robust and economically viable sensor to enable real-time structural health monitoring

EXPERIMENTAL RESULTS: The mechanical properties of UHDC have been characterized using different constituents. In addition, the transport properties and porosity of different mixtures have been analyzed under different curing conditions. According to the results, an appropriate mixture proportion has been obtained in terms of both mechanical and durability properties. The development of a comprehensive mixture design method is still on going.

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Applications of Spatial Analysis Techniques in the Conservation of Paintings

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SUPERVISORS: Ana Calvo (Escola das Artes/Univ. Católica do Porto , Portugal): Alexandre Gonçalves (IST-ICIST)

KEYWORDS: GIS, conservation and restoration, retouching, pictorial characterisation, spatial data acquisition

INTRODUCTION: In the framework of Geospatial Technologies (GT) the study of the terrestrial surface through various processes of acquisition, processing and analysis of spatial information, related to the most varied phenomena, is often done. However, the abstraction of models and methods used for this purpose allows their application in the spatial analysis of any other surfaces, such as the digital images of paintings. This extension of the traditional field of GT allows quantifying multiple spatial characteristics of the surfaces interesting in the documentation for Heritage Studies. Despite the clearly different scales between the two domains of knowledge, the representation and analysis of paintings can be performed with methodologies generally used to characterise the terrestrial surface, being useful in the documentation process for Conservation, especially in the visualisation and in the pictorial spatial quantification. The thesis presents some perspectives on the application of Geographic Information Systems in the spatial analysis of paintings, aiming to document surface phenomena, as well as the results of processes of classification and image analysis with landscape metrics.

MAIN OBJECTIVES: Inspect on the applicability of data acquisition tools and spatial analytical methodologies and functions in the documentation process used in Conservation and Heritage Studies.

EXPERIMENTAL RESULTS: Description, application and result interpretation for several case-studies using geospatial technologies and GIS functions in selected artworks:
- Photogrammetry and orthophotography
- Image classification for the evaluation of geometric properties of the pictorial surface (mainly for the extraction of pathological origin features)
- Landscape metrics

Result of a Maximum Likelihood
Classification for the lacunae in a wall painting
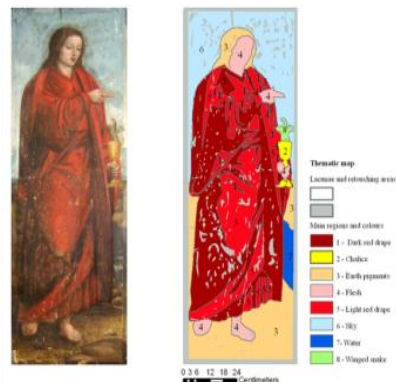
Orthophotograph of a panel painting and the corresponding thematic map of lacunae, retouching areas and main colours.

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Seismic Vulnerability of Pombalino Buildings

Helena Alves Meireles

SUPERVISORS: Rita Bento (IST-ICIST); Andreas Kappos (Aristotle University of Thessaloniki, Greece)

INTRODUCTION: The thesis focuses, first, on the definition of the soil characteristics of Lisbon downtown and on the definition of the seismic action for assessment. The site selected (Lisbon downtown) is set on an alluvium filled valley of soft unconsolidated sediments where considerable seismic site amplification of ground motion is expected. Albeit the importance and susceptibility of the site, not much information is available in the literature for seismic ground characterization. So, a collection of data has been gathered from various sources, mostly from geological and geotechnical surveys. Additional measurements of ambient vibrations have been performed based on the H/V spectral ratio technique (HVSRT). Based on the combination of geological and geotechnical data with HVSRT, it was possible to characterize the alluvium site in terms of average shear wave velocity of the soil ($V_{s,av}$) and depth to bedrock estimates, as well as mapping the site quarters where seismic ground amplifications are expected. The site $V_{s,av}$ of the soil is estimated at ~194 m/s. Second, a focus was given on the interior walls of the *Pombalino* buildings called "frontal" walls. An experimental campaign to obtain the hysteretic behaviour of these "frontal" walls was carried out by static cyclic shear testing with imposed displacements. A total series of three tests were conducted in three identical real size walls. The hysteretic behaviour of such walls subjected to cyclic loading exhibit high nonlinear force-displacement responses and high ductility. As previous experimental studies on "frontal" walls are very limited, these results are an important contribution to the state of the art.

Third, based on the experimental results obtained, a macro-element was proposed for "frontal" walls. This was obtained based on the development of a hysteretic model to describe the cyclic behaviour of the *Pombalino* "frontal" walls. The hysteretic model, based on phenomenological approach, aims to reproduce the response of a wall under general monotonic, cyclic or earthquake loading and is related to a minimum number of path following rules. The model was constructed using a series of exponential and linear functions. There are a total of nine identifiable parameters in this model to capture the nonlinear hysteretic response of the wall. These were all calibrated with experimental data.

Finally, the last part of this study focuses on the modelling of a typical *Pombalino* building with a structural software called 3Muri (www.stadata.com) where the previously described macro-element for "frontal" walls has been incorporated. The modelling includes macro-elements for the masonry panels and, as a new accomplishment for the state of the art, macro-elements also for the internal "frontal" walls. Pushover analyses were carried out and the seismic assessment of the building was evaluated. Further ahead, fragility curves and damage probability plots were obtained. The most important application of such curves is in loss estimation studies and this is further ahead proposed work. Last, some retrofitting strategies were modelled also in 3Muri program and the seismic assessment and fragility analysis were carried out also for these situations.

Hysteresis curves

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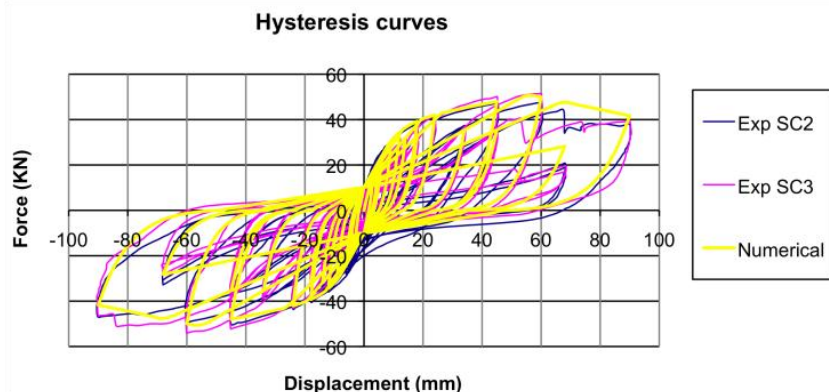
Time-dependent Behavior of RC Elements Strengthened with LWAC

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SUPERVISORS: Eduardo S Júlio (IST-ICIST)

KEY WORDS: LWAC, strength, density, Young's modulus, shrinkage, creep, interface strength

INTRODUCTION: Nowadays, the production of lightweight aggregate concrete LWAC, simultaneously with high strength and reduced density, has an increasing interest. Aiming to develop a mixture design method for LWAC, using lightweight expanded clay aggregates, an experimental research study has been conducted. The mechanical properties, the time-dependent properties and the strength of the interface between LWAC and a concrete substrate have been assessed. The developed method can be used, reliable and accurately, to design not only LWAC but also LWAC with special requirements. Corrections are proposed to codes predictions, mainly for Young's modulus, shrinkage and creep. Important LWAC parameters have also been studied to better predict the interface strength of composite concrete elements using this material.

MAIN OBJECTIVES: (i) to develop a mixture design method for LWAC and adapt it to LWAC with special requirements; (ii) to characterize the mechanical properties of LWAC; (iii) to characterize the time-dependent properties of LWAC; (iv) to study the parameters and characterize the interface strength of composite elements with LWAC; (v) to develop a parametric study to correct the codes predictions which are not correctly considered.

EXPERIMENTAL RESULTS:
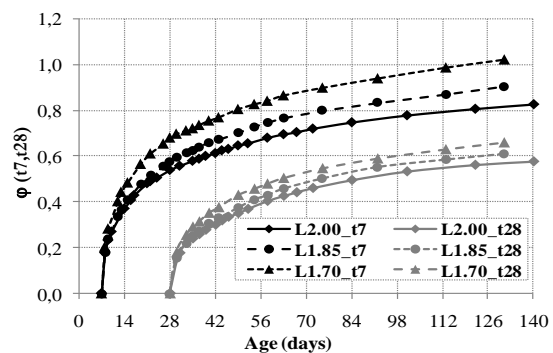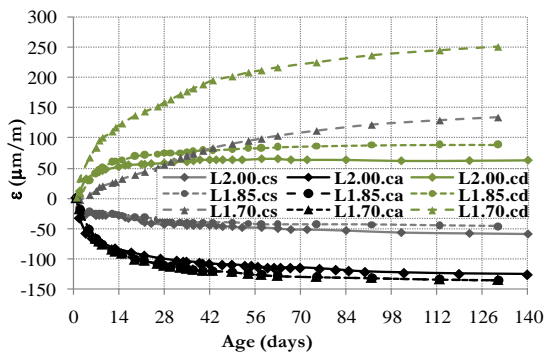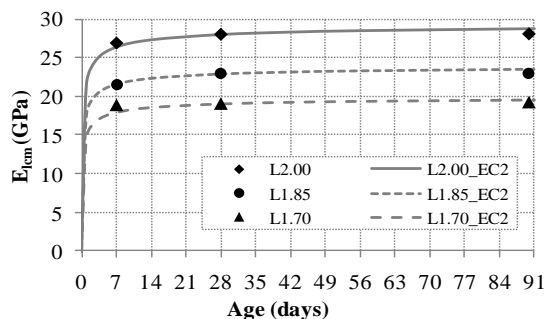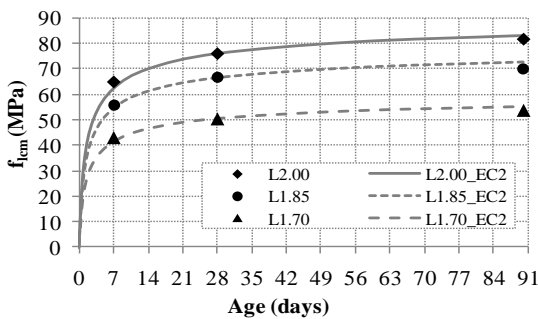
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Use of Nano-enhanced Masonry Walls as Robustness Reserve of Buildings Submitted to Unforeseen Events

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KEY WORDS: Robustness, nano-enhanced clay masonry walls, unforeseen event.

INTRODUCTION: Clay bricks are one of the oldest construction materials, still used nowadays, presenting several advantages. Due to a number of disproportioned collapses of buildings in the past, caused by unforeseen localized extreme events, robustness has become an important structural property and research on this topic is on progress worldwide. However, in these studies, only the structure is considered to resist to the actions in spite of in many real cases collapse has been avoided as a result of the contribution of non structural members. This thesis aims to study the possibility of using non-structural masonry walls as a robustness reserve of buildings when submitted to unforeseen events, also having in mind the sustainability of the construction sector in terms of using industrial by-products to enhance the properties of clay bricks.

MAIN OBJECTIVES: The main objectives are: (i) to develop a more resistant clay brick, both thermal and mechanically, by incorporating industrial by-products, this way also contributing for a more sustainable environment; and (ii) to develop a new concept that consists in considering this new product to build non-structural masonry walls that can be considered as a structural robustness reserve of buildings submitted to unforeseen extreme events.

EXPERIMENTAL RESULTS: in progress

From Tradition to Inovation: Study of the Building Pattern Upstream From Baixa, Following the Earthquake

Joana Alegria

SUPERVISORS: Raquel Henriques da Silva; António de Sousa Gago (IST-ICIST)

KEY WORDS: Baixa, Lisbon´s Reconstruction Plan, 1755 earthquake

INTRODUCTION Com o terramoto de 1755 foi traçado e posto em prática o Plano de reconstrução da cidade de Lisboa que compreendia a Baixa da cidade, a parte mais afectada pelo sismo. O objectivo deste trabalho é estudar a área que confronta com o limite Nascente do Plano, uma área de encaixe, que apresenta uma variedade arquitectónica que traduz a fusão da arquitectura do Plano com as arquitecturas pré-terramoto. Através deste estudo pretende-se entender como é que uma área fundamental da cidade de Lisboa se comportou após o terramoto, tendo em conta a sua localização periférica, mas próxima em relação à área de implantação do Plano de Reconstrução. Percebendo como é que as preexistências são incorporadas naquela nova arquitectura e vice-versa, levar-nos-á ao conhecimento das sua raízes, de como nasceu, se desenvolveu e se adaptou a diferentes contextos, contribuindo assim para o conhecimento mais vasto e profundo da arquitectura do Plano, bem como para a sua valorização histórica e patrimonial.

MAIN OBJECTIVES: O objectivo deste trabalho é estudar o comportamento da área de encaixe que faz a ligação gradual entre o limite Nascente do Plano de reconstrução e a cidade antiga, depois do terramoto. Através da análise detalhada dos aspectos físicos, arquitectónicos, construtivos e sócio-económicos de uma área fundamental da cidade, que compreende, de grosso modo, a Rua de São Mamede, Rua das Pedras Negras, Rua de Sto. António à Sé e a Rua da Padaria, pretende-se perceber quais os elementos provenientes de marcações do Plano, quais os elementos pré-terramoto e quais as alterações/adaptações quer aos elementos do Plano quer às preexistências, tentando saber como é que o novo plano se adaptou ao existente, ou seja, como é que o novo se "encaixou" no antigo. Percebendo como as preexistências são incorporadas naquela nova arquitectura e vice-versa, levar-nos-á a um conhecimento mais vasto e profundo da arquitectura do Plano.

O objectivo específico enunciado relaciona-se com outro mais vasto e complexo - estudar profundamente o centro histórico de Lisboa depois do Terramoto – com a finalidade de caracterizar fundamentadamente os processos da sua modernização, peculiares no contexto europeu pelo modo como as sobrevivências do passado suportaram e orientaram opções radicais de alteração, decorrentes do Terramoto.

Location of the study area

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Seismic Retrofitting Techniques for Ancient Buildings

João Alexandre Medeiros Tavares Guerreiro

SUPERVISORS: João Ferreira (IST-ICIST); António Gago (IST-ICIST)

KEY WORDS: Seismic Reinforcement, Ancient Buildings, Heritage, Masonry walls, Authenticity, Reversibility

INTRODUCTION: Lisbon and other European cities settled in places with high seismic hazard have a significant percentage of buildings with a vertical structural frame in masonry and wooden floors. Those buildings present insufficient resistance levels, given the nature of their materials (with weak resistance and ductility) and their structural assemblage, and should be part of interventions for structural rehabilitation to the satisfaction of the present standards.

The obstacles in the definition of those retrofitting interventions, particularly in case of seismic reinforcement, lie on the lack of experience in the simulation of structural behavior of ancient buildings and the small amount of economically viable solutions available (most still to be characterized mechanically).

Such interventions should be supported by reinforcement techniques guided by the ICOMOS principles for structural interventions, especially the maintenance of the authenticity of the structures and the reversibility of the interventions. Some of them are to be developed at this doctoral program.

MAIN OBJECTIVES: This doctoral program comprehends the following primary objectives:

- Development, production and experimental essay of the chosen retrofitting techniques;

- Evaluation and improvement of the techniques effects to the behavior of masonry walls due to several solicitations.

- Numerical modeling to reply the wall behavior with and without the reinforcement techniques, in the different configurations in study. The models will be calibrated and verified considering the experimental results, and should provide tools for simulation of the effects in real buildings.

 - Development of design rules for the reinforcement, based on the numerical models developed, that can be used in the project of rehabilitation of ancient buildings.

EXPERIMENTAL RESULTS: None meaningfull yet.

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Connection Capacity Between Micropile and Existing RC Footings

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KEY WORDS: bond, strength, confinement, retrofitting, interface, micropile, grout, push-out tests, pull-out tests

INTRODUCTION: Strengthening foundations with micropiles is progressively being used, due to the major advantages that this technique presents. Nevertheless, the influence of some relevant parameters in the overall behavior of the retrofitted foundations has not yet been studied. Generally, micropiles are installed in holes drilled through the existing RC footing, which are then filled with grout. The efficiency of the load transfer mechanism depends on the bond strength of both the micropile-grout and the concrete-grout interfaces. An experimental investigation was performed to specifically study the influence of some parameters on the bond strength between micropile-grout-concrete interface.

MAIN OBJECTIVES: The load transfer mechanism depends on the behaviour of the micropile/grout/concrete interface. Thus, this study aims to contribute to the knowledge of the behaviour of these interfaces, being addressed the effect of: (i) textured of the hole surface; (ii) texture of the micropile; (iii) hole diameter; (iv) micropile embedment length; and (v) level of confinement of the RC footing. Design and detailing guidelines are proposed.

EXPERIMENTAL RESULTS: For smooth micropile inserts bond strength was found to increase with the decrease of the hole diameter and with the increase of the confinement level of the RC footing. For textured micropile inserts the capacity of the micropile-to-footing connection increases with the increase of the insert embedment length and with the decrease of the hole diameter. In addition, it was concluded that an adequate active confinement must be provided to achieve the required capacity.

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Smart Systems for Structural Health Monitoring

João Pedro de Oliveira Dias Prudente dos Santos

SUPERVISORS: Paulo Silveira (LNEC), Luís Calado (IST-ICIST)

KEY WORDS: Structural Health Monitoring, Damage Detection, Damage Localization, Machine Learning, Data Mining, Bridge Monitoring, Operational and Environmental Effects

INTRODUCTION: Structural Health Monitoring (SHM) can be defined as the development of approaches or strategies for damage detection, location, type and severity. Damage can be defined as a structural abnormal behaviour which, in opposition to a fault, does not affect its serviceability or safety. While a damage occurrence is usually undetected unless appropriate SHM systems are deployed on the structures, a fault can be visually detected, directly affects structural performance and can result in partial or global collapse.

This thesis addresses the subject of SHM with the objective of detecting and locating damage in large scale bridges. In the latest years this has been performed with dynamic based monitoring systems, which by using modal analysis can combine large volumes of locally acquired data into few global related measures. Without this procedure data processing would be prohibitive however it also reduces the sensitivity of damage detection algorithms. Among the main reasons is the fact that small magnitude damage can only be detected in high order modes quantities, which are difficult to accurately and automatically detect. The present thesis addresses damage detection and location based on static monitoring by locally controlling variations in dead load effects distribution throughout the structures. Although it may seem simple in concept this procedure is attached to several challenging issues such as traffic and temperature removal in order to obtain, from each sensor's signal, a baseline from which any variation can reflect the effect damage occurrence.

MAIN OBJECTIVES: (i) Define approaches for operational and external effect removal from static SHM data; (ii) Assess the best approaches to outline local damage by normalizing each structural measurement regarding environmental effects; (iii) Define Features that are able to perform Data Fusion and therefore reduce the number of values to be used in damage detection without loss of generality or precision; (iv) Combine Features obtained from the previous objective with numerical simulation of damage, avoiding optimization methods and aiding, thus, in the assessment of type and severity of damage.

EXPERIMENTAL RESULTS: In the framework of the present thesis experimental data is being acquired from two different experimental bridges, located in Portugal: a cable stayed bridge located in Vila Real de Santo António and a Bow-String bridge located at Comporta. Values obtained from these bridges comprise strain, displacements, rotations and environmental data.

$$NI = \left(\frac{2}{K_t (K_t - 1)} \sum_{j=2}^{K_t} \sum_{i=1}^{K_t - 1} B(C')_{ij} \right)^2$$
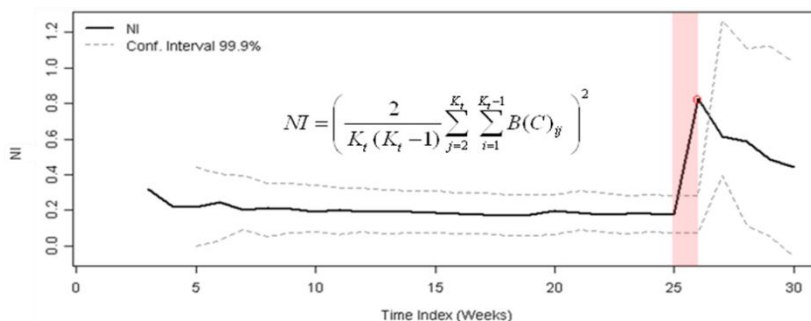
Statistical Classification for Data Fusion. (a) Cluster Analysis (b) Global Damage Index as the squared distance between different clusters.

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Fire Behavior of Reinforced Concrete Structural Elements Strengthened With CFRP Systems

João Pedro Lage da Costa Firmo

SUPERVISORS: João Ramôa Correia (IST-ICIST); Carlos Tiago (IST-ICIST)

KEY WORDS: reinforced concrete, carbon fiber reinforced polymers (CFRP), strengthening systems, fire protection systems, experimental study, numerical study

INTRODUCTION: This study addresses the fire behaviour of reinforced concrete (RC) structural elements strengthened with carbon fibre reinforced polymer (CFRP) systems and the development of appropriate fire protection solutions.

A comprehensive experimental study will be performed including (i) dynamic mechanical analyses and thermogravimetric and differential scanning calorimetry tests; (ii) bond tests on RC-specimens strengthened with CFRP systems at elevated temperature; and (iii) full-scale fire resistance tests on loaded RC-beams strengthened with CFRP systems, comprising different fire protection schemes.

The numerical study to be carried out comprises three stages of development: (i) a FE model simulating the nonlinear thermochemical problem, based on the independent approximation of temperature and material volume ratio fields; (ii) a FE thermomechanical model of the physically and kinematically nonlinear response of the CFRP strengthening systems, based on the independent approximation of deformation and (generalized) stress-resultant fields; (iii) a coupled thermochemical/thermomechanical model of the structural response under fire.

MAIN OBJECTIVES: The main objective of this working programme is the careful assessment of the fire behaviour of RC structural elements strengthened with CFRP systems and the development of innovative and effective fire protection solutions. Such solutions should enhance the structural use of CFRP strengthening systems in buildings, exploiting the advantages they offer over traditional materials. Practical relevance of the results to be obtained implies the fulfilment of two requirements: the availability of proven application recommendations and reliable modelling tools. The numerical models to be developed will allow the simulation of the fire behaviour of CFRP-strengthened RC members, with arbitrary cross-section and different fire protection schemes, and provide thus additional means to support their structural design.

The following results are expected from this study:

In-depth understanding of the bond behaviour between concrete and CFRP strengthening systems at elevated temperature, namely in what concerns temperature and strain distributions, strength, failure modes and critical temperatures;

In-depth understanding of the fire behaviour of RC beams strengthened with CFRP systems, in particular regarding the thermal and structural responses (temperature profiles, strain distributions, deflections, fire endurance, failure mechanisms and corresponding critical temperatures);

Development of innovative and effective fire protection schemes for RC members strengthened with CFRP systems. Such solutions are expected to widespread the structural use of CFRP strengthening systems in buildings; in addition, it will be eventually possible to explicitly consider their contribution to stability in fire design;

Development of numerical models to simulate the thermochemical and thermomechanical responses to fire of RC-members strengthened with CFRP systems, with arbitrary cross-section and different fire protection schemes, with the aim of prototyping structural design supporting tools.

EXPERIMENTAL RESULTS: Experimental study is still in development (2012).

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Ceiling and Roof Structures in Portugal – From Gothic to XIX Century

João Sarrazola Martins

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KEY WORDS: Roofs, Ceilings, Structures, Wood, Construction, History

INTRODUCTION The concern with the preservation of the built heritage has led to a growing interest on the investigation of the design and construction techniques used in the past. This PhD project, aims to complement this study, which is essential to support built heritage conservation and restoration. It is intended, within this project, to perform a complete typological and constructive characterization of the roof and ceiling structures, especially the typically Iberian ones, built in Portugal from the fifteenth century until the end of the nineteenth century, which were built with little technical changes during that period. During the development of the project, a national survey of the ceiling and roof types will be done, identifying the building systems and comparing them with the ones built in Spain. The old methods of tracing will be studied, validating them through the present knowledge. In the scope of the classification, a glossary will be elaborated, that will facilitate to the agents of the conservation and restoration the understanding of old documents.

MAIN OBJECTIVES The project aims to deepen the knowledge about the roof and ceiling structures of Iberian type, built in Portugal from the fifteenth century until the nineteenth century. It is intended to classify roof and ceiling structures, which with some alterations, drifted to the *Mudejar* type ceilings and later, to the *masseira* ceilings (and for some types of false vaults). In the analysis of these structures and their building systems, among other things it will be studied, the ancient graphic methods of design, which are described in some old treatises and work specifications. It will also be carried out structural characterization (using simple models) to identify the function of different elements. Special emphasis will be given to carpentry of *laço*, that is, structures that incorporate decoration of Muslim influence, also known as *Mudejar* ceilings, since the assimilation of these motifs by Christian carpentry, gave rise to an entirely new type of structures, in which the decoration has acquired a structural function. These structures, which are known to exist only in Portugal and Spain and Iberian regions of influence, particularly in South America, are structures which, because of its rarity and complexity deserve a special study, that has not been done under a constructive and architectural perspective. It is also aimed to compare, architectural, structural and constructively, Portuguese ceilings and roofs, with the ones built in Spain, looking for typological and constructive differences. Within the classification, an extensive field and documental survey (in Portugal) will be done and technical glossary will be made to facilitate understanding of old documents. These elements, together with the classification and characterization of the ceilings and building systems will be an important tool for those involved in conservation work and restoration of built heritage.

Roof, Church of São Vicente de Castelo Mendo, XVI Century,
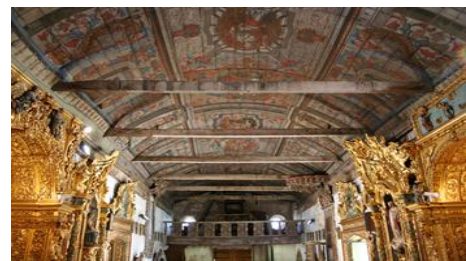
False vault built under Mudejar structure
Church of Podence, XVIII Century

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Sustainable Refurbishment – A Decision Support Tool Integrating Uncertainty. The Case of Portuguese Buildings

Joaquim Manuel Santos Ferreira

SUPERVISORS: Manuel Duarte Pinheiro (IST); Jorge de Brito (IST-ICIST)

KEY WORDS: Life Cycle Assessment, Life Cycle Cost, Refurbishment, Sustainability, Uncertainty

INTRODUCTION: Portugal and the world face an economic crisis that will need some major adjustments of the development model. In the developed countries, like Portugal, the refurbishment of the old stock of buildings – the major part of the urban park – is an urgent need that should be accomplished according to the principles of the Sustainable Construction. For that aim, a methodology based on Life Cycle Assessment, complemented with a Life Cycle Cost analysis, could be an important contribution for contractors and other stakeholders to search for a cleaner and profitable rehabilitation of old obsolete buildings. On the other hand, these types of works are generally characterized by limited resources and a lack of information about the real conditions of the building(s). Therefore, the decision making is always affected by a non-neglecting uncertainty, which is often responsible for economic losses, with a common repercussion in the final price of the real state. Thus, the main objective of this work is to develop of a decision support tool for the refurbishment works in a sustainable and economic approach, integrating the uncertainty, in order to reduce the environmental impacts and costs and to improve the final quality of the contract. For that purposes, the research will comprehend a literature review, based on other existing methodologies for refurbishment, the evaluation of the principal needs and levels of intervention in the Portuguese building stock, their corresponding actions of repair and related uncertainty, the development of the methodology itself and its validation by applying this tool to some real case studies.

MAIN OBJECTIVES: The main objective of this work is to develop of a decision support tool for the refurbishment works in a sustainable and economic approach, integrating the uncertainty, in order to reduce the environmental impacts and costs and to improve the final quality of the contract.

EXPERIMENTAL RESULTS:
The actual phase of this work concerns the literature review, so there are not experimental results yet.

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Structural Health Monitoring of Concrete Structures Using Image Processing and Multi-spectral Analysis

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SUPERVISORS: Eduardo S Júlio (IST-ICIST); Helder J Araújo (FCTUC)

KEY WORDS: Concrete pathology, structural health monitoring, photogrammetry, digital image processing, multi-spectral Analysis

INTRODUCTION: A new method named 'Automatic Concrete Health Monitoring' (ACHM) was developed to monitor the behaviour of concrete structures/members subjected to load and to detect and characterize surface damages in exposed concrete structures. The method uses photogrammetry, digital image processing and multi-spectral image analysis, considering both visible and near infrared spectrum, to evaluate concrete pathology. ACHM proved to be able to automatically characterize and monitor different concrete anomalies.

MAIN OBJECTIVES: (1) To automatically monitor, during laboratorial tests, parameters such as displacement field, strain field and crack pattern; (2) To automatically identify and map anomalies in concrete surfaces, such as cracks, moisture, stains, biological colonization and repair materials.

EXPERIMENTAL RESULTS: Displacement field, strain field and crack pattern

Concrete Damage Maps

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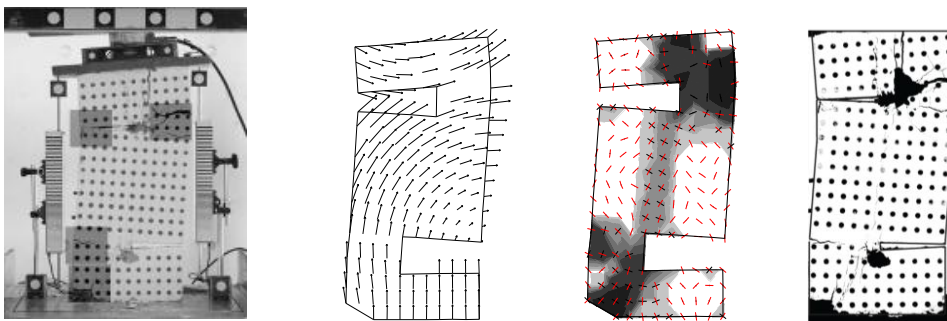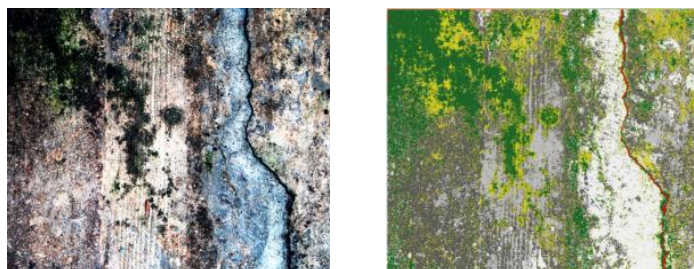
Development of a Prototype of a GFRP-SFRSCC Hybrid Pedestrian Bridge

José de Almeida Gonilha

SUPERVISORS: João Râmoa Correia (IST-ICIST); Fernando Branco (IST-ICIST)

KEY WORDS: GFRP, SFRSCC, hybrid structures, footbridge, experimental tests

INTRODUCTION: This study addresses the structural behaviour of hybrid systems comprising (i) GFRP pultruded profiles and (ii) steel fibre reinforced self-compacting concrete (SFRSCC) material. The unit element of the proposed structural concept is constituted by GFRP I-profiles connected to a SFRSCC thin slab on the top flange. The main objective is to develop a prototype of a GFRP-SFRSCC pedestrian bridge.

Experimental investigations will include (i) material characterisation tests on the GFRP and SFRSCC materials; (ii) full-scale flexural tests on GFRP profiles; (iii) push-out tests between GFRP profiles and SFRSCC slabs, comprising different shear connection systems; and (iv) full-scale flexural tests on a prototype of a GFRP-SFRSCC pedestrian bridge.

Analytical and numerical studies will also be developed: (i) equations for the design of GFRP-SFRSCC hybrid beams will be derived, for both serviceability and failure conditions, and (ii) FE models will be developed to allow for a better understanding of some of the experimental results.

MAIN OBJECTIVES: The main goal is to investigate the structural behaviour of GFRP-SFRSCC hybrid structural systems and to study the viability of their use in civil construction, in particular, in pedestrian bridges. The use of SFRSCC as an alternative to conventional concrete is aimed at taking advantage of its high strength, energy absorption capacity and ductility.

EXPERIMENTAL RESULTS: The experimental results obtained so far in this investigation suggest that the proposed structural solution is feasible. Moreover, the results obtained from testing a small-scale footbridge prototype (6 m long) seem to agree with numerical and analytical predictions both for static and dynamic behavior. This is an important aspect for the design of this structural solution and for the generalization of GFRP pultruded profiles as a construction material. Regarding the connection between the SFRSCC slab and the GFRP profiles, the experimental results show that an adhesive connection presents higher strength and stiffness than a mechanical connection and that a hybrid connection, with both adhesive and bolts, represents an advantage (over the regular adhesive connection) mainly regarding the long term behavior of the connection.
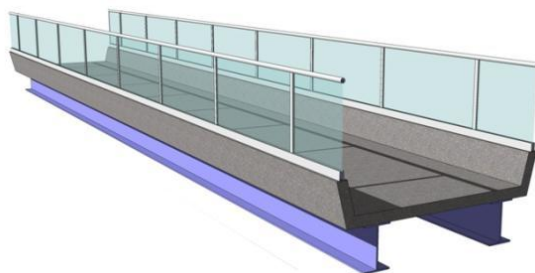
Illustration of the footbridge

Small-scale footbridge prototype

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Life-cycle Assessment "From Cradle-to-cradle" of Buildings Assemblies – Application to External Walls

José Dinis Silvestre

SUPERVISORS: Jorge de Brito (IST-ICIST); Manuel Pinheiro (IST)

KEY WORDS: Building, cradle-to-cradle, energetic performance, environmental performance, external walls, life-cycle assessment, whole-life cost.

INTRODUCTION: The sustainability assessment of a building must represent a part of an integrated evaluation of the building performance. The envelope is one of the main parts of the buildings and external walls directly influence its thermal and environmental performance because of their considerable weight in the initial embodied energy, life-cycle energy consumption and whole-life cost. Therefore, this research proposes an approach to provide the environmental, energetic and economic life-cycle assessment from "cradle to cradle" of building assemblies and exemplifies its application to the external walls. The approach developed in this Thesis followed the guidelines already included in European standards for the sustainability assessment of buildings and construction products. The environmental performance of the external wall solutions are compared from "cradle to cradle" following a "Life-cycle Assessment (LCA)" methodology. The energetic performance considered corresponds to the estimation of consumption of energy for heating and cooling during a building's operation and the economic module is based on the "Whole-Life Cost (WLC)" methodology.

MAIN OBJECTIVES: Development of a LCA approach from "cradle to cradle" innovative at an international level and adequate for construction materials and assemblies;

Integration of the LCA approach with the WLC for each construction material and assembly;

Construction of a LCA database of construction materials and assemblies with national data to be used on the: environmental certification; in building' design tools, including in the selection of covering and insulation solutions for buildings rehabilitation.

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Façade Panels Precast with Eco-efficient Alkali-activated Concrete

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KEY WORDS: Alkali-activated concrete (AAC), façade panels, sustainability, by-product, precast

INTRODUCTION: Nowadays, sustainability is a priority for the scientific community. In the Construction sector, the development of durable eco-efficient materials is a key-issue. For this reason, the use of industrial by-products is a very interesting alternative to OPC. The alkali-activated binders are industrial by-products, such as fly ash, which get hardened using an alkali activator and thermal curing. Alkali-activated concrete also presents the advantage of enhanced durability, essentially due to the decrease of both air void and permeability. Because of the curing conditions, these new cements are particularly suitable for the precast industry. The main goal of this thesis is to develop and characterize the behaviour of precast AAC façade panels.

MAIN OBJECTIVES: The following objectives have been identified: (1) to identify the existing raw-materials for AAC; (2) to develop and characterize the alkali-activated concrete to be adopted; (3) to develop the industrial production method to be used; (4) to design and produce prototypes of facade panels in alkali-activated concrete; and (5) to test models and prototypes to characterize the properties of this new product, including the behaviour of panels-to-façade connections.

EXPERIMENTAL RESULTS: Fly-ash is the industrial by-product selected to be used in this stidy. To develop the alkali-activated binder, first several mortars with different types and dosages of alkali activators, mixture proportions and curing conditions have been produced. In table 1 some mixtures produced and results (consistency and compressive strength) obtained are presented. In these mixtures sodium hydroxide was used as alkali activator and a curing at 90°C for few hours was used.

Table – Alkali-activated mortars mixtures fly-ash based.

Mixture	Binder (kg/m^3)	Sand (kg/m^3)	NaOH		OPC addition (kg/m^3)	Slump (cm)	Compressive strength (MPa)		
			(kg/m^3)	Molarity			4 hours	6 hours	8 hours
M1	660,0	1209,2	297,0	6 M	60,0	16,6	20,71	28,60	43,95
M2	660,0	1241,5	297,0	8 M	60,0	15,6	28,16	28,60	43,95
M3	700,0	1154,2	315,0	12 M	---	17,0	30,77	34,06	34,89

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Structural Glass. Development of GFRP-glass Composite Beams

Luís Guilherme da Cunha Seixas Valarinho

SUPERVISORS: João Ramôa Correia (IST-ICIST); Fernando Branco (IST-ICIST)

KEY WORDS: Adhesive bonding, composite beams, glass, GFRP, flexural tests, numerical simulation, smeared crack models.

INTRODUCTION: Structural glass presents several disadvantages when compared to traditional materials, most notably the fragile behaviour and the reduced resistance to tensile stresses. In order to overcome the above mentioned weaknesses, the glass industry has developed two improved fabrication methods: (i) glass tempering and (ii) glass lamination. As an alternative to changing the fabrication method, several studies have been carried out on composite structural systems that combine glass with other materials. Amongst the composite solutions that have been investigated, it is worth mentioning the combination of glass with stainless steel, carbon fibre reinforced polymer (CFRP) laminates, concrete, wood and steel. In these studies, aspects such as the geometry of the glass elements , the geometry and relative position of the strengthening elements and the type of adhesive were investigated, showing that it is possible to increase the stiffness and strength of glass members, simultaneously guaranteeing more ductile failure mechanisms.

This study addresses structural behaviour of glass and the development of composite beams, constituted by glass panes strengthened with glass fibre reinforced polymer (GFRP) laminates, with the objective to study a new structural combination, having in mind, increasing the post-cracking strength and ductility of glass elements.

MAIN OBJECTIVES: The main objective is to obtain an in-depth understanding about structural glass, developing national technical and scientific expertise in an emerging area of civil engineering. In particular, consistent knowledge is expected to be obtained about the following aspects: (i) physical and mechanical properties of glass; (ii) structural behaviour of glass members; (iii) mechanical behaviour of connections; (iv) methods available to analyse and design glass structures.

Experimental investigations to be carried out will provide a better understanding of the mechanical behaviour of glass-GFRP composite beams. In particular, full-scale flexural tests will help understanding the effects of (i) the geometry of the strengthening elements and (ii) the adhesive mechanical response, on the structural performance of the glass-GFRP composite beams, namely in increasing their post-cracking strength and ductility.

The numerical models to be developed in this working programme (calibrated based on experimental tests), will be able to simulate the structural behaviour of GFRP-glass composite members with arbitrary cross-section, thereby constituting a robust tool for their design. These models are expected to simulate not only the linear behaviour of the beams, but also their post-cracking response up to failure.

EXPERIMENTAL RESULTS: Flexural tests on simple supported beams, with a span of 1.4 meters, I geometry and made of three types of structural adhesives: an epoxy adhesive (EP) and two polyurethane adhesives (one with a low elastic modulus - PU - and another with a higher one - BE)
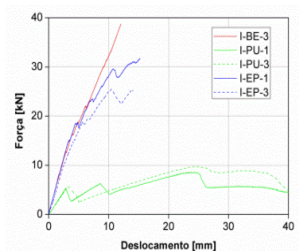
Load vs. midspan deflection curves of the beams tested
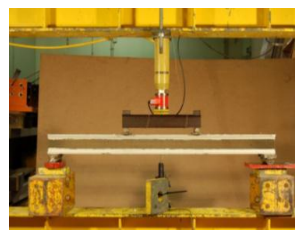
Beams I-BE before flexural tests

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Fire Behaviour of Glass Fibre Reinforced Polymer Pultruded Profiles GFRP

Marco Morgado Gomes

SUPERVISORS: Fernando Branco (IST-ICIST), João Ramôa Correia (IST-ICIST)

KEY WORDS: GFRP profiles, fire, elevated temperature, compression, tension, shear, DMA, TGA.

INTRODUCTION: This study addresses the fire behaviour of glass fibre reinforced polymer (GFRP) pultruded profiles and the development of fire protection solutions that enable their structural use in buildings.

A comprehensive experimental study of the GFRP profiles and the fire protection systems will be performed including (i) dynamic mechanical analyses and thermogravimetric and differential scanning calorimetry tests; (ii) mechanical tests (tension, compression, shear) on GFRP laminates at varying temperature; and (iii) full-scale fire resistance tests on loaded GFRP beams and columns.

The numerical study to be carried out comprises three stages of development: (i) a FE model simulating the nonlinear thermochemical problem, based on the independent approximation of temperature and material volume ratio fields; (ii) a FE thermomechanical model of the physically and kinematically nonlinear response of GFRP, based on the independent approximation of deformation and (generalized) stress-resultant fields; (iii) a coupled thermochemical/thermomechanical model of the structural response under fire.

MAIN OBJECTIVES: The main objective of this working programme is the careful assessment of the fire behaviour of GFRP profiles and the development of innovative fire protection systems. Such systems should enhance the structural use of GFRP profiles in buildings, namely in construction rehabilitation, exploiting the advantages they offer over traditional materials. Practical relevance of the results to be obtained implies the fulfilment of two requirements: the availability of proven application recommendations and reliable modelling tools. The numerical models to be developed will allow the simulation of the fire behaviour of GFRP profiles with arbitrary cross-section and different fire protection systems, and provide thus additional means to support their structural design. A user's manual will be prepared, allowing the fire protection design of GFRP profiles for building construction and recommending construction procedures and technical specifications for the developed solutions.

The following results are expected from this study:

- Development of innovative passive and active fire protection systems for GFRP pultruded profiles. Such solutions are expected to enable the structural use of GFRP profiles in buildings, particularly in construction rehabilitation, making use of their important advantages over conventional solutions;

- Development of numerical models to simulate the thermochemical and thermomechanical response to fire of GFRP profiles with arbitrary cross-section and different fire protection systems, with the aim of prototyping structural design supporting tools;

- Preparation of a user's manual, allowing the fire protection design of GFRP profiles for building construction, according to the fire design concepts of the Eurocodes, and establishing recommendations for construction procedures and technical specifications for the installation of the developed solutions.

EXPERIMENTAL RESULTS: This working programme centres on the study of the fire behaviour of GFRP profiles and its main motivation is the development of adequate passive and active fire protection systems enhancing their structural use in buildings. This implies coupling the experimental research programme with the development of supporting numerical modelling tools.

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Recuperation of Ancient Gypsum Plasters: Characterization and Development of Compatible Gypsum Based Materials

Maria Teresa de Almeida Gouveia Geraldes Freire

SUPERVISORS: Rosário Veiga, Jorge de Brito (IST-ICIST), António Santos Silva

KEY WORDS: Historical heritage, Ancient gypsum plasters, Characterization, Compatible restoration products

INTRODUCTION: Characterization of ancient gypsum plaster samples belonging to several historical periods, collected from North to South of Portugal. Based on the characterization results it was concluded that only between the second half of the 18th century and the first half of the 20th was the presence of gypsum plasters significant in the Portuguese architecture. The development of compatible gypsum based materials is focused on the results of the samples from this period.

MAIN OBJECTIVES: Characterization of the ancient Portuguese gypsum plasters. Development of compatible, ready mix, user-friendly, gypsum based restoration products, to be used even by unskilled workers, in order to improve the preservation of the Portuguese historical heritage.

EXPERIMENTAL RESULTS: The characterization of old Portuguese gypsum plasters (18th to middle XX centuries), from different kinds of buildings and regions of the country, showed different compositions according to their function in the building and the application technique: smooth surface plasters are made of similar proportions of lime and gypsum, while precast decorations' only binder is usually gypsum, sometimes with organic additions.

The physical and mechanical characteristics also vary, in accordance with the lime-gypsum proportions and are affected by the organic additions, sometimes with hydrophobic behaviour.

The determination of the physical properties in the samples of the old gypsum plasters collected is almost finished. Based in the results obtained it is possible to identify three classes of restoration products for Portuguese old gypsum based plasters, and to define, in a first approach, the respective compatibility ranges for some parameters. These ranges will, if necessary, be adjusted later, considering all the results obtained.

The development and test of the restoration products in now in progress and will proceed until final formulations are achieved.

Samples (top) and optical microscopy (bottom)

Higroscopicity
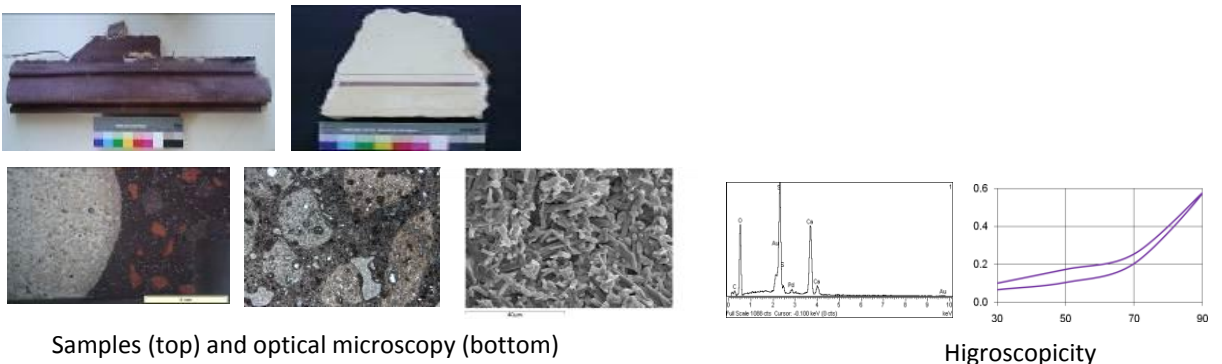
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Rehabilitation of Building Floors With Lightweight High Performance GFRP Sandwich Panels

Mário Alexandre de Jesus Garrido

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KEY WORDS: sandwich panels, GFRP, composites, building floors, rehabilitation, mechanical characterization

INTRODUCTION: This study addresses the development of innovative composite sandwich panels for the replacement of degraded building floors, providing an easy and cost-effective solution for their rehabilitation, and imposing much less weight over the existing construction when compared with traditional solutions.

Prototypes of composite sandwich panels, comprising glass fibre reinforced polymer (GFRP) skins and lightweight cores, will be produced by an innovative vacuum infusion (VI) process. A comprehensive experimental study will be carried out, including small-scale material characterization tests and full-scale static and dynamic load tests on prototypes of sandwich panels. The numerical study will include the development of finite element models of the sandwich panels, allowing simulating their structural response and enabling the optimization of their design.

The study will also include the development of solutions for connections between adjacent panels and between the panels and the supporting walls. This part of the study will comprise experimental and numerical investigations.

MAIN OBJECTIVES: The optimization process of the GFRP sandwich panels will focus on the definition of cross sectional geometry and material properties (of both skins and core), as well as on the definition of the characteristics of the reinforcement elements using stitches/ribs, such as their spacing and orientation. The optimization procedure will take into account different types of criteria, ranging from structural performance (namely the fulfilment of building code structural safety requirements), building physics (thermal and acoustic comfort), and cost efficiency.

EXPERIMENTAL RESULTS: The experimental program contemplates the investigation of the overall mechanical behaviour of full-scale sandwich panels. Static flexural tests (shear and flexural strength), dynamic flexural tests (natural frequencies, vibration amplitude, damping), long-term flexural behaviour tests (creep of panels under constant static loads), flatwise tensile strength (core-skin bonding strength), edgewise compression tests (in-plane diaphragm behaviour) and flatwise compressive tests (punching strength) will be performed.

Small-scale material specimen tests will be used to characterize the mechanical behaviour of the sandwich panels' constituents (cores and faces), focusing on their strengths and rigidities and on the effect of different service temperatures on those properties.

IMAGES

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Analysis of Pultruded GFRP Multicelular Deck Panels – Application on GFRP/STEEL Footbridges

Mário José Loureiro de Figueiredo e Sá

SUPERVISORS: Augusto Martins Gomes (IST-ICIST); João Ramôa Correia (IST-ICIST); Nuno Silvestre (IST-ICIST)

KEY WORDS: GFRP, multicellular pultruded decks, experimental tests, creep, serviceability behaviour, snap-fit connection system, footbridge

INTRODUCTION: Over the past years, Glass Fiber Reinforced Polymer (GFRP) panels have been increasingly used in decks of vehicular and pedestrian bridges, in both new construction and rehabilitation. In particular, multicellular pultruded decks show great potential due to a number of advantages that include lightness, strength, easy and rapid installation and improved durability under aggressive environments. Several joining techniques have been developed for composite bridge decks, particularly at the panel-to-panel connection level. One of these techniques addressed here it is the snap-fit type – a vertical mechanical connection – that significantly improves the construction quality and reduces the installation time, when compared to other connection types for deck assembly. This thesis presents experimental, analytical and numerical investigations (SAP.2000 and ABAQUS) on multicellular GFRP pultruded decks with snap-fit connection, made of polyester and E-glass fibres, for footbridge applications (section 7@90×75×4-5 mm). As part of an extensive study about the mechanical and structural behaviour of GFRP decks, the experimental campaign carried out included the following tests: (i) material characterization on laminated coupons, (ii) quasi-static, dynamic and creep flexural on individual panels (pultrusion direction), (iii) static and fatigue flexural on different types of snap-fit interlock in transverse direction, (iv) in-plane compression and shear and (v) static indentation and impact on pultruded laminated flange. Serviceability (deformability and vibration) and ultimate failure states were investigated, the first phase also on decks filled with rigid polyurethane foam into their cellular core. Another main objective of this study was to evaluate the in-plane stiffness of the deck and the stiffness degradation by cyclic loading in the transverse direction, as well to examine the performance and integrity of the snap-fit mechanical connections – with or without adhesive bonding (provided by two types of structural adhesives – epoxy and polyurethane). Local effects and low velocity impact analysis of pultruded laminated were also discussed using analytical models and considering punch transverse loads. Addition to the panel level joints, deck-to-steel profile connection system was investigated in order to evaluate the composite action and the overall load transfer, by mechanical and/or chemical means – threaded studs fastened and epoxy adhesive, respectively. Lastly, three-dimensional FEM were developed in order to simulate the static, dynamic and buckling behaviour of a full-scale footbridge: total span – 14.0 m; width – 2.5 m. This final stage corresponds to the assembly and construction of a prototype to be applied *in situ* (through an external construction contract). Before their permanent installation in a specific urban area, static and dynamic loading tests were conducted at factory environment.

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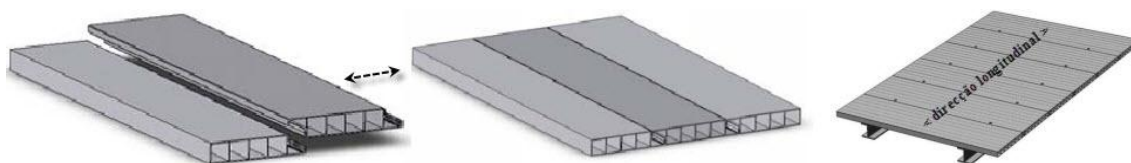
Deck assembly by snap-fitting [*adapted*].

Behaviour and Load Carrying Capacity of Stainless Steel Structural Members

Miguel da Silva Abambres

SUPERVISORS: Nuno Silvestre (IST-ICIST), Dinar Camotim (IST-ICIST)

KEY WORDS: Stainless Steel, Cold-Formed, Structural Behaviour, Generalized Beam Theory (GBT), Elastic-Plastic Analysis, Post-Buckling Analysis.

INTRODUCTION: This work aims to propose new computational tools to accurately analyze the structural behaviour and predict the ultimate resistance of cold-formed stainless steel elements. In particular, original formulations of the Generalised Beam theory (GBT) will be developed, computationally implemented and validated in order to perform physically non-linear first order and post-buckling analysis of thin-walled members made of arbitrary non-linear materials with isotropic/anisotropic hardening. These innovative GBT formulations account for the effects of geometric imperfections and residual stresses, and the results obtained will be validated against the ones provided by shell finite element analysis performed in software ABAQUS. Lastly, and in order to assess the accuracy of the aforementioned numerical models, an experimental program is followed to test cold-formed stainless steel columns, beams and beam-columns.

MAIN OBJECTIVES: The main goal is to develop powerful, versatile and efficient computational tools based on the Generalized Beam Theory (GBT) to accurately analyze the structural behaviour and predict the load bearing capacity of cold-formed stainless steel elements.

EXPERIMENTAL RESULTS: In order to assess the accuracy of GBT-based and ABAQUS-based numerical models in predicting the structural behaviour of cold-formed stainless steel members, an experimental program is performed, comprising tests on columns and beams.
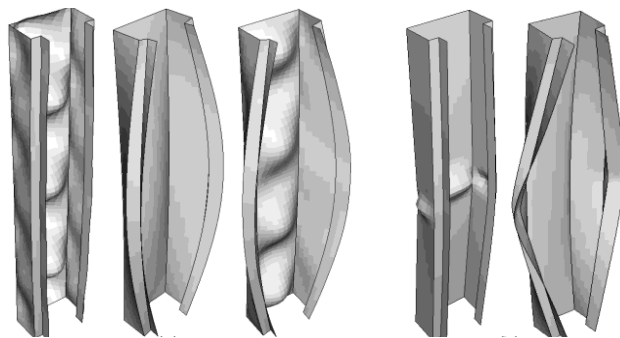
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Seismic Retrofitting of Masonry Structures with Shape Memory Alloys Devices

Miguel Eduardo de Moura Branco

SUPERVISORS: Luís Guerreiro (IST-ICIST)

**KEY WORDS**: shape memory alloys, seismic retrofit, masonry structures, energy dissipation

INTRODUCTION: The main motivation of this dissertation is the development and validation of a *SMA* based device which could be easily used in seismic retrofit of existing structures, taking advantage of the *NiTi* alloy superelastic property. Due to costs associated with the use of bars, it was considered more interesting to conduct this study using small diameter wires. It is intended to carry out an extensive characterization of the behavior of the *NiTi* alloy in both quasi-static and dynamic conditions. The collection of data from previous studies was completed with further experimental works in single wires and as part of energy dissipation devices (superelastic dampers) in simple structures subjected also to dynamic and quasi-static conditions.

After the characterization of the material a numerical framework was developed which could replicate the superelastic behavior of the *NiTi* alloy in dynamic conditions. To this purpose a thermo-mechanical model will be adopted and adjusted to better suit the experimental results obtained. Furthermore, the performance of this material is tested in actual structures. Therefore numerical models of different structures will be developed and the improvement in the seismic behavior due to the *SMA* devices will be evaluated. The three structures intended to cover a diversity of building typologies in a way that it could validate the use of this technology in a wide range of cases.

This work focus particularly in the retrofit of existing structures as it is acknowledged that there are more efficient methods to increase the seismic resistance of a structure using other methods and designs. Nevertheless, most of those methods are very expensive and intrusive to be considered in retrofit projects of common structures, hence the purpose of this work. The dynamic validation of the *SMA* device was performed at the tri-axial shake table at Laboratório Nacional de Engenharia Civil.

MAIN OBJECTIVES: The main objectives are:

Present the state-of-the-art in shape memory technology

Experimental characterization of the behavior of NiTi alloys

Development and validation of superelastic damper

Development of numerical algorithm to replicate superelastic behavior

Study of the retrofit of masonry structures with superelastic dampers
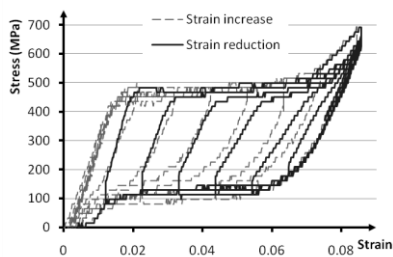
Stress-strain profile of NiTi alloy.

Shake table test setup
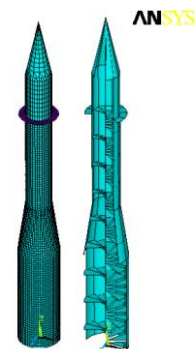
Finite element model of masonry structure.

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Alkali-silica Reaction in Concrete With Recycled Aggregates

Miguel Filipe Barreto dos Santos

SUPERVISORS: Jorge de Brito (IST-ICIST); António Santos Silva

KEY WORDS: Concrete, recycled aggregates, degradation, alkali-silica reactions

INTRODUCTION: Since there is a possibility of incorporating recycled aggregates (RA) as a complement to mineral aggregates (MA) in concrete production, there are some questions on the durability of concrete with recycled aggregates (CRA) that need to be answered.

The durability of concrete with mineral aggregates only (CMA) is conditioned, among other factors, by its degradation due to alkali-silica reactions (ASR). The possible occurrence of ASR in CRA motivated the authors to develop a study about these reactions in concrete with total and partial incorporation of RA.

MAIN OBJECTIVES: An experimental campaign on ASR in CRA is presently being developed in order to understand how the total or partial incorporation of RA in concrete changes this deleterious reaction development, and to what extent the incorporation of RA in concrete is effective without risk of ASR.

CRA are produced and evaluated according to the mix compositions and test recommendations referred to in the specification for CMA. The evaluation of RA and CRA will take into account the specification and the observations of different authors on expansion tests in specimens with this type of aggregate. Changes in CRA properties will be studied through current tests of physic-mechanical evaluation, porous structure and microstructure.

RA from crushing controlled original concrete will be used. Various situations that can influence ASR development were simulated in the study. Three CRA families will be produced with different MA-RA replacement ratios, reactivity levels, RA ages and cement types.

EXPERIMENTAL RESULTS: The experimental campaign is still in development.

Casting of the mortar bars (left) and expansion measurement (right) in mortar bar test.

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Grouts for Old Masonry Consolidation

Nuno Gouveia de Almeida

SUPERVISORS: Ana Paula Ferreira Pinto (IST-ICIST); Augusto Gomes (IST-ICIST)

KEY WORDS: Grouts; Pre-weighted grouts; Old Masonry; Rheological properties; Injectability; Adhesion

ABSTRACT: Grout injection is a commonly used technique for consolidation of old masonry. The research on grout formulation has led to several commercial grouts for consolidation of old masonry based on mineral binders. Like in the field of concrete and mortars, the use of commercial pre-weighted grouts could minimize the problems associated to the in-situ formulation. In spite of the research already done in this field, the knowledge available regarding adhesion between the grout and masonry materials and the influence of the masonry characteristics in the injectability conditions is still scarce. In fact, the effectiveness of injection solutions with these products depends not only on their properties, but also on their adhesion with masonry materials and injectability conditions. This work will contribute to increase the knowledge of commercial grouts for the consolidation of old masonry through their characterization (fresh and hardened state) and the evaluation of their injectability and adhesion.

The characterization in the fresh state will be performed using a Viskomat NT rheometer available on DECivil/IST Laboratory. The rheological characteristics (viscosity and shear and yield stress) will be compared and correlated to the fluidity determined with the marsh cone and slump test. In the fresh state, stability of the grouts will be also analysed performing a bleeding test and by the time evaluation of density. The setting time will be determined with the vicat apparatus.

The assessment of the injectability of the grouts will be based on cubical and cylindrical specimens filled with different materials to measure the influence of the type and size of masonry materials. For this purpose, stone aggregates, fragments of mortars and red clay ceramic will be used.

For studying the adhesion between the grouts and the masonry materials, different existing test methods (pull off and slant shear tests) will be used and adapted for this purpose. Depending on the type of adhesion test, specific specimens will be developed with the same materials used to fill the cylindrical specimens: stone, mortar and red clay bricks.

In the hardened state, mechanical (flexural and compressive strength), physical (capillarity, shrinkage) and porous structure characterisation will be carried out on prismatic specimens and on specimens produced for the injectability tests (cubic and cylindrical).

MAIN OBJECTIVES: Perform a market survey of the existing pre-weighted grouts for the consolidation of old masonry; Study the grouts rheological behaviour and the possibility of establishment correlations between the rheological factors and the fluidity determined with Marsh cone and spread tests; Identify the rheological, mechanical and physical requirements of the grouts that must be established to assure their stability, injectability and the adhesion between grout and masonry materials; Contribute for the definition of experimental tests for the assessment of the grout´s adhesion to masonry materials and injectability..

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Concrete Tall Buildings - Technology, Analysis and Design

Paulo Renato Camacho da Silva Lobo

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**KEYWORDS:** structural concrete, tall construction technology, nonlinear analysis, motion control.

INTRODUCTION: The technological progress of materials verified in recent years, notably regarding high performance concrete in conjunction with ever greater concrete pumping capacity, allowed for a fast change of the preferably used materials in tall buildings. In fact, these structures are currently predominantly constructed of concrete (see Figure). The significant interest on this subject has been reflected in numerous recent conferences and communications. However, it is a field of knowledge controlled by international companies of construction and engineering projects. This appears to be due to the strong interconnection between the design and the large number of technological constraints involved in these structures construction, as well as the specificities of each project, which may have hampered the development of specific technical documents.

A fiber based geometric and material nonlinear finite element program, capable of performing static and nonlinear dynamic analysis of structures, has been developed, which will be used to accomplish some of the objectives mentioned ahead.

MAIN OBJECTIVES: It is intended, as the more general objective of the study, to address the major issues regarding the design of concrete tall buildings. Furthermore, the following specific objectives are enumerated:

typify the construction technologies employed in tall concrete structures so as to allow, on the one hand to organize the construction processes according to the structural systems and, on the other hand, to evaluate the effects of constructive processes in the behavior of tall building structures. It is hoped that this work will also allow to set future goals for the technological development of tall buildings;

evaluate the implementation of active and passive systems to high-rise concrete structures motion control and recentering.
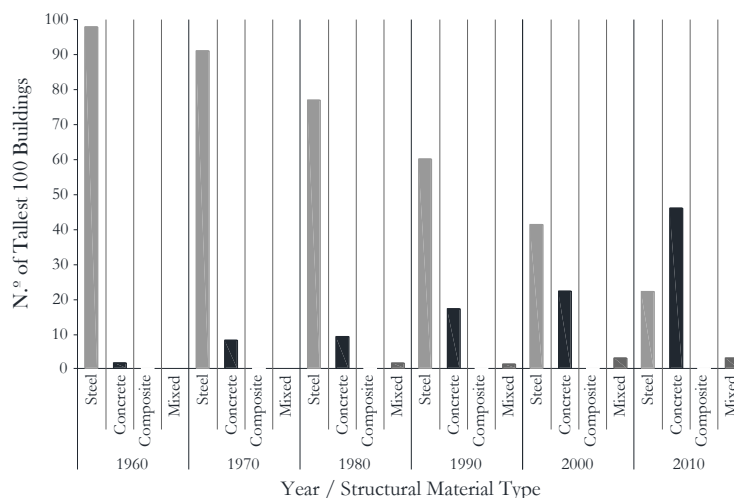
Structural material comparison of the 100 Tallest Buildings in the last decades – Council on Tall Buildings and Urban Habitat (2010

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Web Crippling Analysis of Plain Cold-Formed Steel Beams and Beams Reinforced with CFRP

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SUPERVISORS: Nuno Silvestre (IST-ICIST); Dinar Camotim (IST-ICIST)

KEY WORDS: Generalized Beam Theory (GBT), web crippling, shell finite element (SFE) models, Direct Strength Method (DSM), cold-formed steel beams, CFRP

INTRODUCTION: Steel beams subjected to transverse concentrated loads are prone to simultaneous buckling and plasticity spread in the web region. The latter is referred to as web crippling (cold-formed cross-sections) or patch loading (welded cross-sections). Its complexity explains the absence of a theoretical model, while the majority of the existing studies are experimental. In the context of cold-formed steel beams, existing guidelines are strictly empirical and often lead to considerable errors. The Direct Strength Method presents itself as an innovative and promising alternative, using estimates for the critical (GBT, SFE) and yield (plasticity spread models) loads. Reinforcement of the web using CFRP should increase the load bearing capacity.

MAIN OBJECTIVES: Development of the GBT formulation in order to consider all pre-buckling stress components on second-order analysis. Application of GBT to web crippling and patch loading. Study of the web crippling phenomenon: (i) extensive simulation program on existing experimental results using shell finite element models; (ii) calculation of critical buckling loads associated using GBT. Implementation of the DSM methodology to numerical and experimental results and calibration of curves for each web crippling configuration (EOF, IOF, ETF and ITF). Assessment of CFRP reinforcement on web-crippling behavior through experimental tests.

EXPERIMENTAL RESULTS: The experimental program has not yet been implemented. It is expected that CFRP sheeting in the web region will improve the behavior of cold-formed beams subjected to concentrated loads.
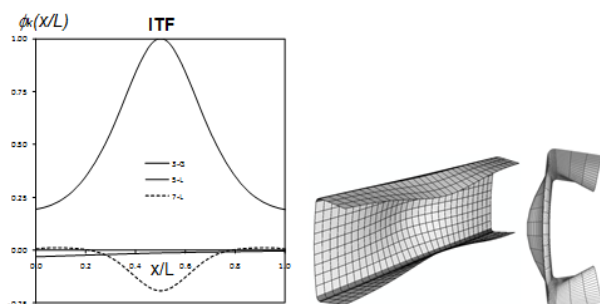
ITF buckling analysis – GBT and SFE results
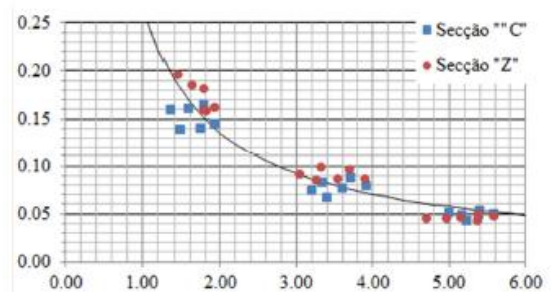
Example of DSM curve fitting

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Assessment of Mortar Consolidation Treatments and Their Characterization by In Situ Testing Techniques

Rita Maria Vilela Nogueira

SUPERVISORS: Ana Paula Ferreira Pinto (IST-ICIST), Augusto Gomes (IST-ICIST)

KEY WORDS: Consolidation treatments, ancient render, lime mortars, *in situ* testing techniques, diagnosis methodology

INTRODUCTION: This project aims to contribute towards the progress of scientific knowledge in the field of Building Conservation, focusing on ancient rendering mortars. Decayed mortars replacement is not always the best option, namely when they are valuable or support of valuable works of art (mural paintings, for example). Instead, consolidation of rendering mortars, which this work studies, is a feasible intervention that may prevent its replacement.

The research will focus on the performance assessment of several mortar consolidation treatments, both by laboratorial and *in situ* testing techniques. The results achieved will allow for progress in the decision making process, concerning intervention on ancient renders and selection of consolidation treatments.

The study also aims to help the development of methodologies for assessing *in situ* conservation condition of renders and the selection of replacement mortar compositions.

The mortar consolidation treatments will be tested on air lime mortars. The consolidation action achieved will be assessed, firstly, on prismatic samples, both degraded and not degraded by salt crystallization, secondly, on mortars applied as renders on masonry prototypes and, at last, on old renders on site.

MAIN OBJECTIVES: The main focus of this research is to assess the performance of consolidation treatments applied on mortars compositions similar to ancient rendering mortars. An additional goal is to help the development of a methodology for the diagnosis of ancient renders through the improvement of the knowledge on the use of some mortars characterization *in situ* testing techniques.

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The Development of Non-iterative Numerical Methods Applied to The Nonlinear Analysis of Structures

Rui Carlos Gonçalves Graça e Costa

SUPERVISORS: Jorge Alfaiate (IST-ICIST), Daniel Dias-da-Costa

KEY WORDS: Nonlinear structural modelling, Non-iterative methods, Nonlinear fracture mechanics, Non-proportional loading, Mixed-mode fracture.

INTRODUCTION: In this thesis, new non-iterative procedures are presented for the numerical analysis of concrete and masonry. Numerical examples are used to illustrate the capabilities of the proposed procedures, namely, their use on structures under proportional and non-proportional loading. A solution control energy based criterion is applied in order to capture critical bifurcation points. It is shown that this new methodology is suitable for the modelling of nonlinear structural behaviour in which localization of initially severe distributed cracking is hard to capture with conventional iterative methods. Furthermore, a new mixed-mode fracture model is introduced, which is particularly adapted to the non-iterative procedures developed.

MAIN OBJECTIVES:
New non-iterative methods to solve nonlinear structural behaviour; new mixed-mode fracture model.

EXPERIMENTAL RESULTS:
The work presented in this thesis is numerical; experimental results are only used to validate the numerical results.

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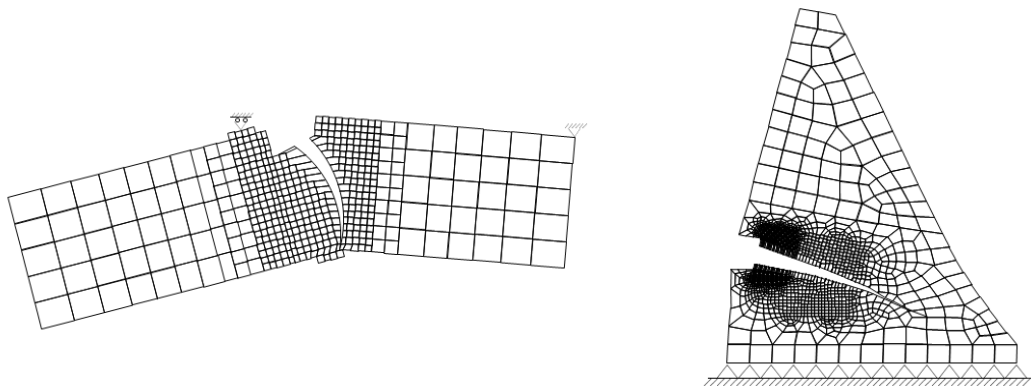
Concrete Air Permeability and Carbonation in Structures

Rui Duarte Neves

SUPERVISORS: Fernando Branco (IST-ICIST); Jorge de Brito (IST-ICIST)

KEY WORDS: Concrete; Structures; Service life; Carbonation; Permeability; Testing; Numerical modeling; Durability indicators; Performance requirements; Prediction.

INTRODUCTION: The present work aims to contribute to improve the knowledge in the prediction of service life using performance requirements and in monitoring site compliance with these requirements. Two properties that can be used as performance requirements: carbonation resistance and air permeability are analyzed.

Within the scope of resistance to carbonation, the spatial distribution of carbonation depth in structures is characterized and the adequacy of the classical model to simulate the evolution of carbonation depth in natural and in accelerated conditions is evaluated.

The relationship between resistance to carbonation in natural conditions and resistance to carbonation in accelerated conditions is investigated and a comparison between carbonation depths estimated by the model of the specification LNEC E 465 and those assessed in structures, with long exposure under natural conditions, is performed.

With respect to air permeability, assessments according to Torrent's method are carried out in specimens and structures. The relationship between air permeability and resistance to carbonation is analyzed.

Based on the information obtained in the literature review and on the analysis of experimental results, some recommendations in order to improve the approach to service life design of structures are formulated, particularly with regard to reinforcement corrosion induced by carbonation.

MAIN OBJECTIVES: Validate the use of the Torrent method, which measures the air permeability, as a method capable of characterizing the concrete durability.

Establish basis for recommending values for the air permeability coefficient of the concrete on finished structures, determined by the method of Torrent, in order to ensure that structures achieve their intended service life.

Relate the resistance to accelerated carbonation with carbonation resistance of concrete used in structures and subjected to real conditions of exposure during a relevant time period.

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Development of the "Shear Friction" Theory for Interfaces between Ultra-high Durability Concrete and Other Concretes

Rui Filipe Simões Meles Saldanha

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SUPERVISORS: Eduardo S Júlio (IST-ICIST); Pedro D Santos (IPLeiria)

KEY WORDS: Concrete interfaces, Ultra-High Durability Concrete (UHDC), Bond, Shear Transfer Mechanisms.

INTRODUCTION: The aim of this thesis is to study the behaviour of concrete-to-concrete interfaces, especially between UHDC and other types of concrete, including Light-Weight Aggregate Concrete (LWAC). Due to the ultra-high compressive strength, high Young modulus, and other properties, it is most relevant to study a general shear-friction theory, applicable to a wide spread range of concrete-to-concrete interfaces, including UHDC-to-LWAC. Moreover, the influence of adhesion, friction and dowel action are intended to be isolated, thus contributing for an enhanced design expression to replace the current approach of EC 2 or fib MC 2010.

MAIN OBJECTIVE: The first main objective is to identify the mechanisms of shear transfer between concrete-to-concrete interfaces quantifying the influence of each one. The main expected output is the proposal of a general design expression. The second main objective is to study the behaviour between UHDC to be used in concrete members cover and other types of concrete to be used as structural material, including LWAC.

EXPERIMENTAL RESULTS: At this stage of the experimental program some results have already been obtained. The major achievement so far was the development of a modified slant shear test, designed to always obtain adhesive failure types, i.e. at the interface. In the standard slant shear test, monolithic failures often occur, i.e. cohesive failures in the weakest concrete half; thus, in these cases, the interface strength cannot be evaluated but only a lower limit is estimated.

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A Transformation Grammar-based Methodology for Housing Rehabilitation: Meeting Contemporary Functional and ICT Requirements

Sara Eloy Cruz

SUPERVISORS: José Pinto Duarte (FAUTL-ICIST), Isabel Plácido (LNEC), Renato Nunes (IST)

INTRODUCTION: This research starts from the premise that the future of the real estate market in Portugal will require the rehabilitation of existing residential areas in order to respond to new life-styles and dwelling requirements that have emerged in an era in which information plays a structuring role in society. The goal of this research is the definition of design guidelines and a rehabilitation methodology to support architects involved in the process of adapting existing dwellings. In addition to defining a general methodology applicable to all the building types, the study focuses on a specific type, called "rabo-de-bacalhau," built in Lisbon between 1945 and 1965 for which a specifc methodology has been generated. Both shape grammar and space syntax were used as part of the rehabilitation methodology as tools to identify and encode the principles and rules behind the adaptation of existing houses to new requirements.

MAIN OBJECTIVES: This research has three main objectives:

Firstly, to identify how the use of technology influences life-styles and creates new dwelling requirements, and how this affects the spatial and functional organisation of dwellings. This work complements Pedro's (2000) and Duarte's (2001) frameworks for incorporating new dwelling modes, new domestic groups, and ICAT-related demands;

Secondly, to define appropriate ICAT sets to incorporate into the spaces in dwellings so as to guarantee environmental sustainability and the social integration of citizens, by adapting them to individual households according to present and future needs. These ICAT sets apply to the dwelling as well as the building, including existing rehabilitated residential stock and new buildings;

Thirdly, to define design guidelines and a methodology to support architects involved in the process of adapting existing dwellings and incorporating ICAT technologies, allowing them to balance new dwelling trends with sustainability requirements.

EXPERIMENTAL RESULTS: The research carried out resulted in a varied set of contributions: i) a characterisation of the "rabo-de-bacalhau" building type; ii) a method for defining the ICAT packs to be integrated into the housing, according to family profiles; iii) the conception of a rehabilitation methodology based on a rigorous process: a general and a specific methodology; iv) the development of a transformation grammar.

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Three-dimensional Numerical Modelling of Concrete-to-concrete Interfaces

Sara Maria de Oliveira Gomes

INSTITUTION: University of Coimbra

SUPERVISORS: Daniel Dias da Costa (UC), Paulo Fernandes (IPLeiria), Eduardo Júlio (IST-ICIST)

KEY WORDS: Concrete, interface, finite element model, three-dimensional software

INTRODUCTION: The monolithic behaviour of two different concrete layers is strictly dependent on the interface strength. As examples of composite structures, concrete bridges with precast beams or repaired/strengthened concrete structures can be pointed out. With this thesis, it is intended to develop a three-dimensional software to simulate the structural behaviour of non-monolithic concrete elements. The concrete cracking and the interface behaviour are the most important parameters to take into account.

MAIN OBJECTIVES: The main objective of this thesis is to develop a three-dimensional software based on the finite element method to simulate the structural behaviour of non-monolithic concrete elements. After the software development, the study of different cases calibrated using experimental results will allow to: i) identify existing gaps, ii) calibrate numerical parameters, and iii) develop the necessary constitutive laws.

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Management of Maintenance Activities In Public Buildings. Model and Definition of Strategies for a Sustainable Intervention

Sónia Raposo

SUPERVISORS: Jorge de Brito (IST-ICIST)

KEY WORDS: Maintenance; Maintenance management; Building stock; Primary schools; Strategies definition; Sustainable approach

INTRODUCTION: Today the management of public built assets acquires a significant importance owing to their size, social relevance and the working, operational and maintenance costs. Being economically relevant in the buildings total cost, the activity of maintenance management can't be done in an improvised and casual way. Currently, initiatives undertaken in this field aim at a sustainable development, or seek to rationalize and optimize the available resources through the implementation of integrated and cost-effective solutions, allowing an acceptable performance of buildings along its life cycle as well as its services.

This essay presents a systematic, objective and flexible methodology for measuring and evaluating the performance of the building stock Maintenance Management Systems (MMS).

MAIN OBJECTIVES: It was developed an analysis tool that integrates the associated technical, economic and organizational factors in the implementation of MMS. In total there were defined 17 key performance indicators: 10 economic performance indicators (IE), five indicators of technical performance (IT) and two indicators of organizational development (IO).

EXPERIMENTAL RESULTS: The methodology was tested on a sample of five primary schools (EB1) in Lisbon, and it was classified with great potential regarding the information that it provides, giving a basis for decision support in building design and construction and its maintenance and operation.
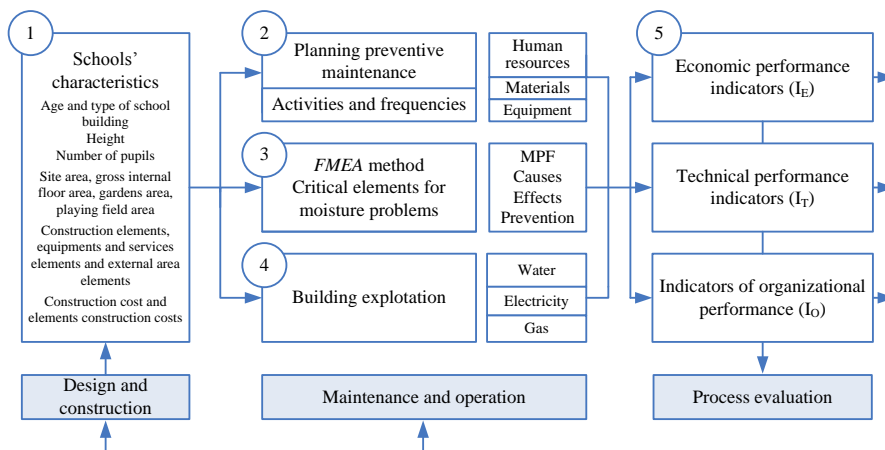
Methodology for measuring and evaluating the performance of the building stock MMS

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Computational and Energy Performance-based Design of the Building Envelope Shape

Vasco Granadeiro

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INTRODUCTION: The envelope of the building separates it from the surrounding environment and its shape impacts the urban scale, hence being considered the most salient characteristic in a building. In addition, it is also decisive for its energy performance. This research, on the building envelope shape design, is based on two principles: the value of architectural compositional principles in design and energy simulation as the method to obtain energy efficient design. However, in the early design stages, when the envelope shape is defined, energy performance information is normally nonexistent, due to modeling for energy simulation being a time-consuming task, frequently overlooked at this phase, when the design is still uncertain regarding many parameters. Departing from an initial architectural design and its corresponding energy simulation results, two problems may emerge: how to improve the design while respecting compositional principles; and the time-consuming task of modeling every design alternative for energy simulation.

MAIN OBJECTIVES: The research proposes a methodology for generating alternative designs for the building envelope, taking compositional principles into account, and providing immediately the corresponding energy simulation results. Compositional aspects of the designs are guaranteed through the use of shape grammar-based design systems and the energy values are provided by automated energy simulation of the designs. Consequently, applying this methodology in early design stages, both geometry and energy performance information become available to assist design decisions regarding the envelope shape. The next step in the research is the optimization of the envelope building shape for low energy demand. The value of such step forward is the possibility to define in early design stages the most efficient building shape envelope with the desired architectural qualities.

RESULTS: The table below displays the values of total annual energy demand per m^2 and total floor area of the nine building designs shown. These were generated by assigning random values to the system variables, therefore, only envelope shape (and floor area, implicitly) is different. The nine designs are ordered, from left to right and top to bottom, in increasing total annual energy demand per m^2.

Design	1	2	3	4	5	6	7	8	9
Total Energy Demand [kWh/(m^{2}a)]	41.70	44.98	47.47	49.13	51.17	52.18	55.71	56.25	59.81
Total Floor Area [m^2]	142.38	81.13	132.63	149.63	149.19	95.88	137.69	96.75	84.31

3-D perspectives of nine designs, ordered, from left to right and top to bottom, in increasing total annual energy demand per m^2
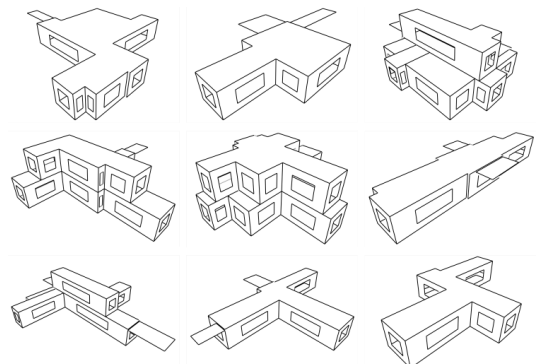
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