DCE 21 4th DOCTORAL CONGRESS IN ENGINEERING

DOCTORAL CONGRESS IN ENGINEERING

Proceedings

4th Symposium on Civil Engineering and Spatial Planning

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Proceedings

of

4th Symposium on Civil Engineering and Spatial Planning

Editors:

Humberto Varum, Álvaro Costa, João Poças Martins,

Daniel Clemente, João Pedro Martins, Paulo Jorge Soares

Porto

June 2021

This volume contains the short-papers presented at the Symposium on Civil Engineering and Spatial Planning, within the 4th Doctoral Congress in Engineering – DCE21, held online, between June 28th and 29th, 2021.

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Universidade do Porto, Faculdade de Engenharia, Departamento de Engenharia Civil, Rua Dr. Roberto Frias s/n 4200-465 Porto, Portugal

WELCOME

We want to warmly welcome all participants to the Symposium on Civil Engineering and Spatial Planning (SCESP), held in the scope of the 4th Doctoral Congress (DCE21) hosted at the Faculty of Engineering of the University of Porto (FEUP), Porto, Portugal, on the 28th and 29th of June 2021. This time, due to the COVID-19 pandemic, the event is entirely conducted in virtual mode. This Symposium is organized by PhD students of the Doctoral Program in Civil Engineering (PRODEC) and Doctoral Program in Spatial Planning (PDPT) at FEUP, with the support of the professors.

The Civil Engineering and Spatial Planning Symposium covers broad, important and multidisciplinary themes, with oral and poster presentations comprising a wide range of topics such as building construction, geotechnics, hydraulics, materials and construction, spatial planning, structures, transport infrastructures, transport planning and territory, and any related multidisciplinary or transversal areas of study.

It is with great honour that we welcome the Keynote Speakers, who elevate the Symposium with their participation:

- Dr. João Pita, Head of Airline Business at the São Paulo International Airport/Guarulhos;
- Eng. Tiago Braga, CEO of Metro do Porto;
- Dr. Tiago Ferradosa, doctorate researcher at Faculty of Engineering of University of Porto and researcher at CIIMAR.

The Organizing Committee received over 54 communications. A total of 38 oral and 16 poster presentations of great quality were selected.

We take this opportunity also to acknowledge all authors for their contributions, the Scientific Committee and the participant Institutions for their support.

Thank you all!!

Porto, June 2021

Symposium Organizing Committee

Message from the Symposium chairs

Although Civil Engineering and Spatial Planning research is increasingly specialised, forums that promote discussions across research fields are critical towards the development of original work. Therefore, following the previous editions, the 4th Doctoral Congress in Engineering's Symposium on Civil Engineering and Spatial Planning encourages the participation of current and prospective doctoral students from different institutions. The Symposium has become a relevant event for researchers who wish to disseminate the results of their work and for those at the early stages of their research alike, and is thus strongly supported by the Civil Engineering and Spatial Planning Doctoral Programmes.

Over 50 contributions, including oral presentations and posters will be presented during two days, covering topics such as Material and Digital advances, Transports and Spatial Planning, or Developments on Seismics, Hydraulics and Urban Forms. The Symposium will also include workshops and round tables with industry partners.

Special thanks are due to the PhD candidates who compose the Organising Committee and to the members of the Scientific Committee who have carefully reviewed the papers that are included in the conference proceedings.

Porto, August 2021

Humberto Varum

Álvaro Costa

João Poças Martins

Scientific Committee

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João Pedro Martins | PhD candidate in Spatial Planning, FEUP

Daniel Clemente | PhD candidate in Civil Engineering, FEUP

PROGRAMME

		SYMPOSIUM ON CIVIL ENGINEERING & SPATIAL PLANNING	
		28th June	29th June
8:30	9:00	Welcoming, rules	Welcoming, rules
9:00	9:30	Welcome Session	Keynote Speaker: Tiago Ferradosa
9:30	10:00	Keynote Lecture	Technical Session III: Developments on Seismics, Hydraulics and Urban Forms
10:00	10:30	Keynote Speaker: João Pita	
10:30	11:00	Technical Session I: Material and Digital advancements	
11:00	11:30		
11:30	12:00		
12:00	12:30		
12:30	13:00		
13:00	13:30	Lunch + Workshops	Lunch + Workshops
13:30	14:00		
14:00	14:30		
14:30	15:00		
15:00	15:30	Poster Session	Round table: 'Early Stage Research with Industry'
15:30	16:00		
16:00	16:30	Keynote Speaker: Tiago Braga	
16:30	17:00	Technical Session II: Transports and Spatial Planning	Awards Ceremony
17:00	17:30		
17:30	18:00		Closing Session
18:00	18:45	Social Program	

Keynote I - Doutor João Pita (28th June, 10:00h-10:20h)

Topic: *I have a PhD and now what? A market perspective.*

Technical Session I - (28th June, 10:20h-13:00h)

Topic: Material and Digital advancements - Moderated by Paulo Soares

- Filipe Almeida, Ana Fernández-Jiménez, Castorina S. Vieira, Nuno Cristelo and Maria de Lurdes Lopes. *Mechanical behaviour of mortars including a hybrid cement and recycled aggregates.* [177];
- Nara M.O. Cangussu, Leandro M. Silva, Stéphanie O.N. Rocha and Lino Maia. *Incorporation of the Sludge of Sewage Treatment Plant on Ceramic Bricks Manufacture* [3];
- João Teixeira, Cecília Schaefer, Lino Maia, Bárbara Rangel, Jorge Lino and Rui Neto. *Workability control in the development of 3D printing cementitious mortars - laboratory methodology* [158];
- João Lázaro, Matheus Pereira, Pedro Alves Costa, Luís Godinho. *Performance of low height railway noise barriers* [187];
- Nelson Traquinho, Rui Artur Bártolo Calçada and Diogo Rodrigo Ribeiro. *Influence of Rail Damages on Dynamic Responses of Steel Railway Bridges under Vehicle Loading-A Review* [298];
- Ahmed M. K. Abouelmaty, A. Colaço and P. Alves Costa. *Vibrations induced by impact pile driving: experimental and numerical analysis* [212];
- Rui Valente, Mário Pimentel and Sandra Nunes. *Tensile response of reinforced UHPFRC elements.* [104];
- Luis Sanhudo, João Poças Martins and Nuno Ramos. *Artificial Intelligence for an Enhanced As-Is BIM Energy Analysis.* [144];
- Mohamed Nour El-Din Abu Shamma, João Poças Martins and Nuno Ramos. *Digital Twins for Buildings Energy Management and IEQ within BIM Standard Specifications.* [145];
- Adeeb Sidani, João Poças Martins and Alfredo Soeiro. *BIM For Safety a General Framework.* [292];
- Mohammad Darabseh and João Poças Martins. *Exploring the Blockchain Adoption Directions in the AECO Industry.* [305];
- Mahmoud Karaz and Jose Manuel Cardoso Texiera. *Developing a Construction Supply Chain System based on Lean Construction and Building Information Modelling supported Internet of Things standards.* [368].

- Fábio Matoseiro Dinis, João Poças Martins, Bárbara Rangel and Ana Sofia Guimarães. *Framework for the semantic enrichment of BIM models through a natural user interface.* [130].

Poster Session I - (28th June, 15:00h-16:00h) - Moderated by Isabel Coimbra

Virtual Session: https://paginas.fe.up.pt/~dce/2021/programme/poster-session/

- Nara M.O. Cangussu, Pollyana L. Ramos, Tulio A.D. Tolentino, Stéphanie O.N. Rocha and Lino Maia. *Concrete with coarse aggregates partially replaced by recycled construction and demolition waste*. [4]
- Sayedreza Jafarzadeh and Cyrus Eshaghi. *Investigating the Retaining Wall Stiffness Relative to the Stiffness of Surrounding Soil in Order to Find the Exact Position of Base Level of Buildings*. [16]
- Ana Thereza Carvalho, Daniel B. C. Machado, Lino Maia and José Santos. *Advantages of use of BIM methodology in civil construction*. [23]
- Ana Thereza Carvalho, Lino Maia and José Santos. *BIM as a tool for Facility Management*. [24]
- Ana Cláudia Proença, Cecília Silva and José Palma-Oliveira. *Designing Cities for Sustainable Mobility Mindsets*. [28]
- Filipe Figueiredo, Eriton Botero and Lino Maia. *Treatment of cassava starch bagasse for use as pozzolan in cementitious materials*. [32]
- Daniel B. C. Machado, Ana Thereza Carvalho, Lino Maia and José Santos. *Uses and benefits of BIM in construction management*. [34]
- Daniel B. C. Machado, Stéphanie Rocha, Alvaro Junior, José Santos and Lino Maia. *Characterization Of Concrete Blocks Commercialized In The City Of Montes Claros - MG*. [35]
- Anas Shrefahe. *City Archive: A tool for raising a city from the ashes. The case of Aleppo, Syria*. [136]
- João Teixeira, Rui Neto, Cecília Schaefer, Jorge Lino, Bárbara Rangel, Lino Maia and Sandra Nunes. *Development of an extruder for laboratory testing of 3D printing mortars*. [157]
- Gonçalo Ferreira, Pedro Aires Montenegro, António Henriques and Rui Calçada. *A probabilistic view on high speed low cost railway bridges.* [186]
- Stéphanie Oliveira Nina Rocha, Jessé Lima, Pedro Quintino, Daniel Bc Machado and Lino Maia. *Evaluation of concrete pavers using plastic as fine aggregate*. [190]
- Stéphanie Oliveira Nina Rocha, Ises da Silva, Izael Junior and Lino Maia. *Partial replacement of Portland cement for by-product waste silica in cored concrete blocks* [193]
- Juliana Carvalho Rodrigues da Silva, Fábio Matoseiro Dinis and João Poças Martins. *Optimization of BIM-based Virtual Reality environments: a workflow proposal.* [355]

- Marina Krauze Thomaz, Denis Alcides Rezende and Lino Maia. Project: "*E-Waste projects, strategies and public services and relation with strategic digital city*". [359]

- Serra Danis and Humberto Varum. *Seismic Performance of Multistorey Flat Plate and Framed Structures with Shear Walls.* [192]

Keynote II – Eng. Tiago Braga (28th June, 16:00h-16:20h)

Topic: *What to expect from a doctorate? A Company's Perspective.*

Technical Session II - (28th June, 16:20h-18:00h)

Topic: Transports and Spatial Planning - **Moderated by Daniel Clemente**

- Mariana Pizzo Diniz and Miguel Serra. *Towards a Quantitative Approach to Morphological Regions in GIS* [200];
- Daniel Tavares, Mariana Pereira, Isabel Coimbra and Fernando Alves. *Heritage as a framework for governance and decision-making: a contextualization* [68];
- Ana Sousa, Tatiana Brandimiller, Tatiane Serrano and Isabel Coimbra. *DAMA – Decision-making, assessment & monitoring, and adjustment of contemporary spatial policies: a contextualization of exogenous challenges* [64];
- Ana Sousa and Sara Cruz. *Understanding Carrying Capacity: a bibliometric analysis* [141];
- João Teixeira, Cecília Silva and Frederico Moura E Sá. *The role of bike sharing during the COVID-19 pandemic: insights from Lisbon's GIRA users* [5];
- Isabel Cunha and Cecília Silva. *Bicycle Accessibility and Equity: assessing the socio-spatial impacts of Lisbon's Bicycle Master Plan* [57];
- António Lobo, Sara Ferreira, Anabela Simões, Liliana Cunha, Carlos Rodrigues, José Pedro Tavares and António Couto. *A human-centred approach to truck platooning* [56];
- João Martins, Álvaro Costa and Paulo Soares. *Reflection on the feasibility and location of an airport infrastructure in the Central Region of Portugal* [82].

Keynote III – Doutor Tiago Ferradosa (29th.June, 9:00h-9:20h)

Topic: *The Joy of Reliable Scour Protections A PhD survival guide – the lessons I took*

Technical Session III - (29th June, 9:20h-12:30h)

Topic: Developments on Seismics, Hydraulics and Urban Forms - **Moderated by João Pedro Martins**

- João Fragoso Januário, Álvaro Costa, Carlos Oliveira Cruz, Joaquim Miranda Sarmento and Vítor Faria E Sousa. *Transport infrastructure, accessibility and spillover effects: empirical analysis of the Portuguese real estate market in the period 2000-2018* [133];
- João Fragoso Januário. *Seismic Risk and House Prices: cross-section modelling of Lisbon's real estate market* [134];
- Jeniffer Viegas, Pedro Baltazar-Soares, Giulio Vignoli, Jaime Santos and Fernando Santos. *Inversion of TDEM data constrained by surface seismic and borehole surveys for geotechnical characterization of the Northen Lisbon Logistic Park (PLLN)* [169];
- Carla Andreia Gonçalves. *The right to the waterfront: addressing climate and environmental justice from a landscape perspective* [143];
- Bonaventura Tagliafierro, Alejandro Crespo, Rosario Montuori and Ioannis Vayas. *Structural safety and computation: from seismic engineering to wave energy* [159];
- Beatriz Queirós, Francisco Taveira Pinto, Paulo Rosa-Santos and Alejandro Crespo. *Simulation of the stability of Antifer units applied on breakwaters using DualSPHysics coupling with Project Chrono* [172];
- Tomás Calheiros Cabral, Paulo Rosa Santos and Francisco Taveira Pinto. *Performance and energy production of a hybrid Wave Energy Converter* [164];
- Tomás Calheiros Cabral, Paulo Rosa Santos and Francisco Taveira Pinto. *Analysis of the functionality and stability of a dual-purpose breakwater-hybrid Wave Energy Converter* [165];
- Daniel Clemente, Paulo Rosa-Santos, Francisco Taveira-Pinto, Cátia Rodrigues, José Correia, Ricardo Esteves, João Ventura and André Pereira. *Recent developments on the E-Motions wave energy converter* [114];
- Francisco Pinto, Paulo Rosa Santos and José Victor Ramos. *Hydro and morphodynamic analysis of five segmented coastal protection structures: The case study of Carneiro Beach, Porto* [166];
- Kaíque dos Anjos Silva, Isabela Dantas Reis Gonçalves Basto, Andrea Sousa Fontes and Yvonilde Dantas Pinto Medeiros. *Analysis of the salinity variation downstream of the Xingó reservoir under the influence of outflows alteration* [163];
- Ana Margarida Bento, Andreia Gomes, João Pêgo, Teresa Viseu and Lúcia Couto. *A novel and pragmatic methodology for scour risk assessment at bridge pier's vicinity* [307];
- Luís J. Sousa, Miguel C. Gonçalves and Pedro Pinto. *Site Production Management: Case Study of the Digitalization of Construction Companies in Portugal* [330];
- Gustavo Lopes dos Santos and Beatriz Condessa. *Increasing Spatial Scales: Olympic Agenda 2020 and Portugal as Olympic Host* [99];

KEYNOTE SPEAKERS

Dr. João Pita

Head of Airline Business at the São Paulo International Airport/Guarulhos

Communication: *I have a PhD and now what? A market perspective.*

Dr. João Pita is Head of Airline Business at GRU Airport – São Paulo International Airport. Over the last six years, Pita has held several positions at GRU Airport, where the biggest challenge is to continuously growth the business in a dynamic market. He also serves as the Latin America representative to the ACI Expert Group on Slots. João Pita is a Civil Engineer and has a PhD in Transport Engineering from the University of Coimbra in 2013.

Eng. Tiago Braga

CEO of Metro do Porto

Communication: *What to expect from a doctorate? A Company's Perspective.*

Eng. Tiago Braga, graduated in Environmental Engineering from the Escola Superior de Biotecnologia in 1998. He has been the CEO of Metro do Porto since 2019. Before that, he was a member of the Board of Directors of Águas do Centro Litoral.

Dr. Tiago Ferradosa

Researcher

CIIMAR - Interdisciplinary Centre of Marine and Environmental Research

Communication: *The Joy of Reliable Scour Protections A PhD survival guide – the lessons I took*.

Tiago Fazeres Ferradosa is a doctorate researcher at Faculty of Engineering of University of Porto and researcher at CIIMAR. Tiago is currently responsible for the R&D unit Offshore Structures & Foundations at the Research Group of Hydraulic Structures and Marine Energy. Tiago has been a visiting MSc researcher at University College London and developed his PhD thesis on the topic of reliability analysis of optimised scour protections for offshore foundations. He is also involved in the several R&D projects related to offshore engineering and marine renewable energy research, such as MARINET, HYDRALAB+, ORACLE, and I.nano.WEC. He performs co-supervision activities of master degree students in civil engineering at the University of Porto and has been responsible for the organisation of more than 15 conferences, courses, symposia and other scientific and professional events. He is the editor of the IAHR Newsflash Europe, member of the editorial panel in 4 international peer-reviewed journals, Guest Editor of SI in Renewable Energy (Elsevier) and reviewer in other 14 international peer-reviewed journals. Tiago is the author of several scientific peer-reviewed publications and organiser of the IOSD course series. He was President of the IAHR Portugal Young Professionals Network, the Coordinator of the Young Professionals of the Portuguese Association of Water Resources and elected member of the Monitoring Committee of the Civil Engineering Doctoral Program between 2016 and 2018. He is also the Business Development Manager at the IT engineering company SimpleAxis. He is the Portuguese apointed member of the Technical Committee 213 - Scour and Erosion. Dr. Tiago is also the awarded researcher of the APRH best PhD thesis of 2018/2019.

Short-papers

Incorporation of the Sludge of Sewage Treatment Plant on Ceramic Bricks Manufacture

Nara Cangussu[1], Leandro Silva[2], Stephanie Rocha[3], Lino Maia[4]

[1] CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; UNIMONTES, Center of Exact and Technological Sciences, Civil Engineering Course, State University of Montes Claros, Campus Prof. Darcy Ribeiro, 39401-089 Montes Claros, MG, Brazil, (naracan@gmail.com) ORCID 0000-0002-3442-6224

[2] UNIMONTES, Center of Exact and Technological Sciences, Civil Engineering Course, State University of Montes Claros, Campus Prof. Darcy Ribeiro, 39401-089 Montes Claros, MG, Brazil, (leandromaxciel@gmail.com)

[3] CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (up202010607@g.uporto.pt) ORCID 0000-0002-0984-4897

[4] CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; FCEE-UMa, Faculty of Exact Sciences and Engineering, University of Madeira, Campus da Penteada, 9020-105 Funchal, Portugal, (linomaia@fe.up.pt) ORCID 0000-0002-6371-0179

Abstract

The treatment process used in most Sewage Treatment Stations (STS) generate as by-product a material named sludge. The amount of sludge grows proportionally with the increase in effluent collection and treatment services, which in turn must accompany population growth. The ceramic industry, due to its production characteristics, presents a great potential for the use of these by-product. The present work evaluates the effect of the incorporation of the sewage sludge in the ceramic mass for the manufacture of massive bricks. Real-scale test specimens were made without sludge addition and with 5%, 10% and 15% (by mass) addition of sludge to replace the clay. The specimens were characterized for linear retraction, water absorption, fire mass loss and compressive strength. The results showed that, for the addition of 15% of sludge, there is a reduction in compressive strength and an increase of water absorption.

Author Keywords. By-product, Sewage Treatment, bricks.

1. Introduction

The landfill disposal of by-product from sewage treatment is a problem that has been highlighted in recent years, mainly due to the large amount of sludge generated and the growing commitment on the part of the agencies that regulates the landfill disposal of these waste to minimize environmental impacts. In many cases, sewage treatment plant designs ignore the destination of this material, which ends up being managed in an emergency situation by operators, with high financial and environmental costs, compromising, in some cases, the benefits of the entire sewage collection and treatment system (DUARTE, 2008). The present work had aimed to evaluate the effect of the incorporation of the sludge of Sewage Treatment Plant in the ceramic mass for the manufacture of ceramic massive bricks. The bricks were characterized according to the following characteristics: linear shrinkage, average water absorption index, loss of mass to fire and

compressive strength, seeking to identify the most appropriate percentage of sludge to be incorporated into the ceramic mass to meet the minimum safety requirements and quality according to current regulations.

2. Materials and Methods

The clay used in this study comes from Montezuma Ceramic, located in the city of Montes Claros, Minas Gerais, Brazil. The sludge used in this work comes from the Sewage Treatment Station COPASA-ETE Vieira, from the same city. The clay sample was characterized in terms of granulometry, according to NBR 7181 (2016), the plasticity limit and the plasticity index, following the NBR 7180 (2016), the liquidity limit, according to NBR 6459 (2016), and the specific gravity, following NBR 6458 (2016). The clay and sludge, after being collected, were dried inside an oven at 110°C for 24 hours, untied and sieved, using the #2 mm sieve (Mesh 40). Four compositions were prepared, one without the addition of sludge and the others with incorporations of sludge into the ceramic mass in the percentages of 5%, 10% and 15% (by mass). For each composition, two specimens were molded, with the following dimensions: (19.0 x 9.0 x 5.7) cm. Table 1 shows the mix proportions that were prepared, as well as the quantities of raw materials used. According to Castro *et al*. (2015), the drying time is necessary for bricks acquire slow and gradual retraction, eliminating water and keeping the structure during burning, without cracks. Subsequently, the bricks were dried in the open air for 10 days and burned in a muffle furnace at a temperature of 900°C with a heating of 5°C/min, until reaching the plateau temperature, maintained for two hours. The cooling was carried out at the same rate until room temperature, around 26°C. Figure 1 (a) and (b) show the specimens before and after the burning.

Mix	Clay (%)	Sludge (%)	Clay (kg)	Sludge (kg)
I	100	0	6,00	0
II	95	5	5,70	0,30
III	90	10	5,40	0,60
IV	85	15	5,10	0,90

Table 1: Composition of the formulations and quantitative of the materials

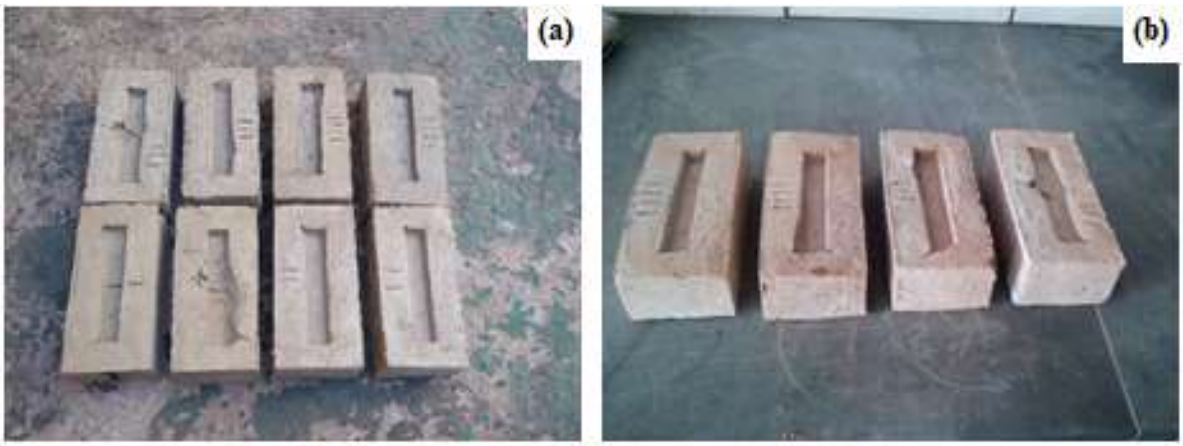

Figure 1: (a) Thermal sludge dryer and (b) sludge collection

Eight specimens were tested to determine the apparent specific gravity, water absorption index and compressive strength. To determine the apparent specific gravity of the burnt specimens by

the dimensional method, according to NBR ISO 5017 (2015). The specimens were measured before and after burning with the aid of KINGTOOLS caliper for determining the percentage of linear retraction. The test for determining the loss of mass on fire is an important parameter which indicates the presence of organic matter in the ceramic mass. To perform the test, the bricks, after being dry, were weighed on a scale digital, before and after burning. The water absorption test was carried out in accordance with NBR ISO 5017 (2015). The specimens were dried in an oven until a constant mass was obtained and, then, immersed in water for 24 hours. After that, the excess surface water was removed from each specimen and the mass was recorded.

The test to obtain the compressive strength was carried out according to the NBR 6460 (1983). Initially, the bricks were sawn in half, with the aid of an electric saw, then the two largest smooth faces were joined through a thin layer of cement mortar of approximately 3 mm. After 24 hours, one side of the prism was covered with the cement paste in order to obtain a regular surface and after hardening, the other side was smoothed. The specimens were placed immersed in water for 24 hours, removed and superficially dried just before the test.

3. Discussion

It is observed that the material has a uniform distribution of the particles, being that 99.7 % is passed through sieve nº 10 (# 2.0 mm), 98.4 % is passed through sieve nº 40 (# 0.42 mm) and 95.0% passed through the nº 200 sieve (# 0.074 mm). Such distribution implies less number of voids in the mass, contributing to the improvement of the characteristics of the ceramics. The clay presented a liquidity limit equal to 43% and a plasticity limit equal to 24%, generating a plasticity index equal to 19%, which characterizes it as clay highly plastic (IP> 15). An increase in the linear burning retraction is observed with the increase of the percentage of sludge incorporated mainly due to the volatilization of organic matter. An increase in mass loss is observed with the increase in the percentage of embedded sludge. These results are due to the volatilization of organic matter present in the clay and mainly in the sludge.

Bricks without added sludge presented a higher water absorption index that the sample with 10% sludge and very close to the limit established by the standard. On the other hand, sample with 15% sludge showed a water absorption index higher than 22%. Thus, this percentage of sludge should not be used, instead of clay, to manufacture of ceramic bricks. With the increase in the percentage of sludge, there is a reduction in compressive strength of the bricks. This behavior can be explained due to the increase in porosity formed during burning, with the volatilization of organic matter present in the bricks.

4. Conclusions

The bricks manufactured in all formulations presented values above the limit established by the standard. However this factor is not related only to the addition of sludge, but it is also influenced by the brick production process, which must be better controlled, in order to generate better quality products. Regarding the absorption index of water, only the formulation containing 10% sludge was below the limit established by the standard, resulting, therefore, in the maximum recommended percentage. Regarding the compressive strength, all formulations showed values higher than the minimum established by the standard. Thus, the incorporation of up to 10% of sludge into the mass ceramics shows itself as a technically feasible alternative to use the by-product of Sewage Treatment Plant.

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Workability control in the development of 3D printing cementitious mortars - laboratory methodology

João Teixeira[1], Cecília Ogliari Schaefer[2], Lino Maia[3], Bárbara Rangel[4], Jorge Lino Alves[5], Rui Neto[6]

[1] CONSTRUCT, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (jhildtex@gmail.com) ORCID 0000-0002-3359-5157
[2] School of Arts, Communication and Hospitality, Architecture and Urbanism, University of the Itajaí Valley, Rua Uruguai, 458 - Centro, 88302-901 Itajaí - SC, Brazil, (cissa.og@gmail.com) ORCID 0000-0003-2335-3565
[3] CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; FCEE-UMa, Faculty of Exact Sciences and Engineering, University of Madeira, Campus da Penteada, 9020-105 Funchal, Portugal, (linomaia@fe.up.pt) ORCID 0000-0002-6371-0179
[4] CONSTRUCT, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (brangel@fe.up.pt) ORCID 0000-0002-5911-9423
[5] INEGI/Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal (falves@fe.up.pt) ORCID 0000-0002-9327-9092
[6] INEGI/Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal (rneto@inegi.up.pt) ORCID 0000-0003-2719-5672

Abstract

Properties in the fresh state are of great importance in the development of a 3D Printing Cementitious Mortar (3DPCM) by extrusion methods. The evolution of workability from mixing to extrusion influences the remaining 3D printing properties. This work presents a laboratory proposal to control workability in an initial phase of mix design of 3DPCM. Four mortars with different water/cement (w/c) ratios and these tests: slump, flow table, and V-funnel were carried out. Right after workability assessment, a mechanical extruder was used to extrude the mortars developed. The results of all tests are presented and compared with a qualitative analysis of extruded samples.

Author Keywords. 3D Printing, Cementitious Mortars, Construction, Extrusion, Laboratory analysis, Materials Development.

1. Introduction

The development of 3DPCM, have been strongly studied for several universities and research centres. The literature presents several properties and printing specifications for a 3DPCM, most of them related to the workability evolution along the printing process. First, high workability is required to transport the material from the mixer to the extruder, as well as a gain in stiffness along the way. This gain in stiffness increases the material's shape retention, allowing it to be extruded in stacked layers (Ma, Li, and Wang 2018; Xiao et al. 2020; Arunothayan et al. 2020) (Table 1).

Property	Why is the property necessary?	Evaluation method	Workability
Flowability	Allows material's transportation from the mixer to the extruder.	Flow table/ slump flow / V-funnel	High
Extrudability	Allows the material to be extruded into uniform and continuous filaments.	V-funnel / filaments extrusion	Low
Buildability / Shape retention	Allows the material to be extruded into stacked layers.	Slump / extrusion of stacked layers	Very low

Table 1: Properties and evaluation methods for the development of 3DPCM.

This work consists in a laboratory methodology using European standardized tests and a mechanical piston extruder, with manual movements (Teixeira et al. 2021), to control workability and evaluate the extrusion capacity of four mortars with different water/cement (w/c) ratios.

2. Materials and Methods

Portland cement (PC) (CEM I 42.5 R) EN 197:2011, limestone filler, tap water, and two sands (2 mm and 4 mm maximum grain size) were used in four mortars with different w/c ratios (Table 2).

Mortar Reference	Portland Cement (kg/m^3)	Limestone Filler (kg/m^3)	Water (kg/m^3)	Sand (2 mm) (kg/m^3)	Sand (4 mm) (kg/m^3)	w/c
Mix 1	302	263	259	132	1187	0.86
Mix 2	312	271	253	132	1187	0.81
Mix 3	321	279	247	132	1187	0.77
Mix 4	330	288	241	132	1187	0.73

Table 2: Mixture proportions of the raw materials used.

The following tests were carried out right after mixing using each batch. In the flow table test, according to EN 1015-3:1999, the mould is filled with two layers, each compacted by at least 10 short strokes. After the mould was slowly filled it was vertically raised and the slump was measured, then the material was jolted 15 times on the flow table disc. The resulting spread diameter was measured in two perpendicular directions, being the average diameter the flow value (mm). The flow is used to evaluate the mixture's flowability while slump is used to evaluate the mixture's shape retention. The V-funnel test was performed according to EN 12350-9:2010, has been used in 3D printing to evaluate the material's deformability capacity when passing through a restricted area (Ma, Li, and Wang 2018). After all tests were carried out, the mortars were extruded in a rectangular sample with an area of 180×80 mm^2. As the printing system does not have a transport mechanism, losing moisture and workability during the tests can be considered a simulation of losing moisture and workability during the transportation phase in a 3D printing system (Figure 1).

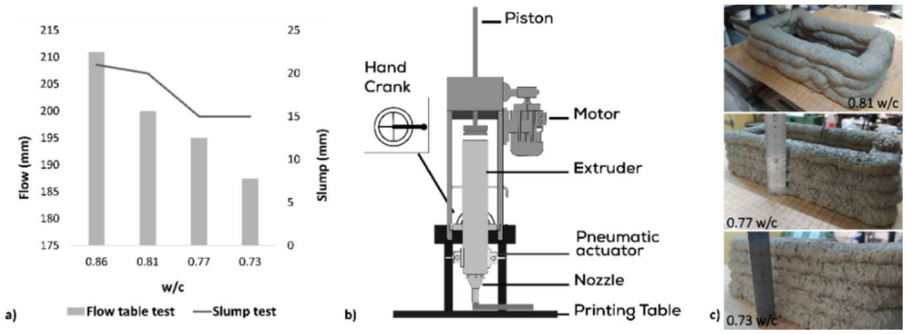

Figure 1: Laboratory methodology to evaluate the workability of a 3DPCM: a) results of slump and flow table tests; b) scheme of the extruder used, c) mortars extruded with different water cement ratios.

3. Discussion

As expected, the slump and flow table tests showed a decreasing trend in workability with lower w/c ratio. This loss of workability becomes a gain in shape retention, evidenced by the low slump and flow value in Mix 3 and 4. This is advantageous for 3D printing during the extrusion phase, increasing filaments quality and layers stability. In the V-funnel test, only two mixtures with higher w/c ratio (Mix 1 and 2) were possible to evaluate the flow time. However, Mix 1 with a flow time of 17 seconds and high values in slump and flow tests, did not allow the extrusion of stable filaments, due to the lack of shape retention after extrusion. The Mix 2, with a flow time of 57 seconds, made possible the extrusion, however with high deformations in lower layers. In Mix 3 and 4 it was possible to extrude the material into layers without large formations. Comparing the quality of extruded samples with the slump tests, is possible to mention that the value for good extrusions must be 15 mm or less. Despite the same slump value in Mix 3 and 4, the flow table tests showed high values in Mix 3. This increase in flow is also noticeable in the extruded samples, where the same volume of material made possible to print only 4 layers in Mix 3, while in Mix 4 was possible to print 5 layers. This can be justified by greater workability in Mix 3, which may have increased the printing flow without increasing the piston pressure on the material. The study suggests that the best mixture for 3D printing is Mix 4 with a w/c ratio of 0.73 (Figure 1).

4. Conclusions

It was demonstrated that the laboratory methodology proposed shows a great way to optimize a 3DPCM, however, other parameters need to be measured for a better characterization of the developed mortars like rheological properties.

The qualitative evaluation of the extruded samples provided the final data for interpreting the test results, being a fundamental stage in the proposed methodology.

In future works, the compositions will be evaluated in an automated system, and a more detailed evaluation of the printed samples will be made.

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Acknowledgments

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Vibrations Induced by Impact Pile Driving: Experimental and Numerical Analysis

Ahmed M. k. Abouelmaty[1], A. Colaço[1] and P. Alves Costa[1]

[1] Department of Civil Engineering, University of Porto, Construct, Porto, Portugal

Abstract

In various construction sites, vibrations are considered a critical aspect. In particular, ones generated from the installation of driven piles. In this work, an experimental test site was developed for understanding of the phenomenon involved in the generation and propagation of vibrations. Additionally, the pile-ground system is modeled by an axisymmetric FEM-PML numerical model developed by the authors, allowing complement the experimental data. Thus, a set of parametric analysis was developed to evaluate the effect of fluctuation of some parameters, as pile penetration depth, drop-height, soil stiffness, soil damping, etc. The comparison between numerical and experimental results is a fundamental aspect, allowing the experimental validation of the numerical tool. Based on the investigation performed, it becomes very clear the suitability of the proposed numerical approach to predict the vibration levels at the ground surface. The estimation of the vibration levels expects in the early project phase can avoid possible constraints in the normal development of the construction activities, with economic and technical benefits.

Author Keywords. Pile Driving, Ground-borne vibrations, Numerical modelling, Experimental test site.

1. Introduction

Predicting ground vibrations as a result of pile driving is a complex problem that is affected by many factors such as energy transmitted from the hammer to the pile, geotechnical conditions of the site, distance from the source, soil-structure interaction, etc. Most studies on soil vibrations induced by pile driving are based on empirical approaches. Unfortunately, this type of approach usually has the usual flaws attributed to empirical methods, especially in terms of applicability and reliability. Therefore, in order to have a more general prediction tool, it is necessary to understand the physical characteristics of the problem and the main variables involved.

In this regard, a numerical approach to model the pile-ground system, based on an axisymmetric FEM-PML formulation, is presented (Colaço et al. 2021). Given the complexity of the problem, an experimental test site is described, allowing experimental validation of the numerical approach under low strain conditions.

2. Experimental activities

An experimental test site located near Aveiro (Portugal) was chosen to perform an experimental vibration test under low strain level Figure 4. For that, an instrumented impact hammer was used to apply an impact at the pile head in order to induce the generation and propagation of vibrations. The vibration field generated was measured throw a set of in-site fixed accelerometers. The accelerometers were utilized to cover an influence zone for the vibrations, with a distance up to 32 meters. The data acquired through the accelerometers was treated numerically in order to compute the experimental low strain transfer functions.

3. Numerical methodology

Regarding the numerical analysis, and in order to get the numerical transfer function between the response at the ground surface and the dynamic load imposed at the pile head, the pile-ground medium is discretized by an FE-PML mesh with a total of nodes equal to 47098, corresponding to a discretized cross-section of 36 m x 11 m. The PML layers are bounding the FEM region, as presented in Figure 2 . Regarding the soil properties adopted, Figure 2 presents the shear wave velocity profile. A Poisson's ratio equal to 0.3 was assumed for the first layer and 0.49 for the others. A damping ratio equal to 0.03 was assumed for all the layers.

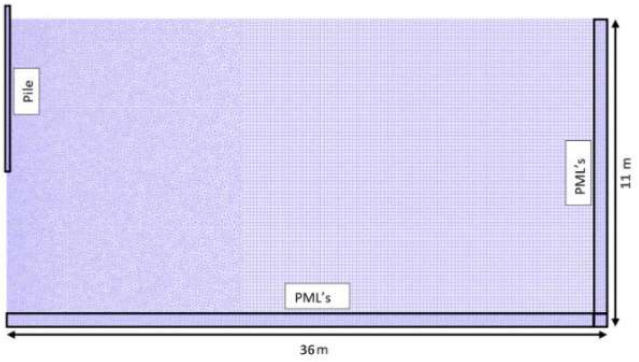


Figure 1: FE–PML mesh adopted to model the pile-ground system.

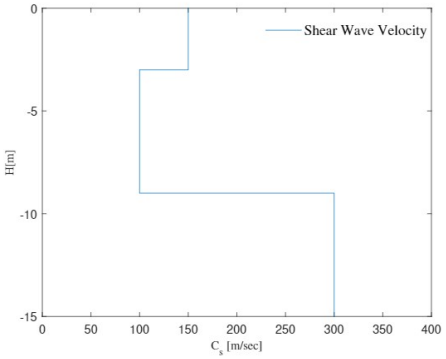


Figure 2: Shear wave velocity profile adopted for the site system.

After computing the transfer functions from experimental and numerical approaches, Ricker pulse (eq. 1) was applied as a loading function in order to get a better visualization of the data in the time domain.

$$R_I(t) = \left[2\left(\pi \times \frac{t - t_s}{t_d}\right)^2 - 1\right] e^{-\left(\frac{\pi(t-t_s)}{t_d}\right)^2} \quad (1)$$

where, t_s is time shift (t_s=0.05), *td* is the characteristic period (t_d=0.03) and *t* is the time.

4. Results comparison

Based on the previous brief explanation, the particle peak velocity resulted from experimental and numerical approach are compared, as shown in Figure 3. It should be highlighted that this validation comprises distances up to 32 meters from the pile. During the influence zone, effects like changes in soil profile could be occur, such this effect justifying differences between numerical and experimental results.

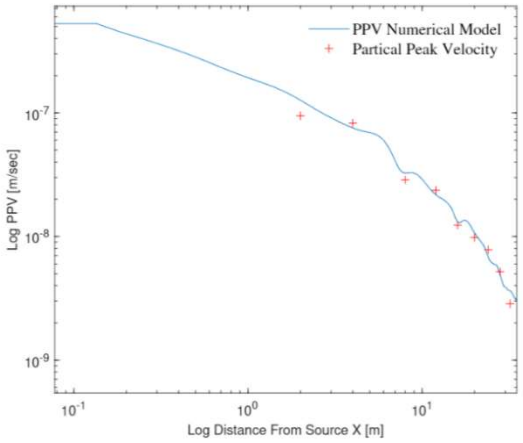
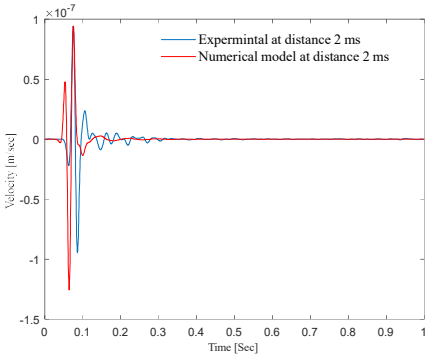


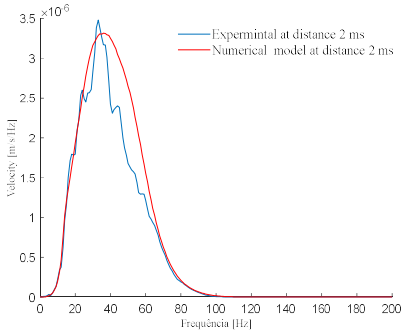
Figure 3: PPV numerical Vs experimental results

Figure 4: Impact pile driving at the experimental test site.

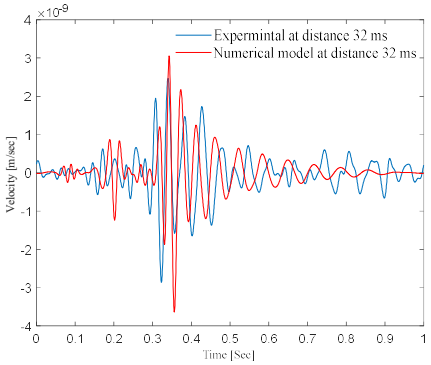
In order to go in a deeper analysis, a comparison was established between the experimental and numerical results in terms of time and frequency records of the vertical vibration velocities. The comparison was established for the extremes recording points, the closest and ultimate ones, as shown in Figure 5.



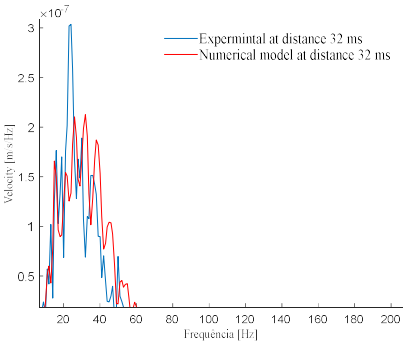
a) Velocity in time domain at distance 2 ms



b) Velocity in freq. domain at distance 2 ms



c) Velocity in time domain at distance 32 ms



d) Velocity in freq. domain at distance 32 ms

Figure 5: Comparison between numerical and experimental result for the extremes distance.

5. Results Discussion

From the previous results, it is evident a remarkable agreement between experimental and numerical results. Even though the experimental activities were carried out under controlled conditions, the numerical model is able to address the main features of the problem. In further works, the numerical model presented will be applied to real pile driving operations.

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Tensile response of reinforced UHPFRC elements

Rui Valente[1], Mário Pimentel[2], Sandra Nunes[2]

[1] PhD candidate, CONSTRUCT-LABEST, Faculty of Engineering, University of Porto, Portugal
[2] Assistant Professor, CONSTRUCT-LABEST, Faculty of Engineering, University of Porto, Portugal

Abstract

The understanding of the tensile behaviour of Ultra-High Performance Fibre Reinforced Cementitious Composites with reinforcing steel bars (R-UHPFRC) is still limited as well as the existing guidelines for structural design. Therefore, the goal of this work is the development of a theoretical model describing the uniaxial tensile response of R-UHPFRC tension ties. The tension tie element is divided into a series of crack elements that are treated individually. An incremental and iterative procedure is used to find the overall load deformation response by ensuring equilibrium at each load step. The numerical load-deformation responses are comparable with existing experimental results from tensile tests, which validates the proposed methodology.

Author Keywords. Reinforced Ultra-High Performance Fibre Reinforced Cementitious Composite (R-UHPFRC), Mechanical model, Tensile behaviour, Tension Chord Model

1. Introduction

Cementitious composites have been improved during the last decades in order to respond to constructive, environmental, and structural demands, as is the case of Ultra-High Performance Fibre Reinforced Cementitious Composites (UHPFRC). Depending on the loading demand, the design of UPFFRC tensile elements might require steel reinforcement. However, suitable methodologies for structural analysis and design as those already existing for reinforced concrete (RC) are still missing.

The main objective of this work is the development of a theoretical model describing the total load deformation response of R-UHPFRC tension ties from elastic phase to failure. The model is supposed to be valid for a wide range of fibre contents, properties and geometries, as well as for different steel reinforcement types and ratios.

2. Methods

In the scope of this work, a tension tie element is defined as a group of single crack elements with variable post-cracking strength. The crack element (Figure 1) is defined by a crack and the portions up to half the distance between the two closest cracks. The solution of the bond-slip problem follows the strategy adopted in the development of the Tension Chord Model (Marti et al. 1998) which provides a closed-form relationships between the rebar stress at the crack section ($\sigma_{s,r}$) and the average deformation of the crack element (ε_{sm}). The load-deformation (σ_N-ε_{sm}) response is found through equilibrium:

$$\sigma_N = \rho_s \sigma_{s,r} + (1 - \rho_s) \sigma_{c,r} \quad (1)$$

and compatibility of deformations:

$$w_r = s_{rm}\,(\varepsilon_{sm} - \varepsilon_{cm}) \quad (2)$$

where the parameter ρ_s is the reinforcement ratio, $\sigma_{c,r}$ is the composite stress at the crack section, w_r is the crack width, and ε_{cm} is the composite average deformation. The value of $\sigma_{c,r}$ results from the contributions of steel fibres (σ_{cf}) and matrix (σ_{bri}). The softening of the matrix is assumed to follow a simple linear law, and the fibre engagement model proposed by (Pfyl 2003) is used to simulate the contribution of the steel fibres. Also a pull-out law proposed by (Redaelli 2009) for UHPFRC is adopted for comparative purposes.

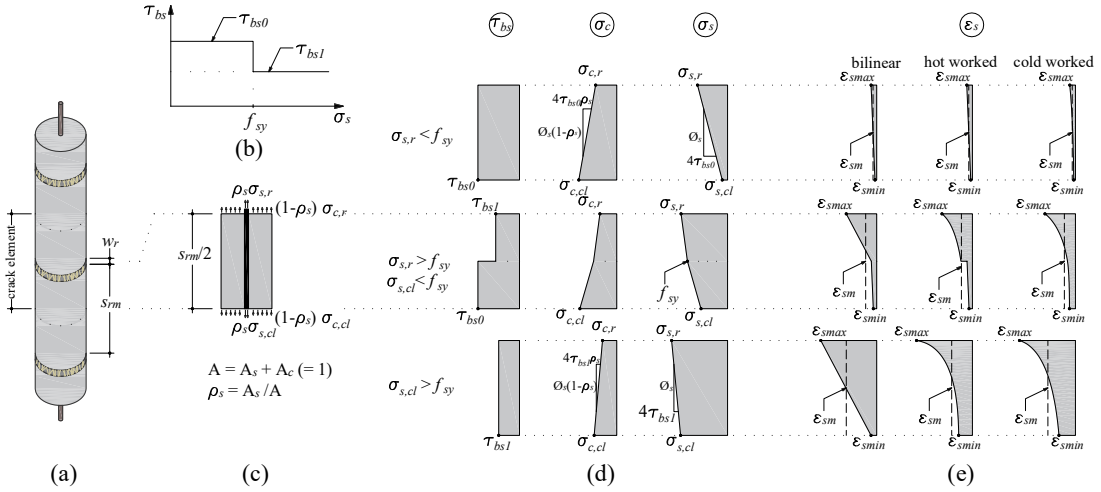

Figure 3: Tension chord model: (a) crack element; (b) bond shear stress-slip relationship; (c) equilibrium at the crack element at cracking; (d) stress and (e) strain distributions in elastic, elastic-plastic and plastic crack elements.

The spatial distribution σ_{cf0} is defined by a frequency distribution that approximates a Gaussian function for which the minimum post-cracking strength and the standard deviation of the post-cracking strength need to be defined. The overall load deformation ($\varepsilon_{sm,g}$) response is found incrementally and iteratively by ensuring equilibrium between all crack elements at each load step.

3. Validation

The numerical and experimental results are compared in terms of load-deformation response to validate the proposed model. Existing experimental results were found in the literature (Jungwirth 2006; Redaelli 2009; Aghdasi and Ostertag 2020) and are used. The Figure 2 shows how the numerical results compare to the experimental results in the elastic and plastic phases of the rebar. The different pull-out laws proposed by Redaelli (i_{soft} = 1) and Pfyl (i_{soft} = 2) are used. In general, there is a good agreement of the stiffness of the cracked element in tension and in terms of ultimate deformation. The model underestimates the energy dissipated in the post-peak stage, in the case of the tension ties tested by Jungwirth and Ostertag.

4. Conclusions

The proposed model assumes a series of parallel and discrete cracks. The individualisation of fibres, rebar and tension stiffening contributions helps to understand the impact of the mechanical properties of the participating materials on the tensile behaviour at the crack level, which is then scaled up to the tension tie level where different cracks coexist. Therefore, the proposed mechanical model allows understanding the experimentally observed behaviour of cementitious composites reinforced with rebar and fibres. The model is capable of properly simulating the axial stiffness of the stabilised cracking phase and the ultimate deformation.

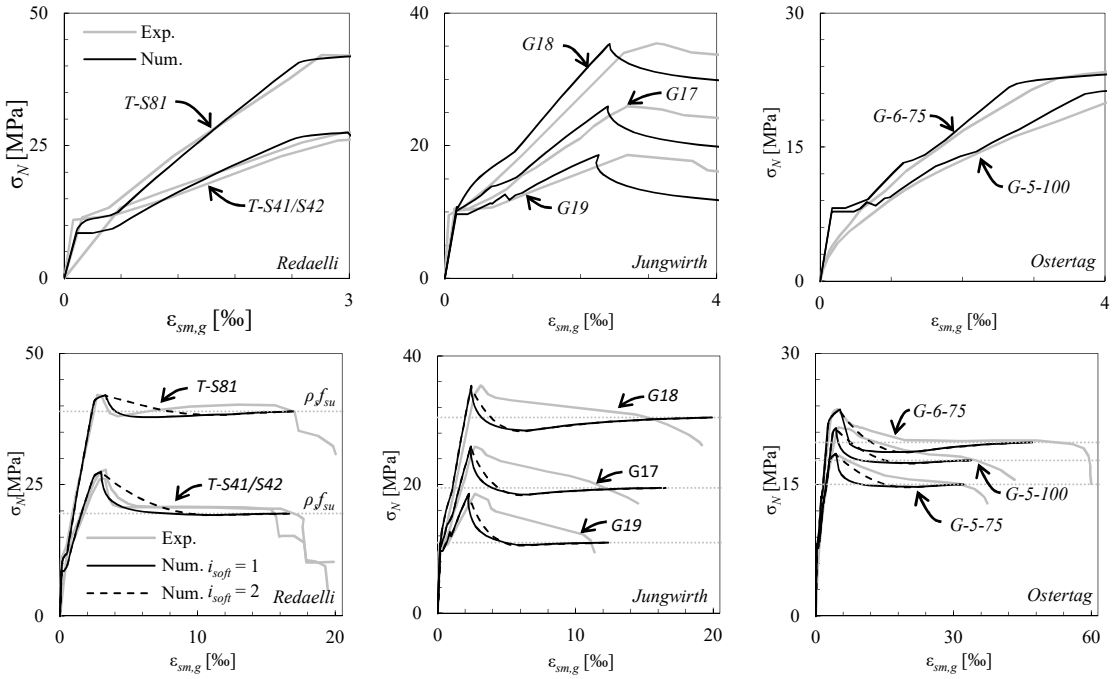

Figure 4: Comparison between numerical and experimental load-deformation responses in the elastic and plastic phases of the steel reinforcement

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Artificial Intelligence for an Enhanced As-Is BIM Energy Analysis

Luís Sanhudo[1], João Poças Martins[2], Nuno M. M. Ramos[3]

[1] BUILT CoLAB – Laboratório Colaborativo para o Ambiente Construído do Futuro, Rua de Campo Alegre, 760, 4150-003 Porto, Portugal, (luis.sanhudo@builtcolab.pt) ORCID 0000-0002-2578-6981
[2] CONSTRUCT, Faculty of Engineering (FEUP), University of Porto, Porto, Portugal, Rua Dr. Roberto Frias s/n, 4200-465 Porto, Portugal, (jppm@fe.up.pt) ORCID 0000-0001-9878-3792
[3] CONSTRUCT, Faculty of Engineering (FEUP), University of Porto, Porto, Portugal, Rua Dr. Roberto Frias s/n, 4200-465 Porto, Portugal, (nmmr@fe.up.pt) ORCID 0000-0002-5331-7429

Abstract

Facing the current pursuit for energy efficiency in the Construction industry, as well as the increase in Building Information Modelling (BIM) related practices, the present paper proposes a methodology to enhance the as-is BIM energy analysis (AIBEA) process, aiming to ease the energy retrofit of the existing building stock and allow for increased energy efficiency in the Construction industry.

The proposed methodology comprises the entire AIBEA process from contract formulation to building energy analysis, tackling several existing research problems such as: identification of contractual requirements and quality verification parameters for BIM energy analysis and the scan-to-BIM process; analysis of laser scanner parameters and its influence over the point cloud; optimal placement of laser scanner stations; artificial training of Artificial Intelligence (AI) algorithms; identification of construction materials in point clouds; among others.

Author Keywords. Enhanced as-is BIM energy analysis, Automated scan-to-BIM, Artificial Intelligence, Point cloud segmentation and classification, Data mapping and material recognition.

1. Introduction

In the last few years, energy retrofit of the existing building stock has quickly positioned itself centre stage of research and application, with several European directives and countries' legislations focusing the topic in pursuit of sustainability and economic goals (European Parliament 2018). Similarly, as a prominent topic within the Construction industry, BIM has risen in importance in scientific and practical communities, morphing itself from a futuristic scholar concept into a vital core piece of the industry (Sanhudo, Ramos et al. 2018). With an increasing overlap of both areas, researchers and practitioners focused on the AIBEA process as an answer to the slow retrofitting the existing building stock, enabling the quick analysis of a building's energy consumption and the exhaustive comparison of constructive solutions to increase its efficiency (Habibi 2017). However, several obstacles still hinder this process's overall productivity and accuracy, with multiple scientific works denoting a growing need to swiftly and automatically acquire accurate and semantically enriched three-dimensional digital models of existing buildings (Sanhudo, Ramos et al. 2018).

To this end, the author's research aims to contribute with an answer to this problem by tackling the problem from two perspectives: (1) the development of supporting documentation and tools for an accurate and swift AIBEA, and (2) the integration and automation of the scan-to-BIM process. To achieve this goal, the author relies on two primary technologies: laser scanning and AI. These are applied to accurately acquire the as-is building geometry and automate the resulting point cloud segmentation, classification, and modelling within a BIM authoring environment.

The development of both perspectives resulted in the creation of a methodology for an enhanced AIBEA, which is comprised on five distinct modules. These are: (1) identification of AIBEA requirements; (2) as-is building data acquisition; (3) point cloud segmentation and classification; (4) automated BIM modelling; and (5) BIM model enrichment and exportation to energy analysis software. These modules and their respective contributions are examined in greater detail in Figure 5.

The methodology was applied to five different experiments to evaluate its performance and identify its advantages and limitations. Each experiment tackled different parts of the methodology, from assessing the proposed models for scan-to-BIM automation to the enrichment of the resulting BIM model with identified material information and its successful exportation to energy analysis software. Given the restricted length of the current short-paper, only one of these experiments will be tackled and discussed in the following section.

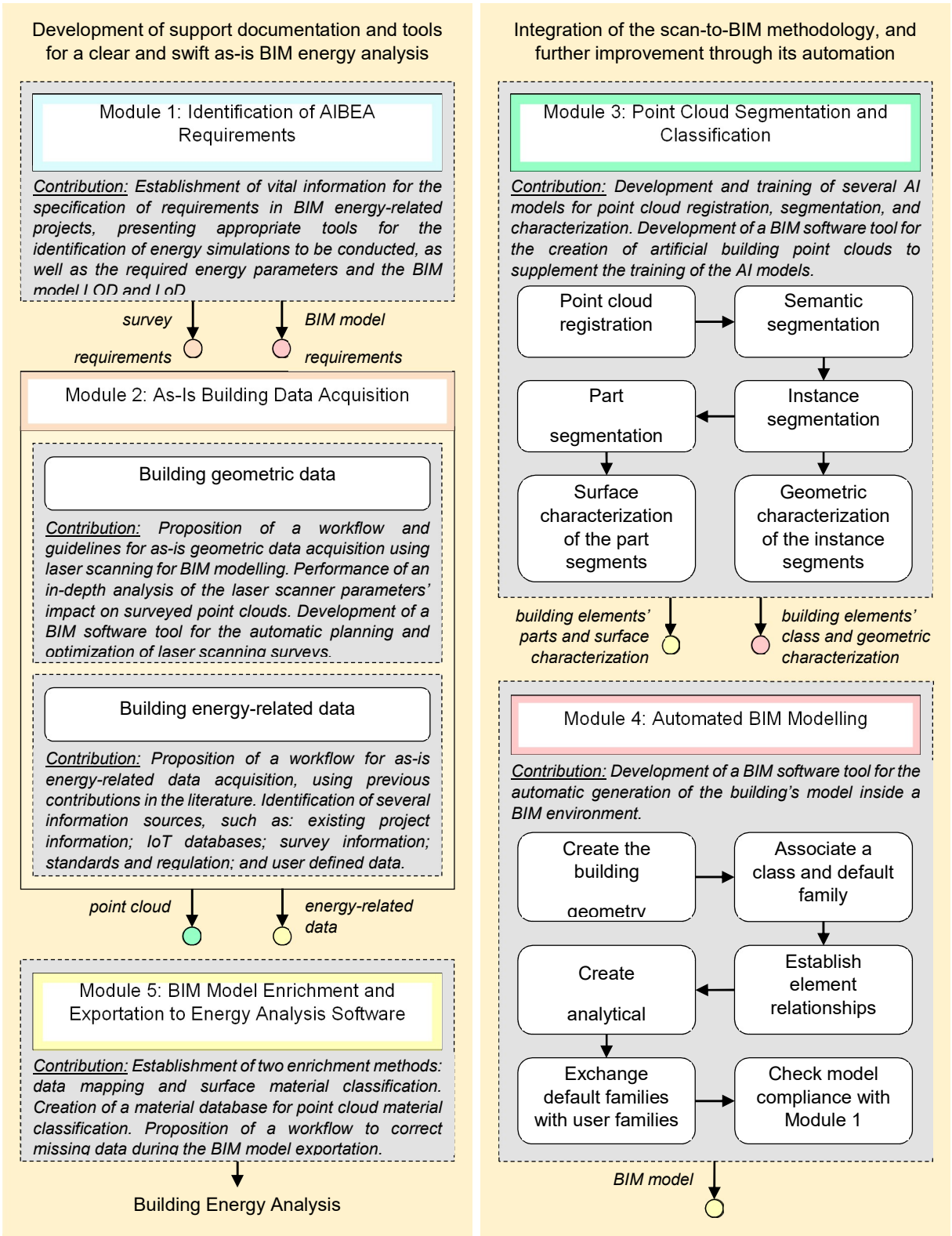

Figure 5: Overview of the proposed methodology

2. Experiment and Results

Figure 6 showcases the results of testing Module 3 and 4 contributions in the S3DIS dataset (Armeni, Sener et al. 2016). The figure portrays the scan-to-BIM process, transforming a room's point cloud into a fully semantically enriched BIM model. Throughout the case study, the developed models achieved a 90.52% overall accuracy during segmentation for 13 different classes: seven structural elements (ceiling, floor, wall, beam, column, window and door), five commonly furniture items (table, chair, sofa, bookcase and board), and a clutter class for the remaining data. It was also found that the extracted geometric data and subsequent modelling were in line with the acquired segmentation, with any error during modelling originating from the ~9.5% miss segmentation. However, it should be stated that since measures were created to reduce this error's impact during modelling, the overall scan-to-BIM process is well over the segmentation accuracy.

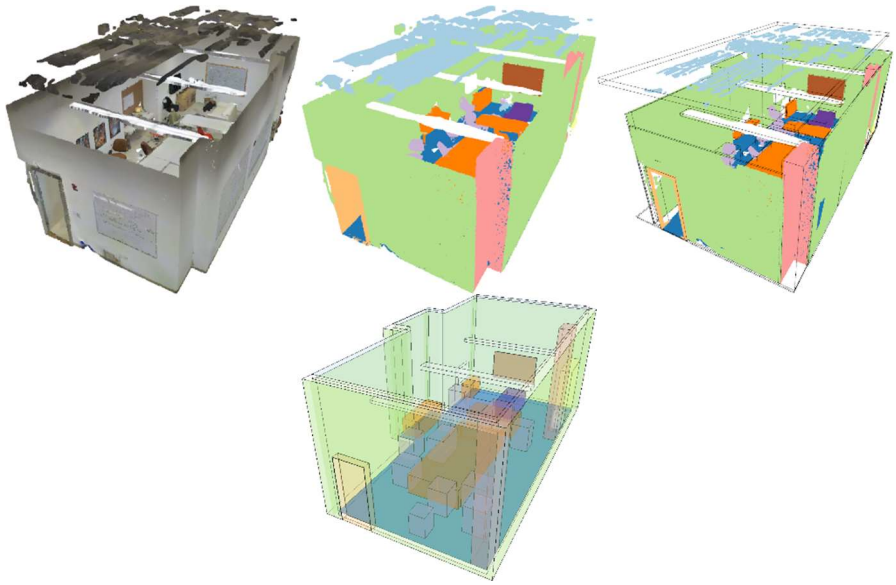

Figure 6: Results from the developed fully automated scan-to-BIM process. Raw point cloud (A); semantically segmented point cloud (B); extraction of geometric features for each identified constructive element (C); and final BIM model (D).

3. Conclusions

The current work presented a methodology to enhance the AIBEA process by developing supporting documentation and automating the scan-to-BIM process. By doing so, several of the existing drawbacks limiting the AIBEA's success were overcame. As such, it is the authors' opinion that the proposed methodology can ease the energy retrofit of the existing building stock and enable the prompt achievement of its related sustainability goals.

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BIM Health and Safety Support Framework for Construction

Adeeb Sidani[1], João Poças Martins[2], Alfredo Soeiro[3]

[1] CONSTRUCT, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (adeeb.sidani@hotmail.com) ORCID 0000-0002-0570-1207
[2] CONSTRUCT, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (jppm@fe.up.pt) ORCID 0000-0001-9878-3792
[3] Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465, Porto, Portugal (avsoeiro@fe.up.pt); ORCID 0000-0003-4784-959X

Abstract

The construction industry still leads other industries with high numbers of injuries and fatalities annually. To have an effective site inspection, monitoring, and training, the AECO (Architecture, Engineering, Construction, and operation) sector gradually integrates new technologies such as building information modelling (BIM).

This paper presents a BIM-supported framework for Safety verification based on two main approaches: a Fully Automated Approach, adopting Automated rule checking, and a Fully Manual Approach, adopting Augmented and Virtual Reality (AR/VR) technologies. Moreover, this process will also enable safety training through AR/VR. The framework follows international standards such as ISO 1650, Directive 92/57/EEC, and PAS 1192-6:2018.

Integrating these technologies in a standardised manner will ease the adoption of the tools, enable clients to acquire a better perception and control of the H&S aspects of the project, assign specific tasks for each stakeholder, and involve H&S measures from the beginning of the project. Some limitations are found in implementing new tools, such as the lack of experience, low demand from the clients, incompatibility of software and data, high cost of hardware and software, and total time preparing BIM models.

Author Keywords. Building Information Modelling, Automated Rule Checking, Augmented Reality, Virtual Reality, Construction, Occupational Health and Safety.

1. Introduction

Construction safety is an international concern, with many injuries occurring in construction sites worldwide (Zhang, Teizer, Lee, Eastman, & Venugopal, 2013a). According to the U.S. Bureau of Labour Statistics, construction had 9.5 fatalities per 100,000 full-time workers (U.S. Department of Labor; Bureau of Labor Statistics, 2019). Accidents can be avoided if the construction managers are careful with supervision during the construction process (Chim, Chun, & Wah, 2018). Thus, the construction site requires regular and advanced monitoring and supervision; besides, new workers must be trained carefully before going to the construction site to avoid unsafe actions. Therefore, to assist manual monitoring and supervisions, automated safety monitoring such as BIM is adopted by the AECO sector (Eleftheriadis, Mumovic, & Greening, 2017).

2. Construction Safety and Digital Technologies

2.1. BIM application in the AECO sector

BIM implementation can provide essential decision-support tools, enables workers, safety specialists and engineers to digitally visualise and monitor construction sites and identify hazards (Azhar, Khalfan, & Maqsood, 2012; Sidani, Duarte, Santos Baptista, et al., 2021). In Europe, BIM adoption is reinforced by Directive 2014/E.U., Article 22 (European Comission, 2014), which refer

to BIM application for public procurement and by the modern international standard for BIM EN ISO 19650-1 (BS EN ISO 19650-1, 2018). The AECO sector is currently implementing several tools and methodologies to assist BIM, such as Automated Rule checking, AR, VR (Sidani, Dinis, Duarte, et al., 2021; Sidani, Dinis, Sanhudo, et al., 2021).

2.2. Fully Automated Verification Systems (Rule Checking)

Rule-based checking systems improve construction operation, allowing effective H&S planning throughout the project's lifecycle (Eastman, Lee, Jeong, & Lee, 2009). Data fusion of OSHA and geometric project data safety rules can create information that can enhance safety education and training at the design and construction stage (Zhang, Teizer, Lee, Eastman, & Venugopal, 2013b).

2.3. Fully Manual Verification systems

2.3.1. Augmented Reality

AR is primarily implemented in construction sites due to the visualisation, information extraction capabilities, support task completion and orientation, lower cognitive workload, manage construction schedules and costs, improve collaboration, increase site assistance, and offer safety training (Bae, Golparvar-Fard, & White, 2013; Pour Rahimian, Chavdarova, Oliver, & Chamo, 2019). Figure 7 demonstrates a guided integration of AR in the AECO sector (Sidani, Dinis, Duarte, et al., 2021).

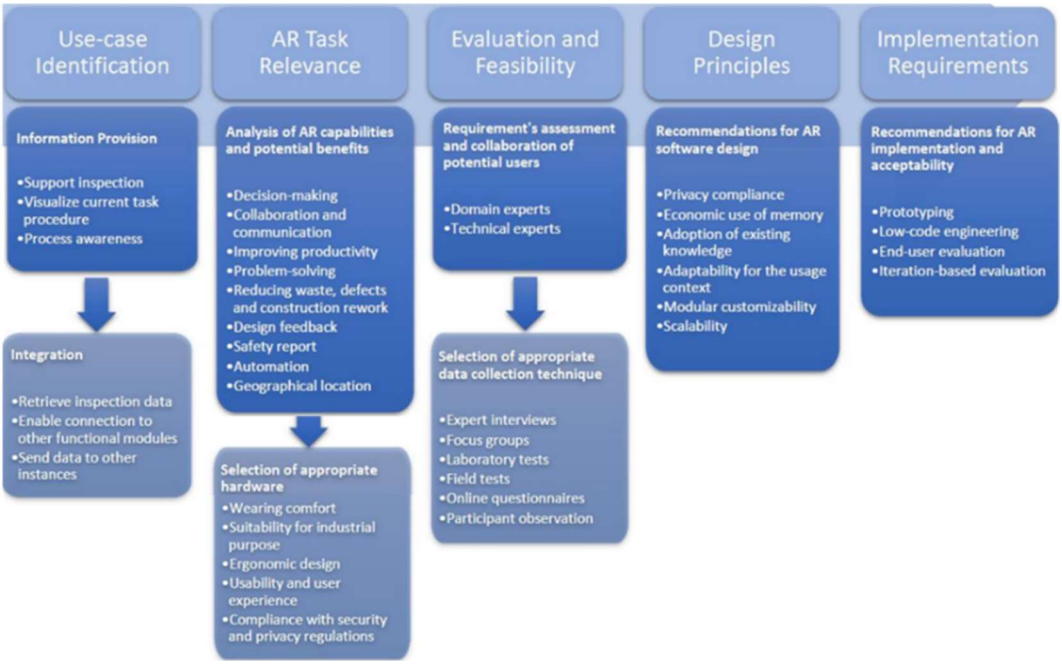

Figure 7 Framework for a Guided Integration of AR in the AECO Sector.

2.3.2. Virtual Reality

BIM-based VR applications enhance design review, team collaboration and communication, decision making, allowing people with different expertise to access BIM information (Sidani, Dinis, Sanhudo, et al., 2021). Figure 8 illustrates an implementation framework of BIM-based VR.

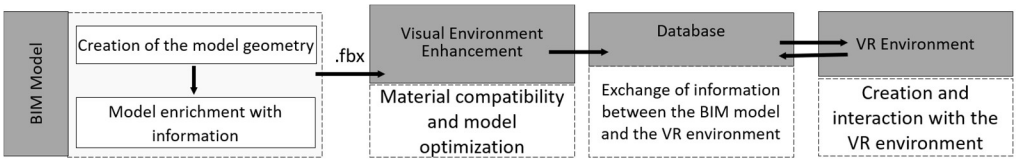

Figure 8 BIM-Based VR Development Framework.

3. Proposed Framework

The proposed BIM for Safety framework Figure 9 combines the technologies mentioned above, generating a BIM for Safety Verification System. Dong mentioned that three aspects need to be improved to elevate the levels of H&S and reduce risks: detecting hazardous areas at a specific time, monitoring and inspection, and training (Zhai, Goodrum, Haas, & Caldas, 2009). The proposed approach for BIM for the Safety verification system aims to improve these three aspects. This system can be divided into Fully Automatic or Fully Manual approaches Figure 10.

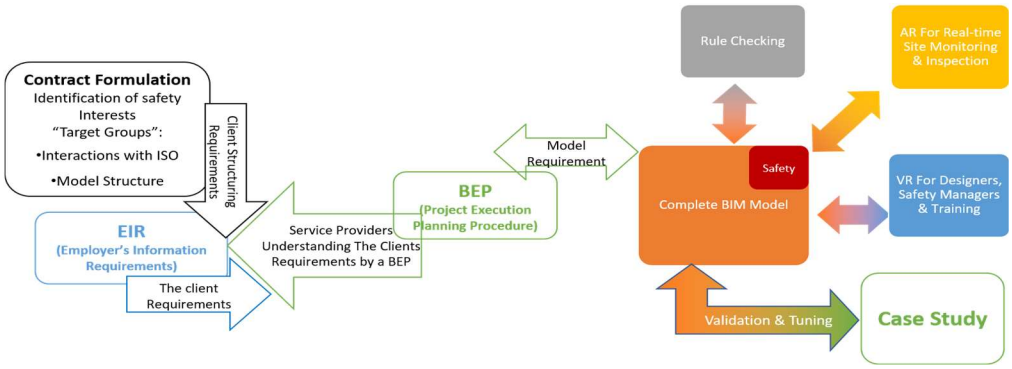

Figure 9 BIM for Safety Framework

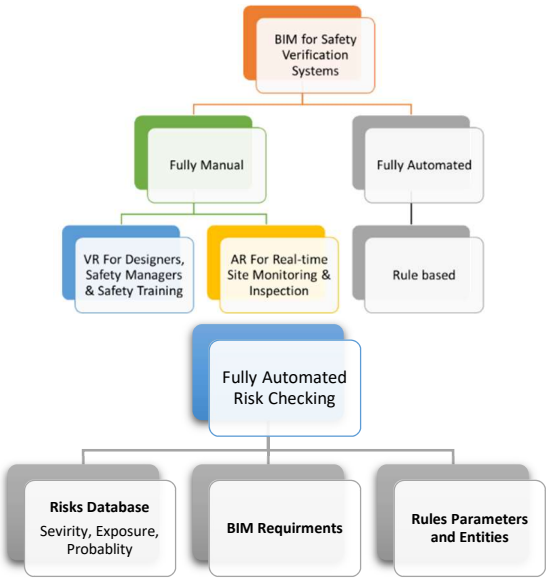

Figure 10 BIM for Safety Verification System Checking Components

Figure 11 Fully Automated Rule

BIM model can be introduced to automated rule checking for Fully Automated Risk Checking Figure 11. Several risks scenarios will be identified and analysed at an earlier stage, categorising them based on their probability, severity, and exposure. The manual approach is divided into off-site risk checking and training using VR and AR for on-site inspection, monitoring, and training, for the risks that cannot be checked automatically.

4. Conclusions

The integration of BIM with Automated Rule checking, AR, and VR aims to indicate the same components of the BIM model by specifying the Level of Development (LOD), permitting professionals in the AECO sector to register, manipulate and specify the content of BIM effectively. The BIM for Safety general framework will be based on the established construction standards, such as EN ISO 19650-1 standard, PAS 1192-6:2018 "Specification for collaborative sharing and use of structured H&S information using BIM, and the Directive 92/57/EEC, implementing minimum H&S requirements at temporary or mobile construction sites.

BIM is still not fully integrated with recent technologies due to the sluggish mindset of professionals, and the AECO sector is too content with current practices. Limitations to be resolved are the lack of expertise using digital tools, low demand from the owners, time spent preparing the BIM models, lack of collaboration and incompatibility of data transfer between appointed parties, data transfer due to the construction site's low Wi-Fi and GPS connectivity levels, constraints regarding non-geometric information attained in the AR systems, BIM-based VR level of realism of the models, and the lack of universal data components.

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Exploring the Blockchain Adoption Directions in the AECO Industry

Mohammad Darabseh[1], João Poças Martins[2]

[1] CONSTRUCT – GEQUALTEC, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias s/n, 4200-465 Porto, Portugal, (darabseh@outlook.com) ORCID 0000-0002-7443-8326
[2] CONSTRUCT – GEQUALTEC, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias s/n, 4200-465 Porto, Portugal, (jppm@fe.up.pt) ORCID 0000-0001-9878-3792

Abstract

Blockchain is a digital data and assets protection technology. The growing interest in exploring ways to adopt Blockchain within the architecture, engineering, construction, and operation (AECO) industry activities are expressed by the increasing number of studies discussing this topic. In order to visualise these directions, the article presents an evaluation of this topic available literature. Topics reviewed include Blockchain for BIM, construction processes and construction data integrity. The study contributes to the field by providing a concise evaluation of Blockchain in the AECO industry research and the recent development by highlighting main directions for Blockchain construction-related studies. The study aims to increase awareness about the topic.

Author Keywords. Blockchain, BIM, Intellectual property, Design

1. Introduction

The aim of digitalising the architecture, engineering, construction, and operation (AECO) industry is to help it overcome its long-term advanced problems such as poor productivity, lack of trust among stakeholders and labour shortage (Mihindu & Arayici, 2008).

Recent technological advances like Blockchain technology are being explored alongside other technologies to improve the overall industry performance by improving the industry data integrity, reduce the need for middlemen, and automate repetitive tasks. This study presents the recent development of the Blockchain application spectrum in the fields related to the AECO industry (Çevikbaş & Işık, 2021).

2. Blockchain and AECO industry

Blockchain applications are trending in several industries. This section contains an introduction about it, followed by a brief review of the proposed adoptions directions in the AECO industry. Interested parties in deeper review refer to (Darabseh & Martins, 2020).

A. What is Blockchain?

Blockchain technology is a new form of digital data-handling technology, where data is stored in a chain of information masses connected using cryptography (Crosby et al., 2016). In addition to that, the Blockchains can execute logical order when certain conditions are met. Blockchains systems allow for advanced interaction through the internet (Dai et al., 2018).

B. Blockchain Applications in the AECO industry

Blockchain as a technology can function alone to deliver its main features to generic data or in synergy with another AECO technology such as Building Information Modelling (BIM) (Liu et al., 2019), Internet of Things (IoT) (Ye et al., 2018), Virtual Reality (VR), Augmented Reality (AR) (Zheng et al., 2019), and Big Data (Aleksandrova et al., 2019) to reinforce these technologies by improving their data management capabilities.

Studies like Nawari and Ravindran (2019b) presented Blockchain as a solution for construction management problems while highlighting the special needs of construction data and the main difference between traditional Blockchains and construction data compatible Blockchains where data size and the number of participants is different.

Building Information Modelling (BIM) and Blockchain synergy is a growing field of research. Safa et al. (2019) consider Blockchain a trust and collaboration booster in the BIM environment, while Nawari and Ravindran (2019b) find Blockchain a technology that can help BIM data management by using it to improve information management processes such as versioning and data exchange. Ye et al. (2018) add to IoT the BIM and Blockchain synergy. The three components were considered essential for future resource-efficient construction data management systems.

Cyberthreats against digital construction activities is a growing risk as more construction data become digitally available. Zheng et al. (2019) presented a framework for roles and privileges for accessing construction data using Blockchain. The system uses contexts instead of rules to grant or deny access to data which could reduce the risk of unauthorised access and data leaks for construction-related data.

Improving the integrity of construction operations data using Blockchain were presented in several studies. Operations of the supply chain (Fitriawijaya & Hsin-Hsuan, 2019), concrete quality production (Bohner et al., 2019), and monitoring structures health (Jo et al., 2018). The studies aim to automate data gathering to reduce human errors and exchange data remotely in a safe way.

The Blockchain technology ability to provide trustless solutions allowed studies like Li et al. (2019) to suggest automating processes where the government is involved, such as tax collection and land registrations, also building permits (Nawari & Ravindran, 2019a). Blockchain allows data traceability which could improve construction design data exchange by allowing the data owner to track its use. The use of Blockchain can reduce the risk of copyright infringements which should encourage participants to exchange data without worrying about proving their ownership for the data shared.

3. Conclusions

The potential of Blockchain in construction is driving the research directions to new territories where data could be protected, and the risk of human error is reduced. Construction processes and operations depend on data and improve data exchange and protection could improve the overall construction process performance.

Blockchain is an emerging technology, and its effect on the architecture, engineering, construction, and operation (AECO) industry activities still not evaluated properly. The currently available studies aim to introduce the technology for the industry rather than develop a fully functional

solution(Darabseh & Martins, 2020). This is expected due to the cautious adoption approach embedded in the industry culture.

The study is an introductory level study that aims to increase awareness about Blockchain technology and its potential in the AECO industry-related applications. The variety in the field of application is an illustration of the potential of the technology. The studies presented show the Blockchain effect on improving BIM related activities which could expand BIM use further. In addition to that, Blockchain allows for trustless data exchange and order executions. The possibility of automating processes such as ownership transfer and licencing assets use as long as the official conditions were met which create automated Intellectual property for BIM and construction design assets.

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Developing a Construction Supply Chain System based on Lean Construction and Building Information Modelling supported Internet of Things standards

Mahmoud Karaz, José Manuel Cardoso Teixeira

Abstract

The construction supply chain is confronted with inefficient resource control and hindered by conventional approaches of production, which exacerbated the fragmented nature of information systems among various organisations. Thus, industry projects perform in siloes that hold vast disparities among production demand and supply; therefore, the current systems cause more wastes in production and environmental performances. Lean construction and Building Information Modelling (BIM) partially undertook that by collaborative platforms that control production on site. However, the construction still without a sufficient level of integration regarding logistics management. Therefore, this research aims to formulate CON4 system that combines information of logistics, production process and products, based on Lean-BIM and supported Internet of Things standards, to provide informed production decisions based on real-time information. CON4 could raise the situational awareness of on-site production, materials transportation, warehouse, and environmental impact.

Author Keywords. Production Theory, Construction Waste, Logistics Management, Connectivity

1. Introduction

Traditionally, construction supply chain (CSC) causes one-third of material waste across the globe and contributes to high percentages of greenhouse emissions (GHG), while construction logistics and transport are responsible for 32% of global energy-related CO2 emissions (Yuan and Shen, 2011; UN Environmental and International Energy Agency, 2017). Inefficiencies in CSC performance caused by three peculiarities of construction production inter alia: 1) converging supply, where all resources are directed, stored and assembled on the site; 2) temporary organisations, leads to unstable and fragmented supply information; 3) make-to-order (one-of-a-kind) projects that cause little standardisation in products and processes (Koskela, 1992; Vrijhoef and Koskela, 2000). A definite weakness with conventional management approaches, however, they cannot address the abovementioned characteristics of CSC; moreover, with firefighting approaches, they operate to consume or store more resources to mitigate risks and absorb uncertainties and variability. To this end, the traditional construction management fails to translate production and waste elimination concepts into theoretical instances, and its' practices lead to harmful ecological footprint, social conflicts, and negative economic impacts (Nahmens and Ikuma, 2012).

Instead, the theory of Transformation Flow Value (TFV) was established to diffuse lean principles into the construction industry, that deals with construction-context, based different problem solving and knowledge management instruments (Koskela, 2000; Dave et al., 2013). This philosophy believes that waste issues can be tackled by collaboration among various stakeholders. In the same vein, lean construction paves the theoretical foundation for information technology and systems extensions, and its' development was interdependent with the growth of Building Information Modelling (BIM), they generally, interact positively to provide integrated information on the process, logistic, and product (Sacks et al., 2010). The integration of Lean principles and BIM functionalities was realised by combining Lean socio-technical systems such as the Last Planner System (LPS) into BIM 4D planning (Sacks, Radosavljevic and Barak, 2010; Dave, 2013). Production control systems such as KanBIM and VisiLean, have addressed the fragmented nature of construction information systems, namely, between site production, design, and planning decision-makers (Sacks, Radosavljevic and Barak, 2010; Dave, 2013).

However, the active monitoring for the status of resources from CSC is not available in real-time, more research is required to support Just-In-Time delivery, that pull detailing and fabrication/assembly information that matches short term planning (Dave and Sacks, 2020). Moreover, although the current contributions in integrating BIM, GIS, and inventory information systems into cloud-based solutions to support CSC (Irizarry, Karan and Jalaei, 2013; Pérez, Fernandes and Costa, 2016; Chen and Nguyen, 2019; Deng et al., 2019), the research still in infancy level, because it separated between Lean-BIM integrations from Transportation Management Systems (TMS) and Warehouse Management Systems (WMS). Thus, without holistic approaches to managing construction products logistics, production, and environmental wastes will be inevitable. The central purpose of this research is to formulate a CSC information system based on lean principles and BIM functionalities with support of IoT standards. The foremost objective is to improve stakeholder's situational awareness, by helping them to query, import and export supply chain information seamlessly. The proposed system is called CON4 that responds to the fragmented nature of construction information systems regarding products and processes. CON4 could assist clients, contractors, suppliers, designers, transporters, subcontractors, recyclers, salvagers, and landfills authorities in establishing evidence-based decisions to reduce production, environmental, social, and economic waste. The following objectives should be addressed to describe and provide CON4 system:

- To connect the last mile among the supply chain, logistics, designers, and production site. The use of Kanban cards and Andon signals are useful to pull the required information about detailing of prefabrication/assembly from site to suppliers and vice versa (Dave and Sacks, 2020). The output of the last planner system (LPS) will be the input into the CSCM system since LPS contains constraint analysis, where the workforce defines the required resources to perform a task for specific trade on specific locations at a determined period (Ballard, 2000).
- To harmonise between Warehouse requirements and Transportation supply, by optimising reception conditions through site layout planning (LSP) and measuring the capacity of inventory on a real-time basis. This step is necessary to avoid site congestion, starvation/overstock, and interruption with typical workflow (Huang et al., 2007). SLP with the assist of 4D planning is a powerful technique to succeed Just in time (Innella, Arashpour and Bai, 2019) and using connected or wireless devices can improve IoT opportunities (Dave et al., 2016).
- To address shipment scheduling and route planning using the integrations between 4D planning and map web service application [14], to monitor levels of GHG emission and offer reverse.

2. Discussion

The construction supply chain is hindered by the fragmented information systems, which are not designed for the construction context. Although the growing advancements in lean and BIM integrations into construction artefacts, the research still focusing on production control systems, rather than holistic designs leverage logistics, product, and process integration. It is envisaged that CON4 could melt the boundaries between various parties across the construction supply chain (CSC). By incorporating the information between the Transportation system, Warehouse system, production planning and control system such as LPS, and BIM for product and process design. It is planned to develop CON4, to address behavioural and technological challenges in the industry, as well as, it is envisaged to raise the situational awareness not only about logistics and production

but also embrace the environmental protection strategies such as reduction of GHG and material waste, through imposing less transportation and reverse logistics. The limitation of this research, the lack of real-world verification for the proposed information, however, based on design science research (DSR) methodology, this study is in the conceptual stage of development of artefact that resolves business problems and aligns with business strategies.

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Framework for the semantic enrichment of BIM models through a natural user interface

Fábio Matoseiro Dinis[1], João Poças Martins[2], Bárbara Rangel[3], Ana Sofia Guimarães[4]

[1] CONSTRUCT - GEQUALTEC, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal, fabiodinis@fe.up.pt
[2] CONSTRUCT - GEQUALTEC, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal
[3] CONSTRUCT - GEQUALTEC, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal
[4] CONSTRUCT - LFC, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal

Abstract

The full-fledged uptake of Building Information Modelling (BIM) methodology is not yet acknowledged by all the actors involved in a construction project. In fact, due to the extensive variability of expertise among the various actors of the construction sector, not all have the necessary skills to interact with BIM models holding information. Conversely, Natural User Interfaces allow for streamlining the interaction process with digital tools so that, in a more democratic and inclusive way, the empirical knowledge of many actors in the construction sector can be capitalised.

This paper presents the work in progress of a framework based on a set of BIM information filtering mechanisms and interaction metaphors to streamline the information management process of enriching BIM models with an unsatisfactory Level of Information (LOI). Moreover, the semantic enrichment process focuses on Virtual and Augmented Reality interfaces and will be further validated using a holistic usability assessment methodology.

Author Keywords. Building construction, Building Information Modelling, Semantic Enrichment, Natural User Interfaces, Virtual Reality, Augmented Reality.

1. Introduction

The Architecture, Engineering, Construction, and Operations (AECO) sector is recognised as a multidisciplinary field where several stakeholders are actively involved in the project development (Liu, van Nederveen, and Hertogh 2017). Whilst the design and subsequent realisation of a building rely on constant critical input from various disciplines resulting in a network of decisions supported by information (Bachman 2003), the diversity of today's demands relies on a series of most often not communicating systems. Additionally, the multidisciplinary and scattered nature of the sector and its projects (Liu, van Nederveen, and Hertogh 2017) provides added complexity to the interaction between information maintenance systems. In particular, the implementation of BIM as a paradigm shift for the industry (Succar 2009) entails inevitable clashes with more traditional and sectorial-embedded approaches. Trade crews and many industry stakeholders still lack the knowledge to take full advantage of BIM potential in the operations phase (Kerosuo et al. 2015) or during real-time communication amongst project teams (Bassanino, Fernando, and Wu 2014). Therefore, well trained AECO professionals are necessary to take advantage of the full potential of BIM processes, although these usually assume a rather narrow position among the actors involved in a construction project.

Given the need for more adaptative and supportive technological developments to afford BIM-based collaboration between stakeholders (Kerosuo et al. 2015), the present study describes the work in progress of developing Virtual and Augmented Reality interfaces to provide semantic enrichment of BIM models. In detail, a framework is described to allow adding semantics to BIM models holding an unsatisfactory Level of Information (LOI) based on a set of information filtering mechanisms and interaction metaphors.

2. Materials and Methods

The proposed workflow comprises three main components and established on a set of gesture or voice filtering mechanisms provided by Virtual Reality (VR) and Augmented Reality (AR) BIM-based interfaces. In particular, the system is composed by:

i) A BIM authoring tool – support modelling-related tasks;
ii) A custom widget – convert an Industry Foundation Classes (IFC) file to JSON format;
iii) A game engine – develop the virtual environment and provide interactions with the BIM model holding information.

In particular, a BIM authoring tool (Autodesk Revit 2021) was used to develop the BIM model, while the resulting files were exported in IFC format (IFC 2x3 Coordination View). Additionally, the Unity game engine was used to develop the virtual and augmented environments, given its cross-platform compatibility. The HTC VIVE Head-mounted Display (HMD) and HoloLens 2 were used to interact with the VR and AR scenes, respectively.

The complete framework and its phases are depicted in Figure 12.

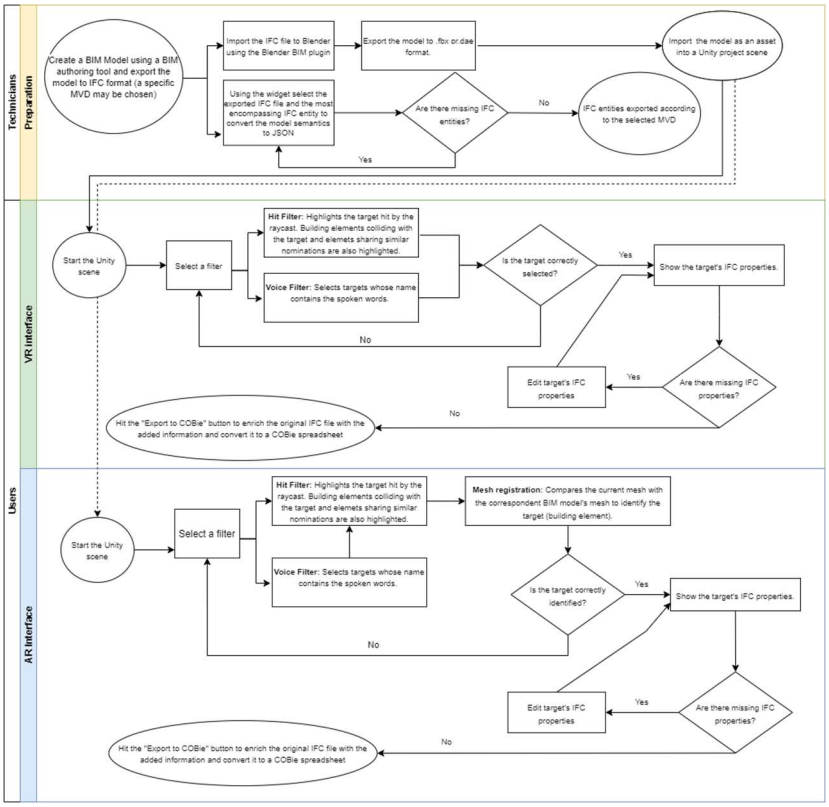

Figure 12: Proposed framework.

3. Discussion and Conclusion

BIM authoring tools comprise a set of systems designed to handle specific tasks, usually holding many features and not meant for short-term and momentary usage. Indeed, a higher cognitive load is patent in some BIM tools, making them unsuitable to be used by the variety of stakeholders involved in construction project teams. As such, the proposed framework aims to improve access to construction information through BIM-based immersive interfaces, adapted to the various skills, backgrounds and needs of AECO actors.

Concerning the assessment of VR and AR interfaces developed according to the proposed framework, an initial stage may comprise preliminary pilot tests. These tests should be performed as a cautionary and best practice to foil possible inconsistencies and work on unnoticed or misplaced assumptions about task design or procedures (Jakob Nielsen 1993). Afterwards, a summative evaluation is suggested as the second assessment stage. This stage requires considerations on the weight of previously chosen usability attributes (e.g., Efficiency, Effectiveness, Satisfaction, among others) and the definition of usability goal lines (Jakob Nielsen 1993).

The proposed framework is in line with current research describing that BIM should be adapted and supported by other technologies to increase its acceptability by different users (Liu, van Nederveen, and Hertogh 2017; Kerosuo et al. 2015). Furthermore, the present study intends to support the development of a set of technologies that may improve access to BIM information by a broader range of AECO actors, even those without previous BIM experience.

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Towards a Quantitative Approach to Morphological Regions in GIS

Mariana Pizzo Diniz[1], Miguel Serra[1]

[1] CITTA – Research Centre for Transports, Territory and Environment, Faculty of Engineering of the University of Porto – up201911789@edu.fe.up.pt, mserra@fe.up.pt

Abstract

The concept of Morphological Regions and the method of Morphological Regionalisation stand out as very important contributions to the study of the historico-geographical structure of the urban landscape. Central to this method, is the understanding of the way in which urban landscapes are structured: the existence of unitary areas which comprise an individualized combination of the three basic form complexes, delimited by their degree of internal morphological similarity. However, from a methodological point of view, the identification of such areas (or morphological regions) remains based on qualitative visual analysis and on the personal expertise of the analyst. We propose to address the method of morphological regionalisation from a quantitative perspective, based on typological descriptions of urban form components derived by algorithmic means.

Author Keywords. morphological regionalisation; classification; typomorphology; GIS.

1. Introduction

The urban landscape is the result of a cumulative, historical stratification process, in which urban entities acquire formal and physical aspects that reflect the cultural and social functioning codes of the precedent periods in the city's formative process. Within the classic studies of the Conzenian School of Urban Morphology, the concept of Morphological Regions and the method of Morphological Regionalisation, stand out as very important contributions to the study of the historico-geographical structure of the urban landscape (M. R. G. Conzen 1960; 1988; 1975). Central to that method, is the understanding of the way in which urban landscapes are structured: the existence of unitary areas which comprise an individualized combination of the three basic form complexes – namely the town plan, the building fabric and the land and building utilization (J. W.R. Whitehand 2009; Jeremy W.R. Whitehand et al. 2011; J. W.R. Whitehand and Gu 2010).

The method of a morphological regionalisation is the most integrative approach in the conzenian repertoire (M. R. G. Conzen 1960; 1975; 1988; 2004). Because rather than emphasizing a particular element of the urban landscape, the emphasis is on the integration of landscape elements and how they constitute a pattern rather than the bits and pieces of individuals sites and buildings: it is a matter of ensembles. Therefore, the method of morphological regionalisation articulates an analytical approach to investigate how urban landscapes have developed historically and doing this in a manner that its informative basis can be incorporated into the various processes of decision-making about urban conservation, planning and designing activities (Larkham and Morton 2011; Oliveira and Yaygin 2020; J. W.R. Whitehand 2009; Kropf 2012).

The traditional method of morphological regionalisation developed in Conzen's classical theory, is, in its essence, a method that classifies urban form components according to their typomorphologies. The paper identifies and addresses this underlying premise of the method of regionalisation, arguing that its qualitative procedures can be translated into quantitative and objective parameters, through multi-variable geometric descriptions of urban form in GIS and through statistical clustering techniques (Serra, Gil, and Pinho 2017; Gil et al. 2012; Larkham 2019;

Berghauser Pont et al. 2019; Jacob Dibble et al. 2015; J. Dibble et al. 2019). We attempt to contribute to the construction of a more robust method of morphological regionalisation, supported by a systematic and quantitative approach, applicable to large-scale comparative analysis of contemporary urban forms, which often elude previous historical typologies.

2. Revising Morphological Regions

The literature review presented in this paper aims to revise the key works within the framework of morphological regions, in order to identify and interpret the fundamental premises of the method of morphological regionalisation (M. R. G. Conzen 1960; 1975; 1988; 2004; Bienstman 2007; Barret 1996; J. W.R. Whitehand 2009; Gu 2019; 2018; Oliveira and Yaygin 2020). The identification of such premises is instrumental to the objective of operationalizing the method. There have been several applications of the method of morphological regionalisation within the classic framework proposed by Conzen, however, the challenges in the selection of these methodological steps are that such procedures are not often explicitly demonstrated (e.g. well-defined instructions).

At the end of this revision process, we comprehend that the recognition of the distinct morphological patterns, specifically the structural *types* of the urban landscape, is the core premise of the method of morphological regionalisation. Once these types are identified, they can be logically classified according to their morphological similarity (or homogeneity), which is the hierarchical representation in plan units and building fabric units. In turn, this hierarchical classification of unit's types is then merged into a composite of regions, where the types of plan units represent higher ranks, while building fabric and land use types comprise the lower ranks. Stemming from this premise, we propose that the structural typomorphologies of the urban landscape can be described by quantitative means and classified according to quantitatively defined morphological parameters.

3. Discussion

Within this theoretical framework, the quantitative descriptions of urban form based on types and classification methods derived by algorithmic means, are central to our approach. The traditional method of regionalisation was carried out on the basis of cognitively recognizing the morphological characteristics (e.g. morphological types) of the from complexes, and classifying them according to a given set of attributes (e.g. age or period of origin, original function, metamorphosis process in time, *inter alia*). In the sequence, these patterns would be visually assembled and ranked according to the degree of morphological similitude within the three form complexes. Therefore, the concept and the method of morphological regionalisation is much of a problem of pattern recognition, in this case of morphological types and their clustering. Cities demonstrate an inherent complexity of urban patterns, which is almost impossible to be structurally grasped and analysed by manual means. The use of available vector datasets of street networks, plot systems and building footprints, supports the analysis of their morphological information through geocomputation and subjecting it to unsupervised/supervised classification algorithms. This algorithmic approach produces consistent and quantitatively defined morphological classifications, which are automatically derived only from the morphological data, providing objective criteria for accurately describing similarities and differences in local urban morphologies.

The acknowledgment of the relevance of clustering techniques to urban morphological research is quite recent, but of growing interest among researchers. The use of such techniques allows the analysis of the complex urban environment from different angles simultaneously, categorizing and

summarizing the relationships between its components without losing grasp of the big picture. In recent urban studies, more specifically the ones of morphological scope, we find reviews of the application of data-clustering techniques within a typomorphological approach, ranging from the unsupervised definition of local typologies at the neighborhood level to the city scale, and even at the worldwide level of analysis (Berghauser Pont et al. 2019; Bobkova 2019; Boeing 2019; Colaninno, Cladera, and Pfeffer 2011; Jacob Dibble et al. 2015; Dong, Li, and Han 2017; Gil et al. 2012; Quan 2020; Serra, Gil, and Pinho 2017; Song, Zhang, and Han 2021).

4. Conclusions

This paper stablishes the initial steps regarding the operationalization of the method of Morphological Regionalization. We therefore expect that the quantification of Morphological Regions will allow for a faster and sounder understanding of urban areas, through the recognition of specific morphological patterns, resulting in descriptions, but perhaps also in prescriptions, of such patterns. Similarly, in planning practice planners would be provided with further understanding about the morphogenetic process in cities: how socio-economic, political and even individual forces intersects the diverse and complex spatial configuration of contemporary urban forms. Within the recurrent debates about fine-grained adaptive/resilient spatial structures and prosperity, safety and social cohesion, there is no doubt that adaptability and resilience are spatial preconditions for the continued evolution of urban systems. Nevertheless, this adaptive urban process must be systematically addressed if we are to align economic growth with social equity. In view of such, a rigorous approach towards an evolutionary analysis of urban form now, more than ever, is relevant in interpreting its future trajectories (Batty 2010; Jacob Dibble et al. 2015).

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Reflection on the feasibility and location of an airport infrastructure in the Central Region of Portugal

João Pedro Martins[1], Álvaro Costa[1], Paulo Soares[2]

[1] CITTA – Research Centre for Transports, Territory and Environment, Faculty of Engineering of the University of Porto – up201306383@edu.fe.up.pt, afcosta@fe.up.pt
[2] Viseu Municipal Aerodrome Director – ps.airlaw@gmail.com

Abstract

The idea of an airport in the Central Region of Portugal is defended by mayors, local industry leaders, residents and as well as emigrants from this region. This purpose is based on the fact that this region is highly industrialized and densely-populated and the region's potential as a travel destination. Due to the impacts that an airport has on the territory and on the transport system, it requires careful planning, especially spatial planning, and economic-financial planning. Therefore, in the context of this problem, it was sought to analyse the feasibility of this airport infrastructure, as well as the possible locations to host it. The existing airfields were characterized and the possibility of expanding their runways was analysed, as well as the existence of space for the construction of all the infrastructures necessary for the service that a modern airport requires. In the case of air bases, their strategic-military context was also analysed. With the aerodromes that best fit these criteria, considering the location of Fátima, a comparison was made between the different locations through an analysis of the transport system and accessibility. After this study, the results show that the creation of an aerodrome/airport in this region is feasible, from all points of view, allowing us to suggest the best location.

Author Keywords. Feasibility, Airport location, Airport infrastructure, Central Region of Portugal, Spatial Planning.

1. Introduction

The Central Region of Portugal is the only Portuguese region that does not have an airport to directly serve. Various agents of society (such as politicians, inhabitants and local industry leaders) affirm the need to build an airport in this region to boost tourism, serving the community of emigrants and the Portuguese descendants, and also allowing companies to expand their business to other markets (Martins, 2018). Alongside this discussion, there is also a debate around location, with several suggestions.

Thus, it is necessary to carry out a two-part study on this topic. First, the feasibility of an airport in this region must be evaluated, taking into account different factors: (1) the proximity of possible locations and urban agglomerations to Francisco Sá Carneiro and Humberto Delgado Airports; (2) population; (3) the concentration of economic activities; and (4) accessibilities. In the second part of the study, it is necessary to determine the best location.

2. Materials and Methods

Based on the existing infrastructures in the Central Region of Portugal, several characteristics were analysed, including: potential runway expansion – a less costly option for the State, the airport concession contract to ANA – Aeroportos de Portugal, S.A., statistical data on population, economic activity – including data on tourism and higher education – were collected. Data regarding climate

and meteorology was collected through information by Portuguese Institute of the Sea and the Atmosphere (IPMA). The orientation of prevailing winds was collected through the online platform windfinder. The data for the city of Fátima are from the Meteorological Station of Santarém. To calculate the radius of influence, the distance from the locations to the points that are 60 and 90 minutes on Google Maps was considered, obtaining the distance-time relationship. This allowed us to analyse the number of inhabitants that are within the radius of influence of each location. The methodology adopted to compare the locations of Ota and Campo de Tiro de Alcochete by the National Laboratory of Civil Engineering (LNEC, 2008) was adapted, as well as some of the points that Ferreira (2013) suggested, in order to make the comparative analysis between the three locations considered. Thus, the same critical decision factors were considered to assess the three locations such as: safety and operational conditions, sustainability of natural resources and risks, nature conservation and biodiversity, spatial planning, competitiveness and economic development, and financing and financial sustainability – table 1.

Critical decision factors	Objectives
Safety and operational conditions	Meteorological and climatic conditions (air temperature mean, precipitation and prevailing winds) and obstacles to navigation.
Sustainability of natural resources and risks	Hydrology, noise and risk of collision with birds.
Nature conservation and biodiversity	The ecological value of the territory and degree of affectation of natural areas in the surroundings (protected areas and habitats).
Spatial planning	Urban dynamics and the conditions present in the Municipal Master Plans.
Competitiveness and economic development	Impact on the regional economy (tourist opportunities for the region, economic growth and employment).
Financing and financial sustainability	Costs, financing and financial sustainability of the infrastructure.

Table 3: Critical decision factors and study objectives (adapted from LNEC (2008) and Ferreira (2013))

3. Discussion

According to the VFR Manual there are 7 aerodromes (Coimbra, Viseu, Santa Cruz, Castelo Branco, Lousã, Proença-a-Nova and Leiria), 2 air bases (Monte Real and Ota), 1 military aerodrome (Ovar) and 1 military infrastructure (Tancos) – Figure 1.

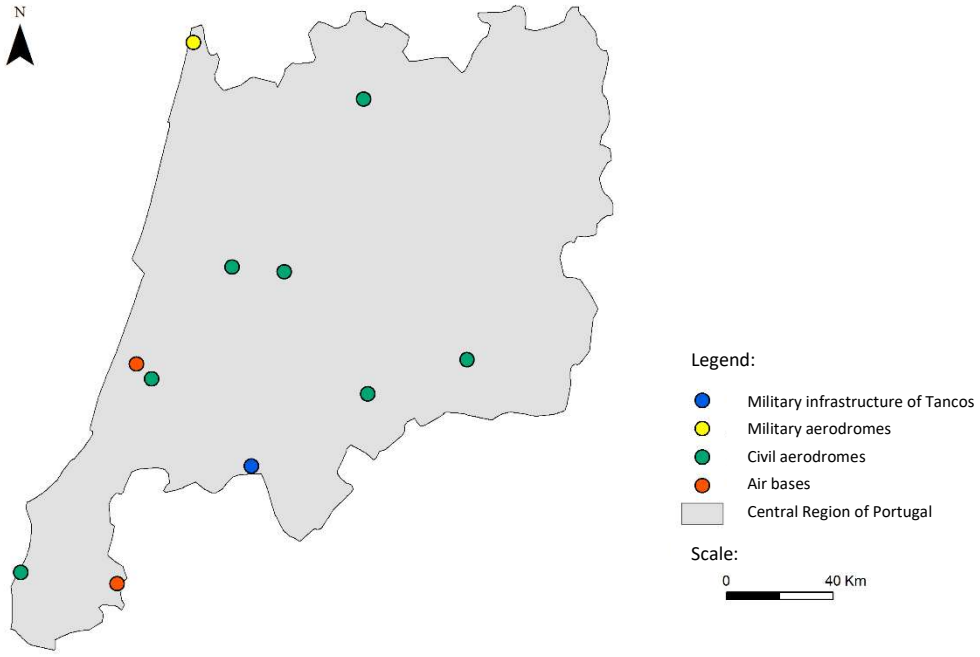

Figure 13 - Existing infrastructures in the Central Region of Portugal (Source: Martins, 2018).

Given the territory and the Portuguese economic situation, we realize that there are no conditions for the construction of a new airport (Freitas, 2013). Nevertheless, the solution may involve an existing aerodrome that offers conditions for airport operation, minimizing cost. Martins (2018) identifies several factors associated with the territory (such as possible obstructions, relief, protected areas, watercourses, etc.); technical issues (maintenance and expansion of the current infrastructure); pre-existing conditions and external elements that condition the discussion and its possible location (legislation, regulations, land ownership, etc.). Addressing the possible locations, we should consult the airport concession contract to ANA – Aeroportos de Portugal, S.A. because this conditions the decision, making it impossible to develop an airport within a radius of 75 kilometres from existing airports. In this way, the Military Aerodrome of Ovar, Aerodrome of Santa Cruz and Military Base of Ota are discarded. Monte Real is an active and important base from a strategic-military standpoint, due to its role as a NATO military base, making its selection difficult. In addition, military aviation has priority, which constitutes a disadvantage in attracting the interest of airlines. The former Military Air Base No. 3 (Tancos) is a good option to host an airport, requiring only a few changes to receive commercial flights. However, Tancos is in service as the Army's Rapid Reaction Brigade and the Paratroopers Regiment. It is also seen as a probable location for the squadrons that are at Military Air Base No. 6 (Montijo). Most aerodromes do not have the option to expand their runways due to lack of space and the orography of their territories. There are still

some cases in which the expansion of the runway could be considered but the costs it would entail are not economically viable, as is the case with the Municipal Aerodrome Bissaya Barreto (Coimbra). Considering this analysis, there are two options of potential aerodrome locations – Viseu and Castelo Branco – and the runway in Fátima.

4. Conclusions

This aerodrome should not be seen as a competitor to the principal national airports, but rather as a complement. Thus, it would be able to receive flights from destinations where there is a large community of Portuguese emigrants and their descendants (for example, Switzerland, France, Germany and United Kingdom); cargo flights; the continuation of the existing regional route between Bragança and Portimão; and receive executive and private flights. In addition, the aerodrome must continue to support instructional flights and aviation schools located within aerodromes.

Therefore, what is at issue is not an International Airport, but a regional aerodrome that allows for quick movement, with shorter waiting times for passengers and airlines alike. On the other hand, it must also be an infrastructure that serves companies in the region, seeking to help the potential of their businesses on an Iberian and European scale. This infrastructure will contribute to the strengthening of territorial cohesion, increasing the competitiveness of the region and its socio-economic development. This paper does not intend to close the discussion around the three locations covered, but to contribute to the debate. It would be interesting to carry out studies based on the economic-financial and engineering points of view to complement the work presented.

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Transport infrastructure, accessibility and spillover effects: empirical analysis of the Portuguese real estate market in the period 2000-2018

João Fragoso Januário[1], Álvaro Costa[2], Carlos Oliveira Cruz[1], Joaquim Miranda Sarmento[3], Vítor Faria E Sousa[1]

[1] CERIS, Instituto Superior Técnico Universidade de Lisboa - joaodfjanuario@tecnico.ulisboa.pt, oliveira.cruz@tecnico.ulisboa.pt, vitor.sousa@tecnico.ulisboa.pt
[2] CITTA – Research Centre for Transports, Territory and Environment, Faculty of Engineering of the University of Porto – afcosta@fe.up.pt
[3] Advance/CSG, ISEG - Lisbon School of Economics and Management, Universidade de Lisboa - jsarmento@iseg.ulisboa.pt

Abstract

Modelling housing prices has long stood as a central research area within urban and regional economics. Several studies have accessibility has been one of the main factors affecting housing valuation (Bowes and Ihlanfeldt 2001; Shin et al. 2007; Martinez and Viegas 2009). This article describes the influence of transportation infrastructure on property valuations, using the mean value of real estate transactions within administrative regions NUTS-III in continental Portugal as a proxy for its valuation between 2000 and 2018, explicitly considering spillover effects from investing in infrastructure. We developed a cross-regressive spatial model with controlling for investment and infrastructure stock and accessibility. The results show evidence of spatial autocorrelation between real estate values, confirming that the positioning of each region is crucial for the development of the market. However, the results are not consistent across all 23 regions, showing positive and negative impacts of road infrastructure investment in real estate values.

Author Keywords. Real Estate, Transport, Accessibility, Investment, Hedonic models

1. Introduction

Real estate prices and valuation are critical in understanding existing urban and regional economics patterns and valuable to help forecast future real estate cycles with real impact in policymaking (Brooks and Tsolacos 2010).

This research falls within the existing literature of real estate prices modelling but expands the existing body of knowledge through two distinct innovations: i) first, it assumes no a priori assumption on which transport variables to use, and considers physical infrastructure stock (e.g. network km), simple accessibility metrics (e.g. travel time) and more complex accessibility indicators (.e. weighted road accessibility indexes); ii) second, it considers potential spillover effects of improved infrastructure/accessibility to neighbouring regions.

This article aims to understand how these investments in transportation infrastructure impacted property valuations across the country, drilling down to the spillover effects of investment in each of the mentioned regions. Therefore, this article contributes to a better understanding of the relationship between our transportation system and real estate across Portugal.

2. Materials and Methods

2.1. Development of a cross regression model

The development of the cross-regressive model was done through five distinct steps:

a) Select independent variables
b) Test for unit roots
c) Test for Granger Causality
d) Test for Engle-Granger Cointegration
e) Analyze spillover effects

In order to access spillover effects in our regions, we've developed a cross-regressive model. Since our analysis will be focused on exogenous regressors, we can base our estimation using Ordinary Least Squares (Le Gallo 2014; Bazzi, et al. 2017). The model is built under higher-order differences (Δ) for all variables, and it is defined as (1):

$$y_{it} = \theta_0 + z'_{i,t-l}\theta_{z'} + \bar{y}_{(i),t-l}\theta_1 + \bar{z}_{(i),t-l}\theta_{\bar{z}} + \varepsilon_{it} \quad (1)$$

Where:

- $\boldsymbol{y_{it}}$ is *n x 1* vector of the mean value of real estate transactions (*valor_med_compra_tot*) of region *i* at year *t,* functioning as our dependent variable, with *n* being the number of years in our time series analysis;
- $\boldsymbol{z'_{i,t-l}}$ is the *n x 1* self-transport variable of region *i* at time $t - l$, with l being the time lag that minimizes AIC for a given i;
- $\boldsymbol{\theta_{z'}}$ is the coefficient for the transport variable at region *i*, and should translate the effects on productivity of increasing variable *z'* in region *i*;
- $\boldsymbol{\bar{y}_{(i),t-l}}$ is the *n x 1* spatially weighted averaged mean value of real estate transactions in neighbouring regions at time $t - l$. It results from multiplying a spatial proximity matrix (*j x j)* by the value of the mean value of real estate transactions of each neighbouring region, with j being the total number of regions under analysis. In order to obtain the average weighted value of the variable, in the shape of a *n x 1* vector, we multiply the multiply the row of the spatial weighted matrix corresponding to region *i* by the value of the variable in each region *j* at a given year *t*. By doing this multiplication, we obtain one value of the final vector to be used in the regression. Since the time distance between regions is not constant between years, we update it for every new year calculated for vector *n x 1*. The proximity matrix accounts only for direct neighbours (*Queen* contiguity matrix) of region *i.* The proximity is then calculated by inverting the square of the distance between the two regions ($\frac{\mathbf{1}}{\boldsymbol{d_{ij}^2}}$) , and it is then row normalized so that the sum of each row is equal to 1. This way, we can weigh the influence of each neighbouring region *j* on region *i* based on its distance for that given year *t*. The diagonal of this matrix is null, so that self-effects within region *i* are not accounted for. Simply put, each element of vector *n x 1* is the result of

multiplying row *i*, which means multiplying a vector *1 x j* by the corresponding values of mean value of real estate transactions for a given year, contained in a *j x 1* vector;

- $\boldsymbol{\theta_1}$ is the coefficient which should translate how the mean value of real estate transactions in region *i* is affected by the mean value of real estate transactions in neighbouring regions;
- $\overline{\boldsymbol{z}}_{(i),t-l}$ is the *n x 1* weighted average transport variable value in the neighbouring regions, and it is calculated similarly to $\overline{\boldsymbol{y}}_{(i),t-l}$.
- $\boldsymbol{\theta}_{\overline{\boldsymbol{z}}}$ is the coefficient which should translate how the mean value of real estate transactions in region *i* is affected by the transport variable in neighbouring regions.
- $\boldsymbol{\theta_0}$ is a constant term and represents the change in y_{it} when there is no change in the explanatory variables (*optional*);
- $\boldsymbol{\varepsilon}$ is the error term;

2.2. Data

The first step was to select the independent variables to be used in the model, from a dataset assembled containing 35 variables measuring transportation and accessibility in infrastructure. Table 4 and Table 5 describe the data used after an initial selection.

Variable	Description	Unit
acess_viaria	Road accessibility	index
sinuosidade	Sinuosity / Winding road index	index
vel_reta	Straight Equivalent Speed	km/h
ext_ferr_merc	Freight railroad extension	km
ext_ferr_pass	Passenger railroad extension	km
ext_rod_tot	Total road extension	km
ext_rod_ip	Principal roads extension	km
ext_rod_ic	Complementary roads extension	km

Table 4 - Independent variable description

variable	count	mean	std	min	25%	50%	75%	max	source
ext_rod_ip	437.00	92.93	47.38	0.28	57.05	83.13	124.18	201.07	FFMS[1]
ext_rod_tot	437.00	1715.96	590.22	924.09	1199.66	1564.80	2039.92	3256.30	FFMS
vel_reta	391.00	74.43	5.82	59.69	70.36	75.98	79.24	83.50	FFMS
ext_rod_ic	369.00	70.74	57.76	1.10	25.20	57.94	99.87	253.72	FFMS
ext_ferr_pass	418.00	114.46	66.91	13.58	65.11	107.14	141.93	314.64	FFMS
acess_viaria	391.00	80.12	29.91	35.85	55.58	76.70	99.63	160.74	FFMS
ext_ferr_merc	409.00	120.15	60.47	14.80	67.96	110.69	163.34	267.09	FFMS
sinuosidade	391.00	73.29	3.71	61.38	70.90	74.36	76.24	81.18	FFMS

Table 5 - Summary Statistics

3. Discussion

The results obtained are not entirely consistent. After testing for unit roots, Granger-causality and Engle-Granger cointegration, we came to conclude that only the regions of Alto Minho, Algarve, Região de Aveiro, Região de Coimbra, Médio Tejo, LMA, Alentejo Litoral and Alentejo Central would meet the criteria to produce meaningful results, tough the results are inconsistent. In regard to self-transport, Região de Aveiro shows negative spillovers. Real estate values in the regions of Médio Tejo and LMA, as well as Algarve, present negative spillover effects on spatial housing. This can be a signal of a "*reverse interaction*" between these regions and its neighbours. We would expect for

[1] Fundação Francisco Manuel dos Santos (FFMS)

the regions of LMA and Algarve to have increase in value before their neighbours since these regions have two of the highest mean value of real estate transactions. In the remaining regions under analysis there is evidence of a positive spillover effect from neighbouring real estate values, especially in the regions of Alentejo Central (0,632%), Coimbra (0,907%) and Aveiro (0,616%).

In regard to the spatial spillover effects from road infrastructure investment in neighbouring regions, Aveiro shows a proven positive spillover effect of 9,026%, benefiting from the investment made in road infrastructure in the regions of PMA, Região de Coimbra and Viseu Dão-Lafões; Médio Tejo also shows to largely benefit (5,383%) from the investment in the regions of Alto Alentejo, Beira-Baixa, Região de Coimbra, Região de Leiria and Lezíria do Tejo due to improved accessibility to Lisbon.

4. Conclusions

Our research suggests there is evidence of spatial autocorrelation in the mean value of real estate transactions. As one would expect, the location of a region in the Portuguese territory is crucial for the development of its real estate market. The research also suggests evidence there seems to be a division between the development of the southernmost coastal region of the country which contrasts with the northernmost interior part of the country. The first shows a positive trend in its real estate market which appears to have been magnified by the investment in road infrastructure. Hence, the model shows a positive effects on investing in road infrastructure, especially in the regions of Alentejo Central and Alentejo Litoral. Despite the large investment in the first decade of this century in road infrastructure, the northernmost interior region – especially Terras de Trás-os-Montes, Douro, Beira-Baixa and Beiras e Serra da Estrela - doesn't show the same level of development and thus the same level of impact concerning real estate values.

Overall, the results obtained were not consistent across all 23 statistical regions. This may be a consequence of the heterogeneity of the real estate market, given the hedonic characteristics of each property, which was not taken into account. Also, given the scale of the analysis, the effects of heterogeneity may be more prominent than they would be in a smaller scale with higher detail as, for instance, across a Metropolitan Area. Also, the limitations of data to administrative regions may not correspond to well to socio-economic patterns captured by real estate prices (Bohman and Nilsson 2016).

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Seismic Risk and House Prices: cross-section modelling of Lisbon's real estate market

João Fragoso Januário[1]

[1] CERIS, Instituto Superior Técnico Universidade de Lisboa
joaodfjanuario@tecnico.ulisboa.pt

Abstract

House prices are a function of several internal and external factors to the property, usually reflected in hedonic pricing models. Traditional economic modelling assumes a rational decision-making process of homebuyers, and thus the perception of risk should also be reflected in property prices. Several authors have analyzed the relationship between natural hazard risk and housing prices and found evidence of changing market dynamics, especially after hazardous events (Palm 1981; Asgary 1997; Fekrazad 2019). However, market responses seem to vary across cultural, geographical and socio-economic contexts. The southern part of continental Portugal is considered to be of moderate seismicity due to its proximity to the Azores-Gibraltar fault, having registered two significant earthquakes in 1531 and 1755 (Borges et al. 2000). This paper assesses the relationship between seismic risk and housing prices in the city of Lisbon, developing a cross-sectional spatial regression model, using spatially lagged exogenous regressors, over a sample of 4248 property sales between 2008 and 2018, using yearly-standardized sales prices. The results show no clear preference for lower seismic risk zones. Homebuyers appear to be oblivious to the seismic risk, which may lead to an increased number of lives at risk as well as significant economic losses. This may result from unawareness of seismic risk or biased perceived susceptibility due to no experience of a recent event (Dooley 1992; McGinnis 2004), which is especially concerning given that half the stock in Lisbon is composed of unreinforced masonry buildings built before any seismic code provision (Simões 2014). These findings provide evidence of the need for urban development policies to raise awareness of the seismic risks and prompt private action to reinforce the existing building stock.

Author Keywords. Real Estate, Seismic Risk, Policymaking, Urban development, Spatial Regression

1. Introduction

Real estate property can be assessed as an heterogenous good, composed by a set of both internal and external characteristic that are valued by the market resulting. This valuation has been derived through implicit prices obtained by regressing the price of the property from its characteristics in what is called in the literature as a hedonic model (Rosen 1974). It is well known that households value location as one of the most important features when buying a house. However, some locations are more prone to be affected by natural hazards such earthquakes (Plafker 1989; McGinnis 2004), floods (Bin and Polasky 2004; Zhang et al 2009) and wildfires (McCoy and Walsh 2014). A rational market would be expected to account for a higher degree of risk in a property's value, translating in a price discount.

2. Materials and Methods

This paper analyzes the implicit pricing of seismic risk through a spatial regression on a sample of 4248 property sales between 2008 and 2018. We assess the relationship between seismic risk and housing prices in the city of Lisbon, by a cross-sectional spatial regression model, using spatially lagged exogenous regressors (Le Gallo 2014).

3. Discussion

Table 6 shows the variables selected for our model, containing a brief description, mean value, standard deviation, range and quartiles. We have normalized the selling prices in the dataset on a yearly basis. This allowed to build a model across different years, without compromising for market trends, controlling for the natural price inflation along the considered timeframe.

Variable	Description	mean	std	min	0.250	0.500	0.750	max
NORMALIZED	Normalized prices	0.991	0.564	0.000	0.620	0.887	1.226	6.001
CONSTRUCTI	Construction Year	1966	28	1550	1951	1959	1989	2018
FLOOR	Building floor	3	2	0	1	2	4	20
AREA	Useful Area	101.652	65.992	10.000	62.000	86.060	123.500	2355.000
LONGITUDE	Longitude	-9.155	0.025	-9.228	-9.170	-9.151	-9.137	-9.100
LATITUDE	Latitude	38.729	0.021	38.694	38.711	38.724	38.744	38.793
VULSismo	Seismic Vulnerability	2.270	0.886	1.000	2.000	2.000	3.000	4.000
HIGH_SEISMIC_RISK	High Seismic Risk	0.355	0.479	0.000	0.000	0.000	1.000	1.000
numberOfRooms	Number of Rooms	2.745	1.784	0.000	2.000	2.000	4.000	15.000

Table 6 – Dependent (Normalized) and independent variables

It is noteworthy that the seismic vulnerability considered in this data only relates to the soil component, with no regard for the structural properties of the building. However, we have considered the construction year. A more recent year should not only be associated with higher levels of comfort (e.g. thermal, acoustic) but also with a better seismic resistance. Note that the 1959 is the median construction year in our sample, giving a rough division between recent RC building and older building typologies[2].

The soil seismic vulnerability has been originally divided in 4 categories[3] of soil resistance:

(1) High - Consolidated Clay Formations, Low Resistance Rocks / Hard Coherent Soils, Soft Rocks

(2) Moderate - Predominantly Consolidated Sandy Formations / Compact Incoherent Soils

(3) Low – Muddy, Sandy and Clayey Alluvial Formations

[2] *source*: LNEC

[3] As per original dataset provided by the Lisbon Municipality

In order to transform this ordinal variable into a binary variable, for simplicity of interpretation of the regression results, we have transformed this scale into: (1) High and Very High resistance; (2) Low and Moderate resistance soil.

Figure 14 shows the spatial dispersion of high-risk soils by property. We can see some of the high-risk soils are located among some of the most noble and expensive city areas such as the downtown area and Avenida da Liberdade.

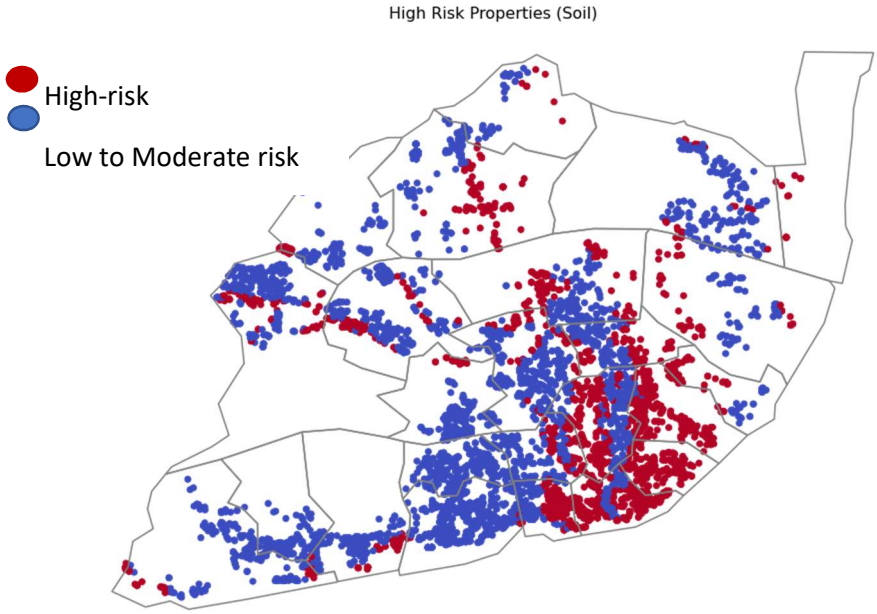

Figure 14 - Seismic resistance by property (soil).

In order to confirm these results, we have developed a OLS estimation spatial lag model as follows:

$$P_i = \alpha + \beta X_i + \delta \sum_j w_{ij} X_i' + \epsilon_i \quad (1)$$

Where P_i is the yearly-normalized selling price, α is a constant, X_i are the property's features, β is a coefficient, X_i' is a subset of X_i to be spatially lagged, w_{ij} is a row-standardized spatial matrix, δ is the spatial autoregressive parameter that indicates the strength of interactions existing between the observations of X_i' and ϵ_i is the error component. Note that $\sum_j w_{ij} X_i'$ captures the average value of feature X_i' surrounding each observation. We have also built a non-spatial regression model for comparison, by removing the spatial component on Equation (1). The results were as follows (Table 7):

Variable	Baseline Regression	Spatial Regression
Constant	-5.906 (0.652)	-5.816*** (0.653)
CONSTRUCTI	0.003 (0.000)	0.003*** (0.000)
FLOOR	0.004 (0.003)	0.004 (0.003)
AREA	0.001 (0.000)	0.001*** (0.000)
HIGH_SEISMIC_RISK	0.012 (0.015)	0.077** (0.036)
numberOfRooms	-0.012 (0.005)	-0.011** (0.005)
W_HIGH_SEISMIC_RISK	---	-0.074** (0.037)
R-Squared	0.042	0.043
F-Statistic	37.550	31.980
AIC	5325.764	5323.760

*Table 7 - Regression results*1

All signs are according to the expected: newer buildings, larger areas are usually more expensive; higher floor are also more demanded due to a better view, less noise and fresher air than lower-floor units (Benson et. al. 1998; Chau, Wong and Yiu 2004). On the baseline regression, despite the positive sign on the *HIGH_SEISMIC_RISK* variable, we found its coefficient to be of no statistical significance. On the spatial regression, despite having a p-value of 3%, the spatial lag component shows a similar coefficient and opposite sign, effectively cancelling out the seismic component.

Based on these findings, we may conclude that households are oblivious to (soil) seismic risk. This is consistent with previous findings that individuals' perceived risk of hazard occurrences is far less than perfect due to cognitive heuristics (Peng 2021). However, we should note that only the soil component is accounted for in this model therefore further research is needed to account for the structural component of each building typology.

4. Conclusions

Despite the soil vulnerability in the city of Lisbon being publicly[4] available, households seem not to factor in seismic risk when buying a property, which reflects in the lack of statistical significance of the seismic component in our spatial lag hedonic model. This is consistence with previous findings on the influence of cognitive heuristics and perception bias in the decision-making process (Hallstrom and Smith 2005), especially when assessing the risk of low-frequency events. However, seismic resistance can be factored in by households by choosing newer RC buildings, which would

[4] https://www.lisboa.pt/fileadmin/cidade_temas/seguranca/documentos/Carta_de_Vulnerabilidade_Sismica_dos_Solos.pdf

be consistent with the positive coefficient in the construction year. We recommend further research on risk perception of Lisbon's inhabitants in order to confirm these results.

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Inversion of TDEM data constrained by surface seismic and borehole surveys for geotechnical characterization of the Northen Lisbon Logistic Park (PLLN)

Jeniffer Viegas[1,2], Pedro Baltazar-Soares[3], Giulio Vignoli[2,4], Jaime Santos[1], Fernando Monteiro Santos[3]

[1] Instituto Superior Tecnico, Department of Civil Engineering, Architecture and Georesources, Lisbon, Portugal E-mail: Jeniffer.viegas@tecnico.ulisboa.pt
[2] Universitá di Cagliari, Department of Civil and Environmental Engineering and Architecture, Cagliari, Italy
[3] Faculdade de Ciências da Universidade de Lisboa, Department of Geographic Engineering, Geophysics and Energy, Lisbon, Portugal
[4] Geological Survey of Denmark and Greenland, Department of Groundwater and Quaternary Geology Mapping, Aarhus, Denmark

Abstract

Investigate the earth's interior and identify its structure and materials distribution, as well as to characterize its geomechanical parameters, are the base for any further project since for the development of foundation projects the knowledge of the subsurface is critical. The application of geophysical methods for geotechnical characterization has become a common practice due to the possibility of investigating large areas in a short time, with a great ratio of cost-effectiveness. This paper presents a study case where the inversion of Time Domain Electromagnetic Data (TDEM) constrained by a reference model created with information from seismic surface waves and boreholes was applied to investigate the subsurface of the Nothern Lisbon Logistic Park. The goal was to understand how important prior information is for the inversion of TDEM data, and how well this technique can describe the subsurface. By coupling diverse techniques, we got an image with more information from the subsurface, for example in this study, we identified the shallowest layer and its thickness.

Author Keywords. Geotechnical Characterization, TDEM, Inversion, Surface Waves.

1. Introduction

Geophysical methods have become an increasingly common practice in different areas such as mining, archeology, environmental studies, hydrology, geotechnical characterization, among others.

There have been numerous applications of these methods in geotechnics. Solberg (2016) combined geotechnical studies, electromagnetic data collected by helicopter, electrical tomography, and electric cone data to investigate an area where landslides occurred, in Trondheim - Norway in 2012. The fact that they performed an electrical tomography shortly after the landslide was useful to outline future risk areas and to develop a possible evacuation plan for the population. Giordano (2016) carried out electrical tomography and surface seismic tests to study the stability of a natural bridge in Piedmont-Italy. As both methods are non-invasive, it was possible to investigate the state of the bridge without damaging it. The investigation allowed the description of the natural state of the rock mass that composes the bridge and possible mechanisms of instability.

The present work aims to take advantage of different information, from geophysical and geotechnical methods to improve the subsurface characterization. The subsoil image provided by

the TDEM method is improved by introducing a reference model created based on surface seismic and borehole surveys.

Located in an alluvial area of the Tagus River, the area under study is placed in Castanheira do Ribatejo (Vila Franca de Xira) and is designated for the creation of the Lisbon North Logistics Platform (PLLN). The site has extensive geotechnical information such as SPT, CPT, Vane tests, as well as laboratory tests. Surface seismic tests were also carried out, namely active tests - Multichannel Acquisition of Surface Waves (MASW) and passive tests - Horizontal to Vertical Spectral Ratio - (HVSR).

2. Methodology

The TDEM method is an inductive method that works under Maxwell's equations. For grounded TDEM, an electrical cable is placed on the ground forming a square or rectangular loop. The loop is energized by passing a strong direct current(dc) through it. The d.c flowing in the cable gives rise to the primary magnetic field, this field is stationary and does not induce underground currents. To induce underground currents, the current in the cable is rapidly switched off, however, the magnetic field is not cut off instantaneously, but it does change sharply. The variation of the primary field generates electric fields which give rises to eddy currents in conductors, the faster the variation in the primary field the stronger the eddy current induced. To counteract the effect of these eddy currents, according to Lenz's law, a new magnetic field (named secondary) is then created which tends to cancel the variation (decrease) of the primary field. The receiver will read the variation of the secondary field, $\frac{dB}{dt}$.

In the present work, the acquisition of electromagnetic data was performed with the TEM-FAST 48 HPC equipment. This equipment allows obtaining two parameters as a function of time, the resistivity (Ohm.m) and impedance (V / A).

The configuration used was a 25m square loop where the transmitting source (Tx) and the signal receiver are coincident. A 150m profile was studied by executing 15 loops spaced 10m apart.

3. Results

To understand the influence of the need for a priori information, two tests were performed, with the same parameters (mesh discretization, weight matrix values, number of iterations, etc.), differing only in the reference model. In test A the reference model is a homogeneous medium with a resistivity of 25 Ω.m In test B the reference model is defined in 4 layers as shown in Figure 1.

Figure 2 represents the geological profile resulting from a survey carried out in the study area. The profile has 3 lithological layers: a 1.80m thick surface layer identified as a landfill, an intermediate alluvial layer 14.8m thick, and the last layer identified in this survey, a layer of clayey sand 1.40m thick. It was also identified in this survey that the water table was 2.20m deep.

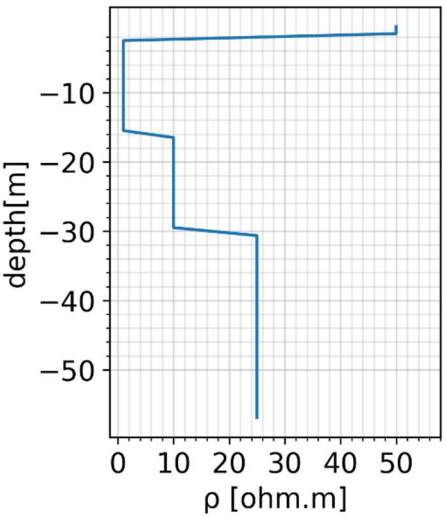

Figure 1: Reference Model Used

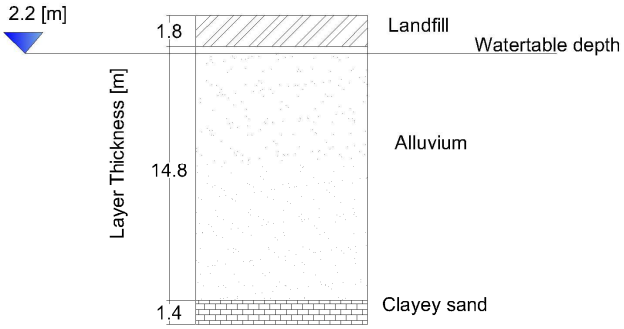

Figure 2: Geological profile from a borehole close to the place where the TDEM was carried out

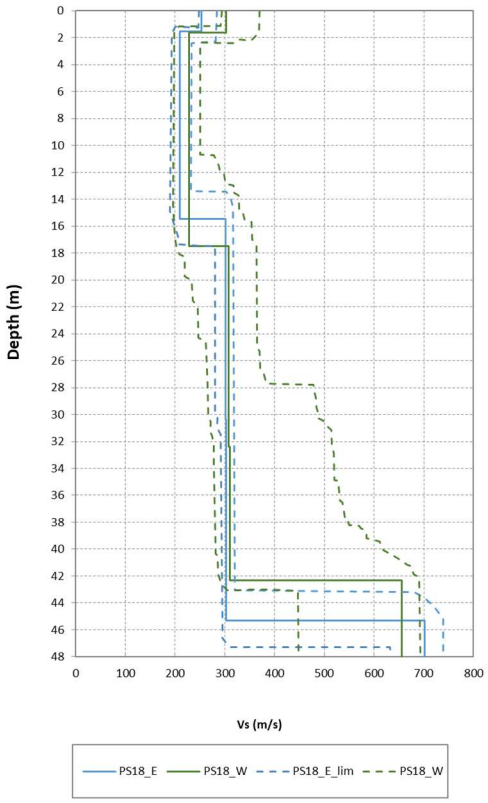

Figure 3: Seismic Profile from joint inversion of MASW + HSVR. From Lopes et al. (2018)

Figure 3 represents the seismic profile obtained at a location very close to the TDEM survey. The seismic active MASW and the passive HVSR methodology were applied. The MASW was carried out over 48 m with 24 geophones spaced 2m each. The energy source used was a 10 kg hammer, with data being recorded in the two directions of the profile, East and West, indicated in Figure 3 as PS18_E and PS18_W. HVSR data were collected at the central point of the 48m alignment.

The dispersion curve provided by the MASW data and the ellipticity curve provided by the HVSR data were jointly inverted. The result is associated with a range of possible results defined by a maximum and minimum value of 1.3 x misfit, described as PS_E_lim and PS_W_lim in Figure 3. A detailed description of the procedure for acquiring seismic data and processing them is given in Gouveia (2017) and Lopes et al. (2018).

The resistivity values presented in the reference model shown in Figure 1 were chosen based on known values for several materials available in the literature (Parkhomenko 2012, Samouëlian 2005, Braga 1997 and Rashid et al. 2018), taking into account the information available in the geological profile (Figure 2) and seismic profile (Figure 3). Thus, considering a resistivity of 50Ω.m for the landfill layer, 1Ω.m for the alluvial layer, 10Ω.m for the clayey sand layer, and 25Ω.m for the bedrock.

Figures 4 and 5 show the inversion result for the 15 TDEM acquisitions plotted side by side for test A and test B, respectively. Test B identified one more layer than Test A, the most superficial layer, designated as landfill in the reference model. Both identified an intermediate layer, possibly alluvium, named as layer 2 for test A and as layer 3 for test B. Tables 1 and 2 show the approximate values for the resistivity and thickness of each layer for tests A and B respectively, on the ninth acquisition.

Table 3 represents the values used in the reference model. Through its analysis and comparing it with table 2, it is possible to notice that, as expected, model B has values of resistivity and thickness of the layers close to the reference model. Despite the discrepancy between the intermediate layers, both models identified the bedrock at a depth of 30m.

As mentioned in Parkhomenko (2012) and Samouëlian (2005), the resistivity in rocks and soils is given by the conduction of ions in the pores, so the porosity and the material that fills the pores have a great influence on the resistivity value. In the case under study, the water level was quite shallow, at a depth of 2.20m and it was brackish water, which leads to very low resistivity values between 0.1Ω.m and 11.6Ω.m. Besides, the fact that it is a soil rich in clay leads to a specific effect of these materials, known as a double diffusion layer, which makes the TDEM method reach only a depth of 30m.

4. Conclusion

This study aimed to investigate the need and influence of introducing a good reference model in the inversion process of TDEM data.

The analysis of test A and B allows concluding that the introduction of an accurate reference model leads to a more uniform result, with smoother variations and with resistivity values closer to those

indicated in the reference model, which is desirable when one has a high degree of confidence in the proposed reference model. Without the introduction of a reference model, the result was sparser, missing the first layer, this result would be enough for a first characterization of geotechnical layers and the bedrock depth. However, for a geotechnical project, an accurate resistivity and thickness of each layer are relevant, for which the result from test B would more suitable.

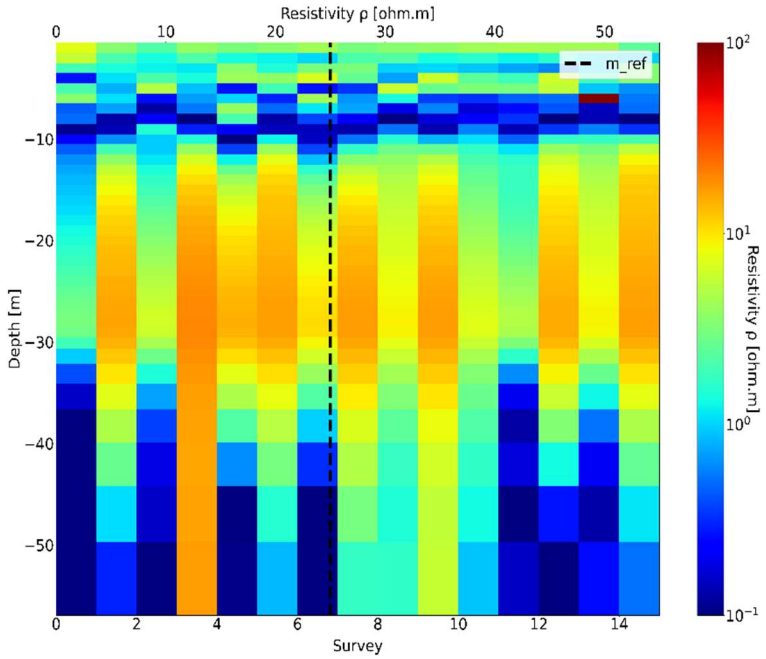

Figure 4: Test A: Inversion with homogenous reference model

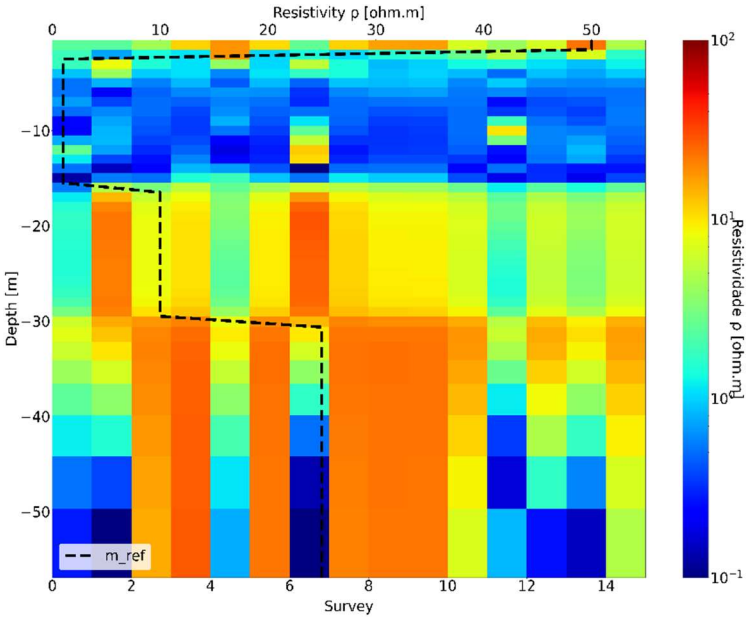

Figure 5: Test B: Inversion with reference model with 4 layers

Table 1: Resistivity values and layer thickness for each layer at the 9th acquisition for Test A

Layer	Thickness [m]	Resistivity [Ω.m]
1	4	0.7 to 3.9
2	7	0.1 to 6.0
3	18	3.8 to 9.2
4	-	0.5 to 25.0

Table 2: Resistivity values and layer thickness for each layer at the 9th acquisition for Test B

Layer	Thickness [m]	Resistivity [Ω.m]
1	1	16.0 to 33.0
2	3	0.8 to 1.5
3	10	0.3 to 0.9
4	15	4.2 to 11.6
5	-	19.1 to 25.0

Table 3: Resistivity values and layer thickness for each layer on the reference model

Layer	Thickness [m]	Resistivity [Ω.m]
1	2	50.0
2	12	1.0
3	14	10.0
4	-	25.0

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Structural safety and computation: from seismic engineering to wave energy

Bonaventura Tagliafierro[1], Rosario Montuori[1], Alejandro Crespo[2], Ioannis Vayas[3]

[1] University of Salerno (Italy)
[2] Universidade de Vigo (Spain)
[3] National Technical University of Athens (Greece)

Abstract

In this work, two emblematic case studies are presented that involve the use of high-end numerical simulators to evaluate the response of structure systems under hazardous natural phenomena. The performance of two devices – a seismic isolator for pallet racking systems and a point-absorbing wave energy converter – are investigated. These are currently under development, and have been investigated through analyzes whose purpose is to evaluate their performance and reliability under extreme events: earthquakes and storms respectively. Numerical simulations with physics engines, ever since related only for non-scientific purposes, can now complement scientific projects targeted at developing novel concepts, mostly related to low-budgeted research.

Author Keywords. Numerical modelling, OpenSEES, DualSPHysics, Project Chrono, Coupling, Structural safety, Design methodology.

1. Introduction

During their lifespan, infrastructures face countless threats generated by a constantly changing environment. Disasters resulting from natural and man-made sources, such as floods, earthquakes, storms can cause significant damage. While technological advances in computing have created programs that allow us some basic understanding of how hazardous events can threaten our infrastructure, existing computer programs do not provide enough support to allow a level of responsiveness that matches the complexity of the problems presented by each threat.

Whereas most design procedures for designing standard iterative structures are based on linear procedures, defined as an approximation of reality through complex analysis or static data available from past observations, any new device made to work in a new environment must be studied considering an adequate level of detail. The difference between these two extreme case scenarios lies in the reliability of the procedures used to assess the system input from the surrounding environment and in the response of the item to such external factors. In case of lack of previous information, experiments and multiphysics simulations can represent a valid alternative, if not the only one.

The safety factor and reliability for structural systems, or their subcomponents, can often be calculated following a coded approach, such as the Eurocode framework (CEN 2020). Simplified approaches are proposed for traditional structure classes along with the level of acceptance regarding adequate performance. However, for out-of-the-box cases, this assessment implies an unknown on both sides: the response of the artificial object to extreme natural phenomena and the event itself. For such cases, numerical modeling is the only viable option when experimental

configurations are impossible (e.g. asteroid rovers (Sunday 2020)) or unfathomably expensive (e.g. bridges).

2. Numerical framework for seismically isolated structure

The scientific community is now placing more and more importance on the safety of industrial facilities due to our society's dependence on such facilities (see Simoncelli 2020). We have learned that we cannot afford downtime in the supply chain, for example, and that having more resilient systems could directly improve the quality of our lives. A key role along the supply chain is played by warehouses, where goods are stored awaiting shipment of the last mile. The internal structures of most warehouses include hundreds of meters of pallet racking - they are modular structures (Figure 1 - center), which are repeated to form the shelving system. The minimum requirements for the safety of those facilities have been ever since provided by common wisdom and not at all considered as a cost to society.

Conceived to increase the performance of pallet racking systems, the seismic isolator presented in Figure 1, IsolGOODS®, was studied with the open-source OpenSEES (Open System for Earthquake Engineering Simulation) code (McKenna 2000) under non-linear dynamic analyzes, facing the challenge of considering different models of friction to describe the randomness of the friction properties (Tagliafierro 2021b). The device exploits the operating principle of the pendulum that allows for uniform performance regardless of the mass of the superstructure. This is in fact a vital feature that makes this device be at a point of advantage. It was engineered by FIP MEC (Italy) to provide a new concept targeting racking structures, heavily damaged by the Emilia 2012 (Italy) earthquake.

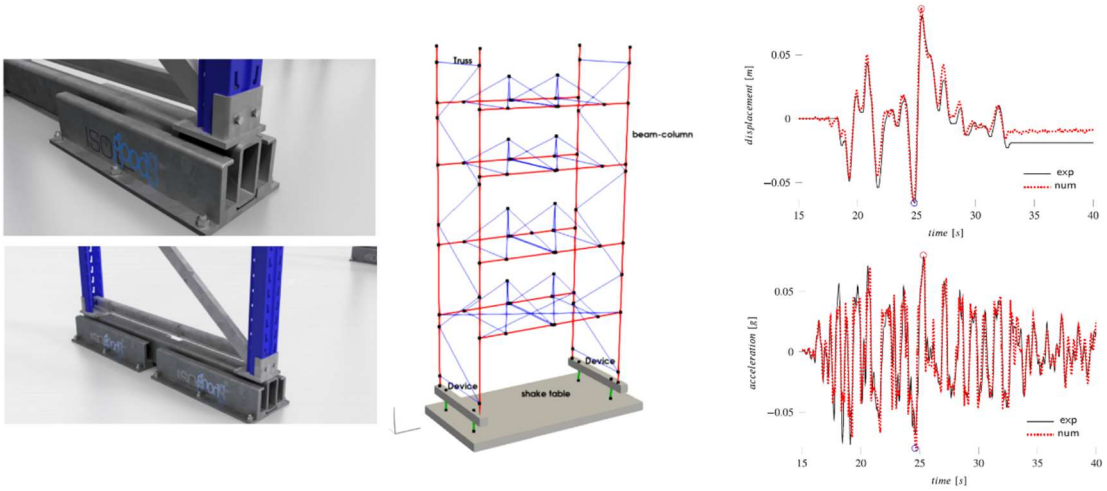

Figure 15: IsolGOODS® device as used into the experimental campaign; 3D view of the numerical model as built in the OpenSEES environment; and validation for displacement and acceleration time series (Tagliafierro 2021b)

The numerical model was validated against the results of the shaking table tests and then used to perform advanced analyzes to provide information on the applicability of this new anti-seismic

device (Figure 1 - right). The Incremental Dynamic Analysis (IDA – Vamvatsikos and Allin Cornell 2002) consists in performing a series of nonlinear dynamic analyses by scaling the ground-motion records to which the structure is subjected until a local or global collapse is reached. The procedure was used to identify the gain in seismic performance of the proposed system: it was found that the device is able to provide non-seismic structures with safety indexes higher than the minimum required by law for similar seismic zones. The IDA procedure requires a considerable computational cost, accounting for the numbers of ground motion to be used and the nature of the FEM simulation. For the aim of the research, presented in Tagliafierro 2021, a Matlab® code was set up to manage the whole process and by using the OpenSEES code an external solver, called in the routine when the structure response was needed.

3. Simulation of point-absorber wave energy converters

Ocean wave energy is on the verge of being competitive on the global market. It is estimated that huge wave energy farms (> 1MW) will surely bring down the levelized cost of energy (LCOE) before 2030 (IRENA 2014). Wave energy converters (WECs), machineries that convert kinetic wave energy into electricity, are often handled with numerical tools used for the offshore construction industry. However, it is important to deploy specially developed tools to account for all the features that can affect their performance and are vital to build a reliable framework. Numerical modelling of WECs, especially for survivability analyses, needs more complex and sophisticated approaches, guaranteeing high fidelity modelling procedures that can solve high non-linear interactions and include viscous forces. The SPH method is considered among the best approaches for performing this task (Penalba 2017).

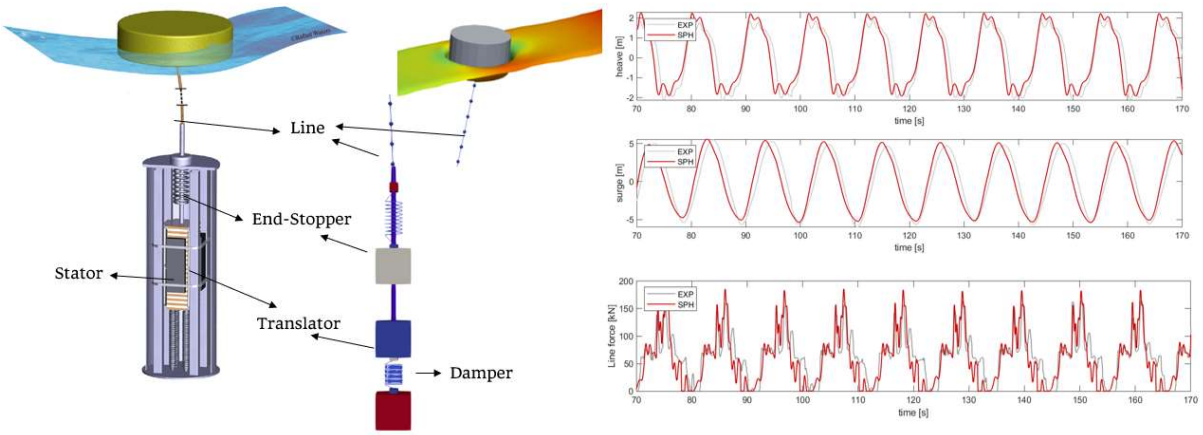

Figure 2: Schematics depicting the parts of the WEC (Waters (2007) Copyright 2007 AIP Publishing LLC.) and their counterparts in the SPH model (left). Comparison of the numerical and experimental heave, surge, and line force(right) (Tagliafierro 2021a).

The wave energy converter developed at the University of Uppsala (Sweden) represents an unprecedented concept, although presented almost 20 years ago, due to the particular mechanics involved (Figure 2 - left). A taut-moored buoy is attached to a power take-off system located at seafloor level and generates electricity thanks to a linear translator driven by the heave/surge motion of the float. First numerical assessment of the behavior of the proposed device, after also its deployment at sea, were given in Sjökvist (2017), which utilized several numerical models (from

a linear to VOF solvers) to compute the maximum expected forces into the mooring line. Data presented in Sjökvist (2017) (H=7.20m and T=10.70s) is used here to validate the proposed numerical model (Figure 2 - right), described in the following.

A numerical model that takes into account the general behavior of the system has been integrated into the open-source DualSPHysics framework. The configuration presented in Waters (2007) is modeled with the SPH-based DualSPHysics (Domínguez 2021) code, leveraging external libraries to promote a reliable modeling of the parts that make up the WEC (Ropero-Giralda 2020, Tagliafierro 2020). The multiphysics Project Chrono library (Tasora 2016), which is developed as a general-purpose simulation package for multi-body problems, is used to reproduce the internal mechanics of the PTO system (Figure 2 - left), whereas the open source MoorDyn library (Hall 2015) manages the dynamics of the line that transfers the motion of the buoy to the translator. This numerical study will include time series for embedded focused waves to perform a survivability analysis of this WEC to such model of Ultimate Limit state condition. Figure 3 shows three different instants of the simulation with a focused wave train, when the highest peak is striking the buoy.

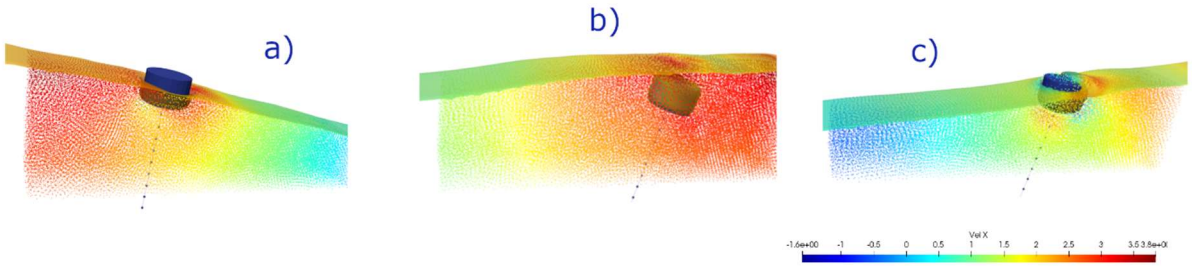

Figure 3: Three instants of the impact of the main crest of the focused wave train. a) crest approaching; b) crest; and c) through approaching.

3. Conclusions and remarks

The results of the two presented ongoing pieces of research demonstrate that the way forward to improve numerical modeling to simulate complex phenomena is through the coupling of different algorithm libraries to fully exploit the strengths of each. The resulting multiphysics simulations can better complement our ability to investigate complex scenarios by providing immediate feedback on possible mitigation efforts that can be undertaken to reduce damage and loss, always according to the skill of the designer.

A final remark by the authors: the scientific community has widely recognized the development and use of open-source tools which are then disseminated around the world for research purposes, and more. However, it is important that scholars develop comprehensive frameworks – as primers – in which clear and meticulous procedures should be set up through the union of theory and application. Therefore, the published research represents a milestone that can be recognized and referenced for practical use.

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Simulation of the stability of Antifer units applied on breakwaters using DualSPHysics coupling with Project Chrono

Beatriz Queirós[1, 2], Francisco Taveira Pinto[1, 2], Paulo Rosa-Santos[1, 2], Alejandro Crespo[3]

[1] Department of Civil Engineering, Faculty of Engineering of the University of Porto, Portugal
[2] CIIMAR, Interdisciplinary Centre of Marine and Environmental Research of the University of Porto, Portugal
[3] Environmental Physics Laboratory, Universidade de Vigo, Ourense, Spain

Abstract

Rubble mound breakwaters are the most used structures for coastal protection, working like obstacles to the natural propagation of ocean waves and effectively promoting wave energy dissipation. Traditionally, to assess the hydraulic and structural behavior of rubble mound breakwaters, physical models were used. Nowadays, there was a remarkable evolution in the application of advanced numerical models, like the meshless method smoothed particle hydrodynamics (SPH), to an extensive range of complex hydrodynamic phenomena in the field of coastal and port engineering. The complementary use of physical and numerical models allows performing a comprehensive study of complex phenomena related to the interaction of waves with the breakwater in terms of wave loadings, overtopping, and damage assessment. The present manuscript aims to use high-resolution and accurate results from physical model tests to validate the application of DualSPHysics solver on the simulation of the fluid-structure interaction and the interaction among different bodies (e.g., sliding Antifer units) by coupling with Project Chrono.

Author Keywords. Rubble mound breakwaters, Antifer, damage, numerical modelling, SPH, DualSPHysics, Project Chrono.

1. Introduction

Rubble-mound breakwaters are the most used structures for harbor protection and may also support technologies for ocean energy harnessing, improving the sustainability of ports and their infrastructures. Those structures can be subjected to frequent and high magnitude actions from the maritime environment, making its design process challenging due to the complexity of the physical phenomena involved. Over the last few years, the DualSPHysics SPH model proved to be an appropriate option to simulate, with accuracy, some highly non-linear problems with complex boundaries. In the coastal engineering field, it has been demonstrated that DualSPHysics solver is a robust computational tool to simulate violent free-surface flows, solid-solid interactions, modeling damage and failures, fluid-structure interaction (Domínguez *et al.*, 2021, Zhang *et al.*, 2018, Altomare *et al.*, 2014, Barreiro *et al.*, 2013). However, to keep improving reliability and confidence in the results, it is essential to continue its development and validation against reliable experimental data. To this end, the propagation and breaking process of regular waves running up smooth and rough slopes armored with one row of Antifers are reproduced, numerical and physically, in this paper. In this way, it is possible to validate the capability of DualSPHysics to simulate fluid-structure interactions and solid-solid interactions by coupling with other models, such as Project Chrono, and by comparing with the experimental results.

2. DualSPHysics model

Smoothed Particle Hydrodynamic (SPH) is a fully Langrangian particle method (Altomare *et al.,* 2014), which presents as the most relevant advantages the exact conservation of mass and momentum as well as the meshless properties (Domínguez *et al*., 2021). In SPH, thedomain is discretized into a set of particles. For each particle, the values of the representative physical variables (velocity, position, density, and pressure) are computed as an interpolation of the properties of the surrounding particles (Barreiro *et al*., 2013). The particles interact according to Navier-Stokes's equations. The model and governing equations are described in detail in Domínguez *et al*. (2021). The DualSPHysics is a weakly compressible SPH-based solver. It is an open-source numerical code very efficient in coastal engineering applications. In the present study, the code is designed to simulate an experimental facility. It includes an implementation to generate regular and irregular waves with desired wave height and period. The waves are generated using moving boundaries to simulate the movement of a piston wavemaker. The software also included the active wave absorption system (AWAS), which corresponds to a technique applied in experimental facilities to absorb the reflected waves that travel back to the wavemaker (Zhang *et al*., 2018, Domínguez *et al*., 2021). Some recent code developments are also applied to the case study, namely the modified dynamic boundary condition (mDBC), which is applied to the solid surfaces (English *et al*., 2021) and the density diffusion term (DDT) (Fourtakas *et al*., 2019). Besides the simulation of the fluid-structure interaction, now the software allows the interaction between solid bodies (Antifer blocks, for example) assessment. This feature can be achieved by the implantation of the Project Chrono library in the DualSPHysics code. The work of Canelas *et al.* (2018) includes details of the implementation and validation with fluid–structure–structure interaction cases.

3. Validation

The DualSPHysics code is used here to model the propagation and interaction of the regular waves with smooth (PVC) and rough slopes (rock) armored with one row of Antifers. As the first step, the code is validated by experimental tests performed in a channel built inside the wave basin of the Hydraulics Laboratory of the Hydraulics, Water Resources and Environment Division of the Faculty of Engineering of the University of Porto. The flume has a total length of 28 m, with an effective section of 0.80 m wide and 1.2 m high, and a maximum water depth of 0.50 m. On the left of the flume there is a piston-type wave generator and at the end of the flume a slope (1:2) with one row of Antifers. The Antifers properties and theoretical stability conditions were defined using the formulas of Hudson (CIRIA, CUR, and CETMEF 2007) and Van der Meer (1988) (Freitas 2013). To analyze the behavior of the structure to different wave conditions, simulations were done using regular 2nd order waves perpendicular to the structure alignment. The experimental tests result in the surface elevation, the wave run-up, the percentage of damage, and relative displacement of the blocks. The configuration of the DualSPHysics simulation is based on the real dimensions of the experiment, so that the numerical tank is 16 m long, 0.80 m wide, and 2 m tall. The initial water level is 0.50 m. The numerical conditions were the same as the experimental test conditions.

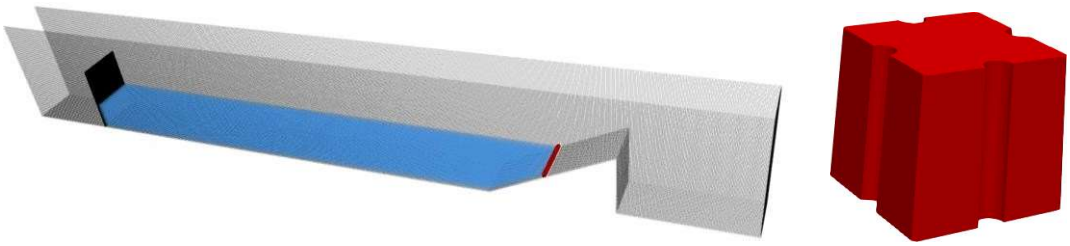

Figure 1: Case study numerical domain (left) and Antifer unit (right).

4. Conclusions and future works

The work carried out demonstrates the advantages of designing the experimental testing plan "*ad hoc*" applying some of the most recent functionalities of the DualSPHysics SPH code, which highlights the relevance of following a composite modelling approach in this type of Coastal Engineering topics. Furthermore, the agreement between the numerical and the experimental results is critically analysed and discussed. After successfully validating the numerical model, the next research step corresponds to the numerical and experimental simulation of a rubble mound breakwater section to assess the damage of the active zone for a wide range of wave conditions.

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Current status and future perspectives on the Hybrid Wave Energy Converter

Tomás Calheiros Cabral[1,2], Paulo Rosa Santos[1,2], Francisco Taveira Pinto[1,2]

[1] Department of Civil Engineering, Faculty of Engineering of the University of Porto, Portugal

[2] CIIMAR, Interdisciplinary Centre of Marine and Environmental Research of the University of Porto, Portugal

*Correspondence: tcabral@fe.up.pt.

Abstract

This paper presents the 3D physical model tests performed to study the Hybrid Wave Energy Converter, or h-WEC, which combines an Oscillating Water Column and an OverTopping device and is integrated into rubble-mound breakwaters. The hybridization leads to higher efficiencies compared to its individual components, and for a broader range of hydrodynamic conditions: the device tested reached an overall hydrodynamic efficiency of circa 44.4%, a wave-to-wire efficiency of 27.3%, and the annual electricity production was estimated at 35 MWh/m for the case-study location of the Port of Leixões. The h-WEC's integration into the breakwater led to an increase in the movement of blocks of the toe berm, but on the other hand resulted in a significant reduction of the overtopping volumes. Future physical model tests will also assess the impact forces acting upon the device and the pressure inside the breakwater's internal layers.

Author Keywords. hydraulics; hybrid WEC; oscillating water column; overtopping device; physical modelling; annual energy production.

1. Introduction

Wave energy represents a vast resource that has not yet reached the level of commercial viability to make it competitive against other renewable energy sources, such as hydro, solar or wind power. Research needs to be carried out not only to ensure higher conversion efficiencies, but also to improve the Wave Energy Converters' functional and lifecycle readiness.

Combining two proven technologies into one hybrid device presents a solution to increase the energy conversion efficiency, as well as to broaden the range of working conditions (Calheiros-Cabral *et al.*, 2020a; Calheiros-Cabral *et al.*, 2020b; Cappietti *et al.*, 2018). Furthermore, integrating WEC devices into harbour defence structures leads to high levels of operational efficiency, fatigue resistance, and structural integrity, as it allows cost-sharing in capital expenditure, facilitated connection to the main power grid, and simplified access for O&M operations (Vicinanza *et al.*, 2019). Notwithstanding, the impact of these non-conventional breakwaters on the structures' primary function of harbour protection needs to be thoroughly assessed (Calheiros-Cabral *et al.*, 2019; Clemente *et al.*, 2019).

The hybrid-WEC (h-WEC) is a Wave Energy Converter (WEC) device that combines two proven wave energy harvesting concepts, the Oscillating Water Column (OWC) and a multi-reservoir Overtopping Device (OTD). It has been designed to be easily integrated into rubble-mound port breakwaters, it is modular and scalable, making it adaptable to a plethora of harbour defence structures. This device has been studied in terms of energy conversion efficiency and impact on the functionality (overtopping volumes) and stability of the armour layer of the breakwater into which it is integrated using physical modelling. Notwithstanding, additional research is being conducted to further improve the device's design and to determine techno-economic parameters that will enable to assess, and hopefully improve, its potential of producing electricity at a competitive

market price, as well as allow to develop design methodologies that ensure a reduced impact on its harbouring breakwater and structural stability.

2. Current status of the HWEC

A. Preliminary design

The h-WEC was designed to be integrated into the case-study 300 m planned extension of the North breakwater of the Port of Leixões. After a preliminary numerical study of the OWC using Ansys® Fluent and of the OTD using WOPSim 3.11 under an individual approach, three different configurations (A, B and C) were holistically studied using physical modelling, Figure 16. These designs were optimized based on the geometric parameters most influencing their power production, such as the number of reservoirs of the OTD, their crest heights and length, also taking into consideration practical aspects such as: sufficient distance between the reservoirs' slabs to allow human access for maintenance, and the length and shape of the entrance of the OWC. The OWC's PTO was modelled using a camera lens diaphragm to simulate a self-rectifying turbine. Five configurations of the PTO were tested by changing the diaphragm's aperture, i.e., orifice's diameter, from 3.3 mm to 14 mm.

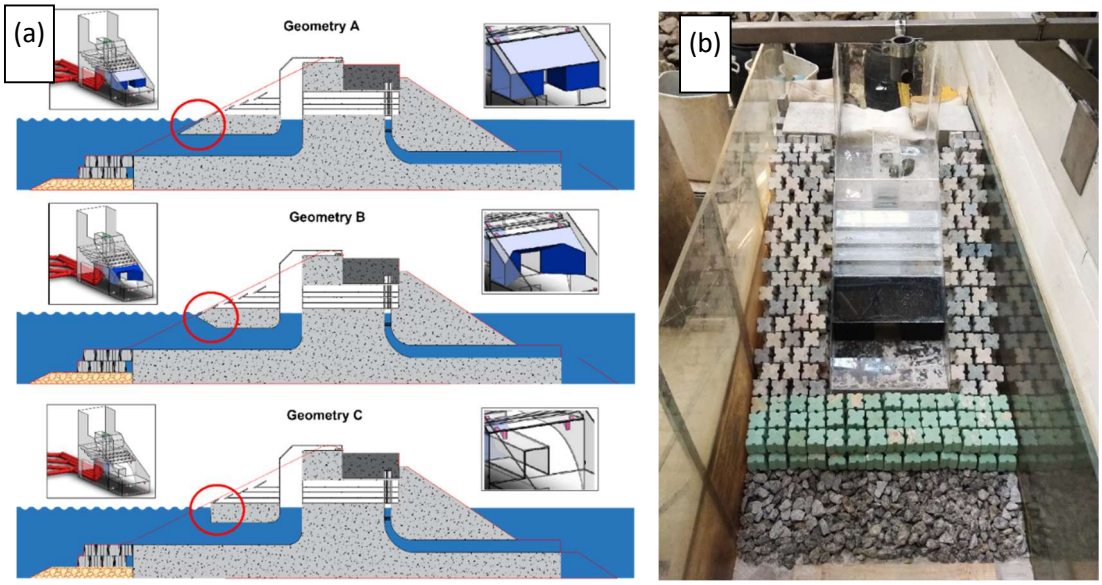

Figure 16: (a) Three h-WEC designs developed and (b) physical model of the h-WEC (Geometry A).

A physical model campaign was carried out at a scale of 1:50, testing a 40 cm wide model of the h-WEC for a total of 14 regular wave conditions with wave heights ranging from 2 to 8 cm and wave periods from 0.85 to 2.12 s, and a total of 27 hydrodynamic conditions with irregular waves representative of the case-study's wave climate with significant wave heights spanning from 2.2 to 18.2 cm and peak wave periods from 0.96 to 2.26 s, as well as three representative water levels.

B. Wave energy conversion efficiency for regular waves

The hydrodynamic efficiency of the OWC, calculated as the absorbed power averaged over the test's duration divided by the time-averaged energy flux of the incident waves, is shown in Figure 17.

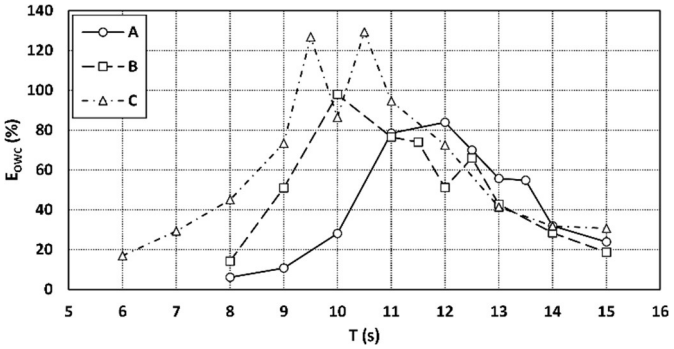

Figure 17: Hydrodynamic efficiency by wave period.

The hydraulic power captured by the OTD component was calculated based on the mean overtopping flow and the respective reservoir's crest height, Figure 18.

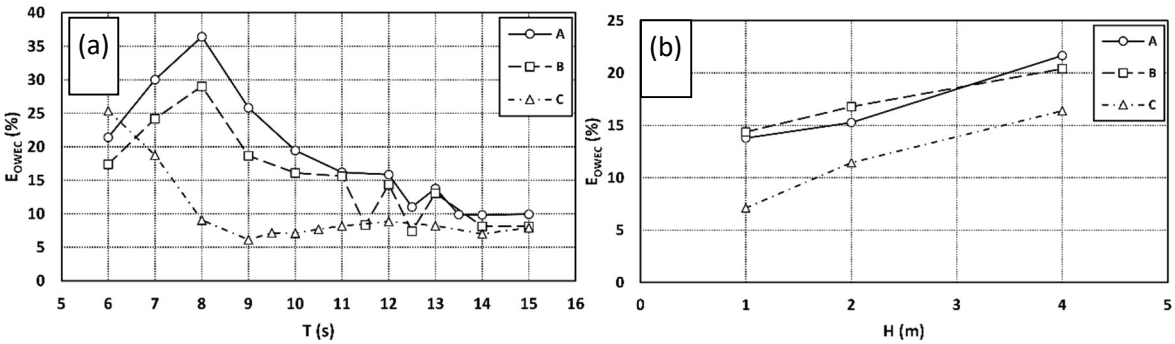

Figure 18: Hydraulic efficiency of the OTD component by (a) wave period with a fixed wave height (1 m) and (b) by wave height with a fixed wave period (resonant period of each tested geometry).

The results show that both the OWC and the OTD reached high hydrodynamic/hydraulic efficiencies (up to 129% and 36%, respectively). The OWC showed better results for wave periods above 9.5 s, with maximum hydrodynamic efficiencies obtained for wave periods between 10 and 12 s. The OTD showed better results for wave periods below 9 s, with maximum hydraulic efficiencies obtained for wave periods between 6 and 8 s.

The joint hydrodynamic/hydraulic efficiency of the h-WEC by wave period is presented in Figure 19.

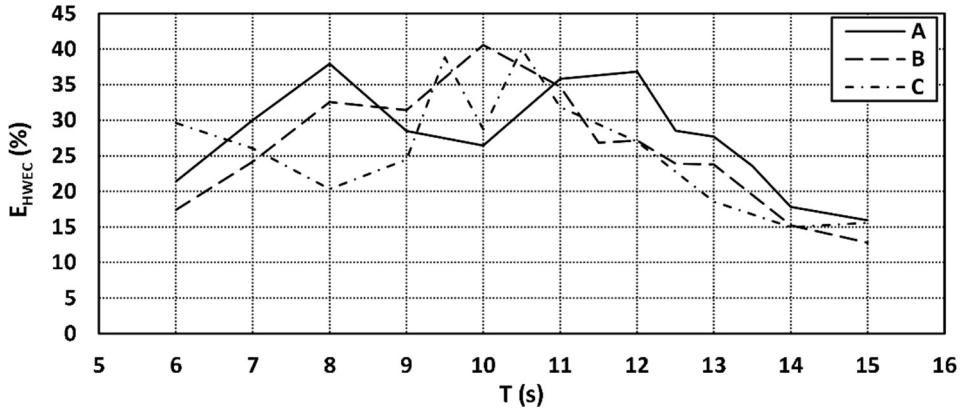

Figure 19: Joint hydrodynamic/hydraulic efficiency of the HWEC for the three tested geometries.

The h-WEC's mean total hydraulic efficiency with regular waves was 27.2%, 25.7% and 25.7% for Geometries A, B and C, respectively. The hybridization led to a device with higher efficiencies than its independent components, for a broader range of wave conditions, therefore reducing dependency on the characteristics of wave conditions to produce power.

C. Power production under irregular waves

The power production of the device was calculated for the mean annual wave conditions in the site of the breakwater. Seven representative sea states (combining significant wave heights and peak wave periods) were considered to assess the power production of the device, as well as three representative water levels (MSL, LWL and HWL). The sea states were chosen to cover the resource matrix as much as possible, Figure 20, and encompassed 96.8% of the total annual energy and 84.1% of the occurrences.

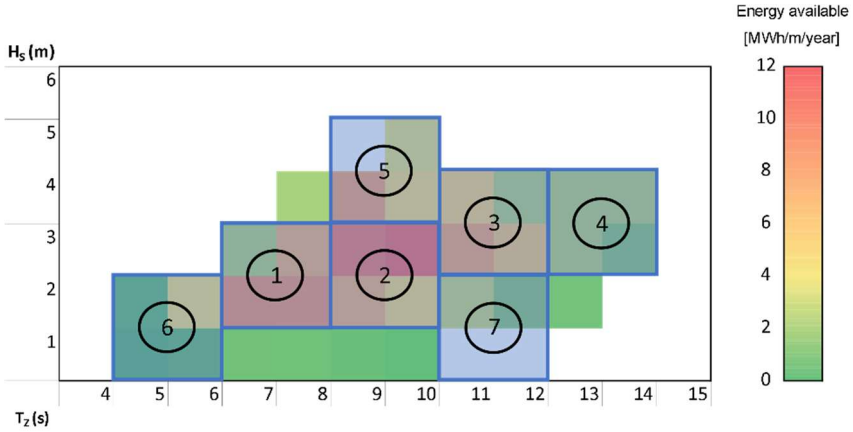

Figure 20: Characteristic sea states considered during the experimental campaign.

Preliminary tests were carried out for nine hydrodynamic conditions (five for the MSL and two for the LWL and HWL) to choose the best performing geometry. Afterwards, the remaining hydrodynamic conditions were tested to assess the Annual Electricity Production. The efficiencies of the conversion steps that fall outside the scope of this study were taken from the literature. Figure 21 shows the estimated energy production of the best performing geometry (B) for each tested sea state divided by component alongside the wave-to-wire efficiency.

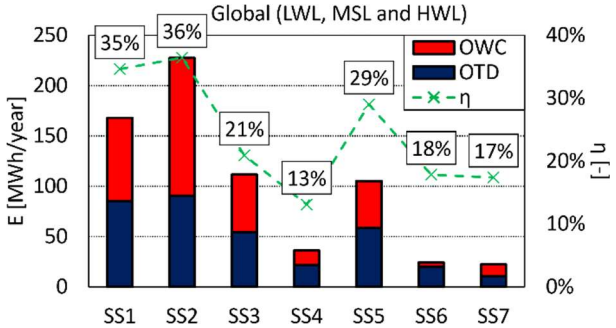

Figure 21. Energy production of the h-WEC divided by component and wave-to-wire efficiency.

The total estimated electricity production of the h-WEC amounted to 695 MWh/year for a 20 m wide (full-scale) device, or circa 35 MWh/year/m. Hence, a 240 m wide device could provide more than 50% of the Port of Leixões total electricity consumption in 2019 (14 500 MWh).

D. Impact of the h-WEC on the breakwater's functionality and stability

The impact of the integration of the h-WEC on the case-study breakwater's functionality and stability was assessed by comparing overtopping volumes over the structure and the stability of the blocks in the armour layer and toe berm with and without the device integrated into the breakwater. The tests were carried out for the LWL and HWL, significant wave heights increased from 0.12 m to 0.16 m for the LWL and 0.182 m for the HWL, with wave periods of 1.84 s and 2.26 s.

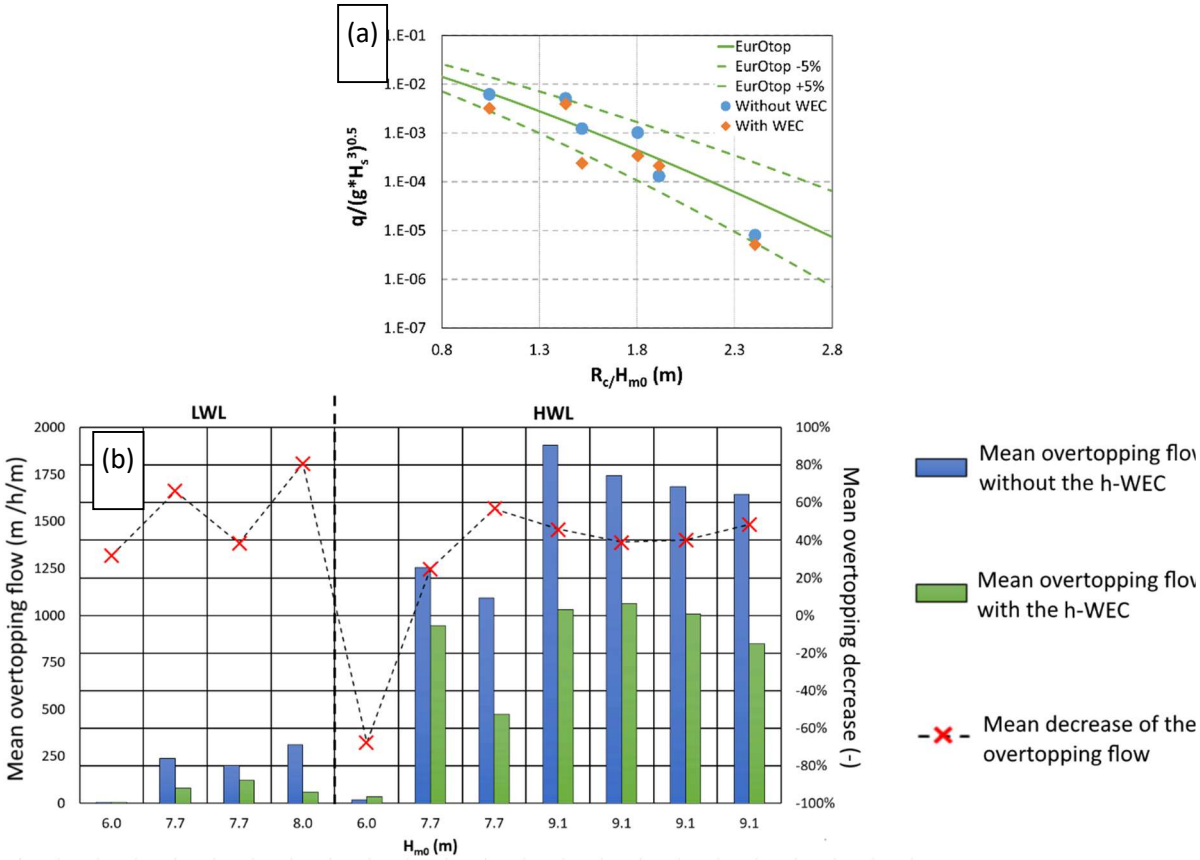

Figure 22. (a) Relative overtopping rate curves following the mean value approach using a roughness coefficient of 0.77 and comparison with EurOtop values and (b) overtopping discharge variation for each sea-state with the integration of the h-WEC.

The overtopping discharges over the structure significantly decreased with the integration of the h-WEC into the breakwater, on average 50%, excluding SS1 for the HWL which was considered as an outlier given the usual uncertainty in the prediction of overtopping discharges (Romano *et al.*, 2015), especially high for very low discharge data, which typically show a wider variability.

3. Future perspectives

Further physical and numerical research will be conducted namely to assess impact forces on the device and inside the internal layers of the breakwater. Furthermore, the stability of the breakwater's armour layer and toe berm will be thoroughly assessed using laser scanner technology to create high resolution point clouds with a +/- 1 mm accuracy complemented with photogrammetry. Moreover, numerical models will allow to study the device for a broader range of wave conditions and characterize the power production on a more precise time scale, such as inter-monthly.

4. Conclusions

A novel and innovative hybrid Wave Energy Converter has been studied using numerical and physical modelling (Calheiros-Cabral *et al.*, 2019; Calheiros-Cabral *et al.*, 2020a; Calheiros-Cabral *et al.*, 2020b; Clemente *et al.*, 2019; Koutrouveli *et al.*, 2021; Rosa-Santos *et al.*, 2019). The h-WEC has shown promising results, with a wave-to-wire efficiency of 27.3%, and the annual electricity production for the case-study location of the Port of Leixões estimated at 35 MWh/m. Future physical and numerical modelling studies will further assess its efficiency, stability, functionality, structural design and will provide techno-economic parameters leading to a holistic viability analysis of the technology.

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Recent developments on the E-Motions wave energy converter

Daniel Clemente[1], Paulo Rosa Santos[1], Francisco Taveira Pinto[1], Cátia Rodrigues[2], José Correia[3], Ricardo Esteves[3], André Pereira[2], João Ventura[2]

[1] Departmento de Engenharia Civil, Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 PORTO, Portugal; CIIMAR - Centro Interdisciplinar de Investigação Marinha e Ambiental (up201009043@edu.fe.up.pt/pjrsantos@fe.up.pt/fpinto@fe.up.pt)
[2] IFIMUP and Faculty of Sciences of the University of Porto, Rua do Campo Alegre, 4169-007 Porto, Portugal (catia.92@hotmail.com/ampereira@fc.up.pt/joventur@fc.up.pt) ORCID 0000-0002-9558-0954/0000-0003-0494-3009 Authenticus R-000-1Q2
[3] inanoEnergy, Edifício FC6, Rua do Campo Alegre 1021, Porto, Portugal (migueldiascorreia@inanoe.com/ricardoesteves@inanoe.com)

Abstract

This extended abstract summarizes the latest developments regarding the E-Motions, a promising wave energy device capable of converting wave/wind induced roll oscillations of multipurpose offshore floating platforms into energy. This concept has been subjected to an experimental study (1:20 geometric scale) for three hull designs: half-cylinder, half-sphere and trapezoidal prism. The study encompassed free decay and inclination tests, as well as subjecting the variants to various combinations of wave height and wave period (parametric approach, regular waves, and case study irregular waves). Outcomes point towards an overall good hydrodynamic response for the half-cylinder, while the half-sphere and, particularly, the trapezoidal prism require design adjustments (shape, dimensions and/or mass distribution). Values for the average power reached up to 13.36 kW, 8.19 kW and 4.17 kW, respectively (regular waves). Upcoming developments involve a numerical modelling stage that includes an optimization procedure for operational wave conditions (ANSYS® Aqwa™), and a survivability analysis (DualSPHysics).

Author Keywords. E-Motions, Marine renewable energy, Physical modelling, Numerical modelling, Performance optimization.

1. Introduction

In terms of operation, the E-Motions is capable of converting wave (or wind) induced roll oscillations of offshore floating platforms into electricity. This device is versatile, as it only consists of three parts - a floating platform, a superstructure and a power take-off (PTO), as depicted in Figure 23, and can be adapted to a myriad of floating structures at sea. Because of E-Motions' configuration, it also protects sensitive equipment from the surrounding environment and enables integration with other systems (*e.g.*, sensors or other energy conversion technologies).

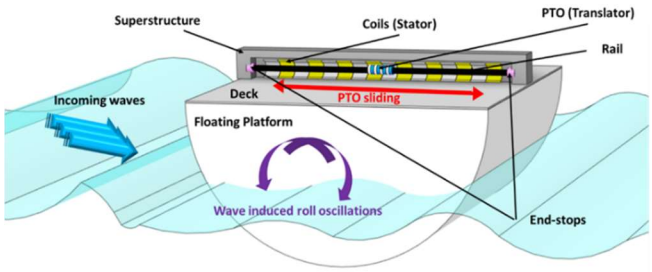

Figure 23: Schematic of the E-Motions and its operation mode.

Since its proof-of-concept study (Clemente, Rosa-Santos, and Taveira-Pinto 2016) the E-Motions has experienced developments aimed at improving its efficiency in converting wave energy into electricity. From the preliminary numerical modelling stage, which was the scope of a preceding DCE communication (Clemente, Rosa-Santos, and Taveira-Pinto 2019), three variants were selected for a new physical modelling stage: half-cylinder (HC), half-sphere (HS) and trapezoidal prism (TP). The follow-up experimental study featuring reduced-scale versions of these three designs is the scope of this paper, along with the latest advancements on the numerical modelling stage.

2. Facilities, Equipment and Methods

The experimental stage was conducted within the wave basin of the Hydraulics Laboratory of the Hydraulics, Water Resources and Environment Division (SHRHA) – Faculty of Engineering of the University of Porto (FEUP). The basin includes, on one end, a multi-element piston-type wavemaker system for wave generation and sea-state reproduction, and, on the other end, a dissipative rubble-mound beach. For this study, three physical models of the selected E-Motions variants, at 1:20 geometric scale, were constructed in methacrylate, Figure 24. Despite the relatively different dimensions and mass distribution, the free floating models were expected to have a natural roll period in the vicinity of 2.00 s (or 9.00 s, prototype value), aiming at resonance behavior for roll. The superstructure was constructed from metal rods and an aluminum encasing, while the PTO was constituted by a hollow aluminum box and a set of evenly-spaced neodymium magnets along a hollow PVC encasing. The PTO damping was reproduced through magnetic interactions between the magnets (stator) and the hollow box (translator), following on Lenz's law. With regards to equipment, six infra-red Qualisys motion tracking system markers and three cameras were deployed to track the motions of the models in real-time, thus enabling an analysis of their hydrodynamic response, while six resistive-type wave probes were setup to record on the free surface elevation, as well as reflection and transmission coefficients. Two mooring steel chains (diameter of 6 mm) were used for the setup of the mooring system, perpendicular to the incoming waves.

Figure 24: E-Motions physical models: half-sphere, trapezoidal prism and half-cylinder (from left to right).

3. Results

The preliminary free decay (initial imposed tilt about the roll degree of freedom, followed by a release of the model) and inclining (measurement of the tilt imposed by an eccentric load on the

model, about the roll degree of freedom) tests corroborated the expected hydrostatic properties of the physical models. This includes the natural roll periods, which exhibit acceptable deviations of 10% or less from the expected references.

The hydrodynamic response under regular waves is summarized in Figure 25, from which it is noticeable that the HS, but mainly the HC, exhibit relatively larger roll amplitudes over the considered wave conditions (seven tests, with varying wave period for a fixed wave height of 2.0 m or 0.1 m in prototype or model values, respectively). It is also perceptible that the PTO has an important influence on the roll oscillations, as it leads to an overall reduction of the amplitudes. This is mainly observed within the resonance range and is in more significant for the HS, the lightest of the three models. The reduction is justified by a de-phasing between the roll oscillations (floating platform) and the sliding motions (PTO), as observed during the experiments. In terms of power output, the HC achieved a maximum average of 13.36 kW, while the HS yielded 8.19 kW and the TP 4.17 kW (prototype values) very close to their respective resonance range.

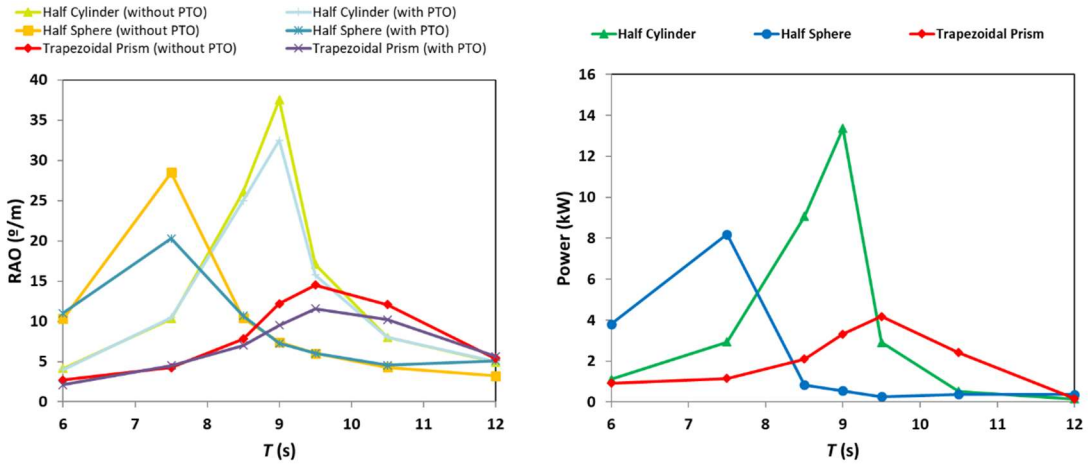

Figure 25: Response amplitude operator (RAO) and power output for the three E-Motions variants (prototype values).

As a follow-up on the regular wave tests, the three physical models were studied under irregular waves (significant wave height H_s between 1.33 m and 4.249 and peak wave period T_p from 8.96 s to 13.73 s, in prototype values). Eight sea-states, each with a specific H_s-T_p combination, were selected based on two reference case studies – Aguçadoura and São Pedro de Moel (Silva, Martinho, and Guedes Soares 2018). From the analysis of the hydrodynamic response, an equivalent pattern to that of regular waves was attained. It should be noted, however, that the HC demonstrated a somewhat consistent response and power output over the considered sea-states. Lastly, all E-Motions variants were subjected to a preliminary survivability test (irregular waves with a significant wave height above 5 m, prototype value). The three models withstood the reproduced wave conditions with no damage or infiltrations being observed.

The numerical modelling stage, following two complementary approaches, is ongoing. For operational conditions, the Boundary Integral Element Method (BIEM) software ANSYS® Aqwa™ has been selected, given its reliability and computational efficiency. Calibration procedures for all three E-Motions variants (regular waves, with and without the PTO) are nearly finished, with a good agreement between the numerical and experimental models being achieved (power output and

roll amplitudes). This will support the follow-up benchmarking numerical analysis of different E-Motions' sub-variants, subjected to irregular wave action, aimed at optimizing the WEC's design and improving its performance. The second approach resorts to the meshless CFD code DualSPHysics, which is required for a preliminary survivability assessment of the E-Motions. Although more suitable for analyzing extreme sea-state scenarios than Aqwa™, which loses considerable accuracy for very large wave and/or body motion amplitudes, it is less computationally efficient. Thus far, the calibration procedures have focused only on the HC variant (regular waves, without PTO), but the initial outputs are encouraging, with further developments being foreseen in the upcoming months.

4. Conclusions and future work

The physical modelling with the 1:20 geometric scale variants of E-Motions concept was carried out successfully. A significant hydrodynamic response, in terms of amplitude, was observed for the HC, while the remaining designs performed poorer. Average power outputs vary between a maximum average of 13.36 kW, for the HC, and a minimum of 4.17 kW, for the TP. On the numerical modelling, the calibration procedure yielded a good agreement with the experimental data in Aqwa™ (all variants, with/without PTO) and DualSPHysics (HC, without PTO). An operational optimization procedure and survivability analysis are to be carried out with these numerical models, respectively, as a future development.

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Acknowledgments

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Hydro and morphodynamic analysis of five segmented coastal protection structures: The case study of Carneiro Beach, Porto

Francisco Pinto[1]; Paulo Rosa-Santos [1]; Victor Ramos[1]

[1] Hydraulic and Water Resources Institute (IHRH) of the Faculty of Engineering of University of Porto, Portugal, ftaveirapinto@fe.up.pt, pjrsantos@fe.up.pt, jvrc@fe.up.pt

Abstract

Beaches and the adjacent seafronts can be hardly affected by extreme events. Detached breakwaters are one coastal protection solution to better shelter the coastline and consequently urban coastal areas in those cases. To mitigate the consequences from overtopping and storm events in the Carneiro beach in Porto, five detached breakwaters were designed. This paper presents the conclusions of the numerical study performed to assess the impact of those structures in the local hydro- and morphodynamics, as well as the research topics that should deserve further attention in the subsequent research works. The Delft3D-WAVE module was used to propagate waves to the coast, the Delft3D-FLOW module to simulate the hydrodynamic conditions and the Delft3D-MORPHOLOGY module to reproduce the sediment transport. With this integrated modelling approach, it was possible to analyze the effectiveness of the five structures designed to shelter Carneiro beach. Those structures were capable to provide calmer conditions on the lee side, although relevant scour phenomena occur mainly on the head section of the breakwaters.

Author Keywords. Delft3D, Detached Breakwaters, Sediment transport, Coastal Erosion.

1. Introduction

The present hydro and morphodynamic study is located at Carneiro beach, in Porto. The case study comprises Carneiro beach and part of Ourigo beach, covering approximately 400 m of the beach stretching northwards from the Felgueiras's vertical breakwater to the second set of rocky outcrops emerging on the sand. Few of the seafront of Porto's beaches have a huge bathing potential due to the smaller number of rocky outcrops. However, due to the lack of natural protection, the Carneiro beach is more exposed to the extreme maritime conditions that, during storm events, causes the removal of sand, with its deposition offshore and on land, by overtopping the wall of D. Carlos Avenue (Figure 1).

Figure 1: Location of Carneiro beach.

Thus, APDL intends to stabilize the sand of Carneiro beach in a width that, on the one hand, promotes its bathing use and, on the other hand, prevents the occurrence of the phenomena of

overtopping and wave action [1]. The main objectives of this numerical study of the solution purposed for the improvement of the current conditions of Carneiro beach consist of the analysis of the effectiveness of the five detached breakwaters in promoting the breaking of the incident waves and, consequently, reducing the energy reaching Carneiro beach [2]. This research study also aims to provide a first approach to analyse the scour phenomenon and its consequences, aiming at reducing coastal risks of exposed seafronts, by using an integrated numerical modelling approach.

2. Numerical model

During this study, the Delft3D numerical model was used, which is composed of three main modules, namely: the flow module (Delft3D-FLOW), which simulates the entire hydrodynamic behavior; the wave module (Delft3D-WAVE), which is responsible for wave propagation using the SWAN software; and the morphodynamic module (Delft3D-MORPHOLOGY), responsible for simulating the sediment transport.

The conservation of the momentum quantity is simplified to the hydrostatic pressure law, as a result of considering shallow waters in which the vertical flow accelerations are considered zero. The vertical momentum conservation is given by:

$$\frac{\partial p}{\partial z} = -\rho_w g \qquad [1]$$

where ρw represents the sea water density, g the gravity acceleration and z the vertical direction.

The momentum equations for both horizontal directions are:

$$\frac{Du}{Dt} = fv - g\frac{\partial \zeta}{\partial x} - \frac{g}{\rho_0}\int_{z'=z}^{z'=\zeta}\frac{\partial \rho_w}{\partial x}dz' + v_h\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) + v_v\left(\frac{\partial^2 u}{\partial z^2}\right) \qquad [2]$$

$$\frac{Dv}{Dt} = fu - g\frac{\partial \zeta}{\partial x} - \frac{g}{\rho_0}\int_{z'=z}^{z'=\zeta}\frac{\partial \rho_w}{\partial x}dz' + v_h\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) + v_v\left(\frac{\partial^2 v}{\partial z^2}\right) \qquad [3]$$

where ζ represents the free surface elevation, f the Coriolis' force and both the u and v the two orthogonal Eulerian velocity components. In addition, v_h and v_v represent the horizontal and the vertical kinematic eddy viscosity coefficients, respectively [3].

For the construction of the numerical model, two grids were generated in order to locate and represent the case study domain: the first one with the smaller domain was used for the FLOW module (Figure 2a) whereas the second one with a larger and extended domain was used for the WAVE module. Apart from the first stage of the numerical model setup, the five detached breakwaters were implemented on specific positions according to the project of Consulmar. Figure 2b shows their location and geometry: two vertical breakwaters (breakwater 4 and 5), two rubble mound breakwaters (breakwater 2 and 3) and one detached breakwater with the armour layer composed of Antifer blocks.

3. Results

Within this section, a brief, synthetic and clear analysis of scour phenomena near the five coastal protection structures was performed. For that purpose, it was important to first analyze how the

flow velocities and their directions near the bottom vary. Thus, the highest flow velocities occurred mainly between the breakwaters, including the head of Felgueiras' vertical breakwater.

During the simulations for two different water levels (mean sea level and storm surge level), including two different wave peak periods (10 s and 16 s) and five significant wave heights (4 m, 5 m, 6 m, 6.5 m and 7 m), a submerged sand bar was formed in front of breakwater 1, which resulted from an accumulation of sediments close to Felgueiras' vertical breakwater and extended through breakwater 1, gaining volume as the tests went on.

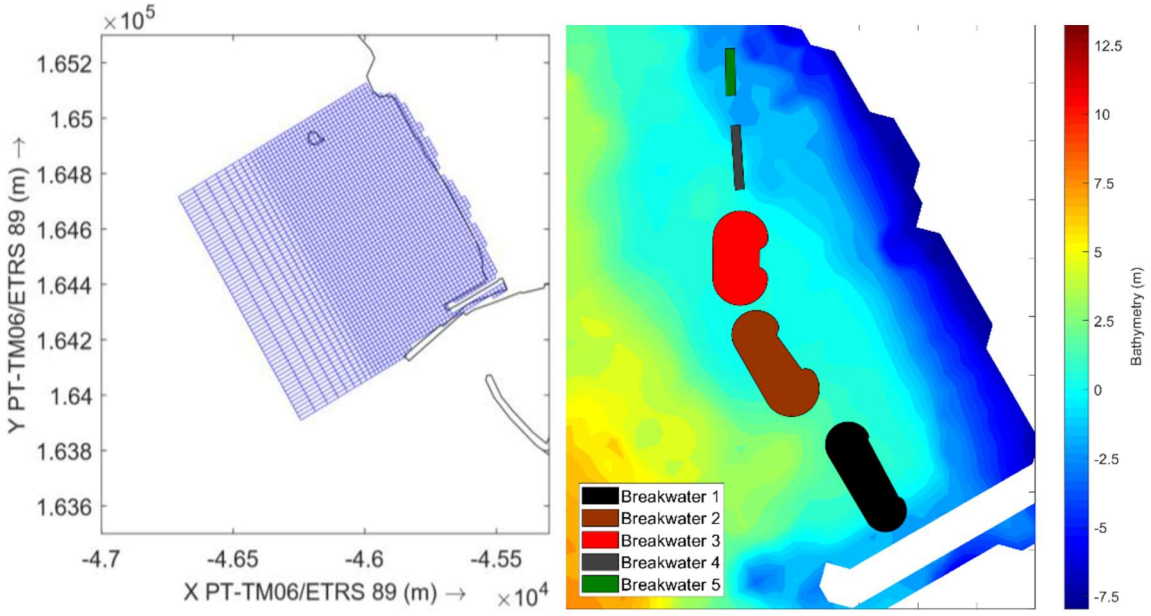

Figure 2: Illustration of the numerical model setup: (a) FLOW grid domain and (b) the five detached breakwaters' location and its bathymetry nearby.

After comparing two tests for different maritime conditions, it was possible to perform an analysis focused on two critical zones of breakwaters 1 and 2, namely the head and the trunk sections. Regarding irregular and oblique incident waves, it was clear that with the increase of the significant wave height, the scour hole increases its dimension (Figure 3).

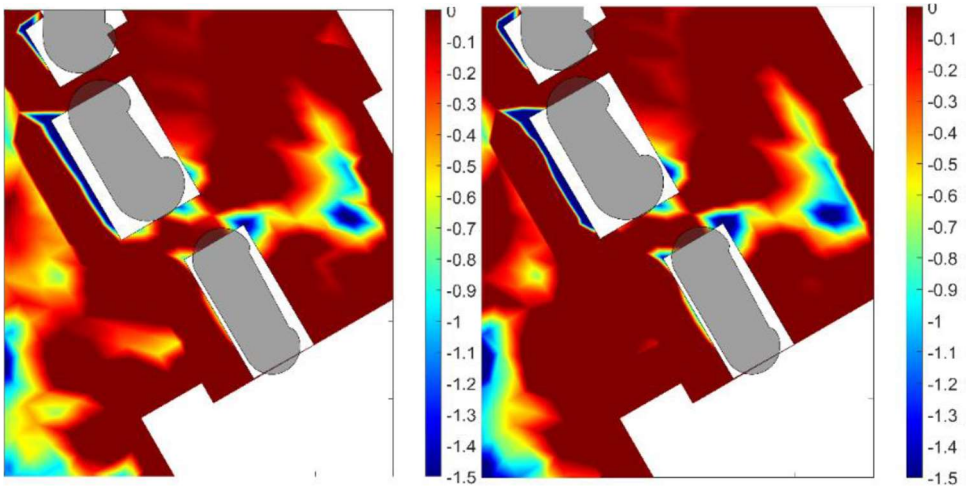

Figure 3: Cumulative scour around breakwater 1 and 2 due to the increase of the significant wave height.

4. Conclusions

The analysis of the results showed that, with the increase of the significant wave height, there was a clear increase in the extent and depth of the scour hole near the head of breakwaters 1 and 2. Furthermore, as the water level increased, there was an increase in the depth of the scour hole near the trunk section and, finally, when the peak wave period increased, the scour hole also increased. Regarding future developments, it is essential to present new outcomes on the scour phenomena development as well as on the effectiveness of nature based coastal protection solutions, using more accurate numerical modelling approaches.

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Analysis of the salinity variation downstream of the Xingó reservoir under the influence of outflows alteration

Kaíque dos Anjos Silva[1], Isabela Dantas Reis Gonçalves Basto[2], Andrea Sousa Fontes[3], Yvonilde Dantas Pinto Medeiros[1]

[1] Universidade Federal da Bahia, Av. Adhemar de Barros, s/nº, 40170-110, Salvador - BA, Brasil1
[2] Universidade do Porto, Faculdade de Engenharia, R. Dr. Roberto Frias, 4200-465 Porto, Portugal
[3] Universidade Federal do Recôncavo da Bahia, R. Rui Barbosa, Cruz das Almas - BA, 44380-000, Brasil 3

Abstract

This paper aims to analyze the effects on the salinity parameter caused by changes in the outflows of the Xingó reservoir (Brazil). The methodology consisted of collecting information to identify if there was, or not, an influence in the salinity conditions of the water due to the alteration in the hydrological regime of the river. To this end, observed daily flow data and simulated with the Mike 11 numerical model were compared. The analysis considered three distinct hydrological periods: wet (September 2008 to October 2009); dry (May 2017 to April 2018); and a peak flow of 3,000 m³/s (February 2021). The analysis of the data from the studied period demonstrated that the existence of a flood would cause a dilution of salinity throughout the channel of the studied stretch, making it possible to meet the limit adopted by CONAMA Resolution No. 357/2005 for freshwater class 2.

Author Keywords. Hydrodynamics, Salinity, São Francisco River.

1. Introduction

The São Francisco River basin faced a period of scarcity from 2011 to 2018 and, consequently, the Agência Nacional de Águas (ANA) made successive flexibilities to reduce the outflows restriction of the São Francisco reservoir complex to ensure that the multiple uses of the river would not be impaired. The last one took place in 2017, where the minimum outflows restriction was originally 1,300 m³/s, reduced to 550 m³/s (ANA, 2019).

Although the new rules provide for the reduction of water deficits (Basto et. al. 2020), there has also been a reduction in the water level in the channel downstream of the reservoirs, generating numerous inconveniences for users. In the lower stretch of the river, the conflicts occurred due to the alteration of the water quality for human supply. To mitigate such effects, the ANA elaborated Resolution No. 2,081, December 04, 2017, which it established limits for the minimum average daily outflows for the reservoirs complex, which are defined according to their respective stored volumes and the minimum outflow for Xingó is 700m³/s (ANA, 2017). In addition, this resolution provides for the implementation of two flow pulses (peak flows) for the maintenance of aquatic ecosystems. In light of the above, this work aims to study the spatial and temporal distribution of the salinity parameter in the face of the Xingó reservoir outflows alteration, when comparing the wet and dry periods, as well as a simulation referring to a peak flow of 3,000 m³/s.

2. Materials and Methods

The study area is located in the physiographic region of the lower São Francisco, downstream of the Xingó reservoir. This area is about 200 km long, between the states of Sergipe and Alagoas, from the Municipality of Piranhas to Piaçabuçu.

The topographic (cross sections), hydrologic (average daily flows), and water quality (salinity) data necessary for the hydrodynamic representation were acquired by the monitoring work of the Companhia Hidrelétrica do Rio São Francisco (CHESF, 2020) and the Agência Nacional de Águas (ANA, 2019). This monitoring was done through hydrometric stations whose locations are illustrated in Figure 1.

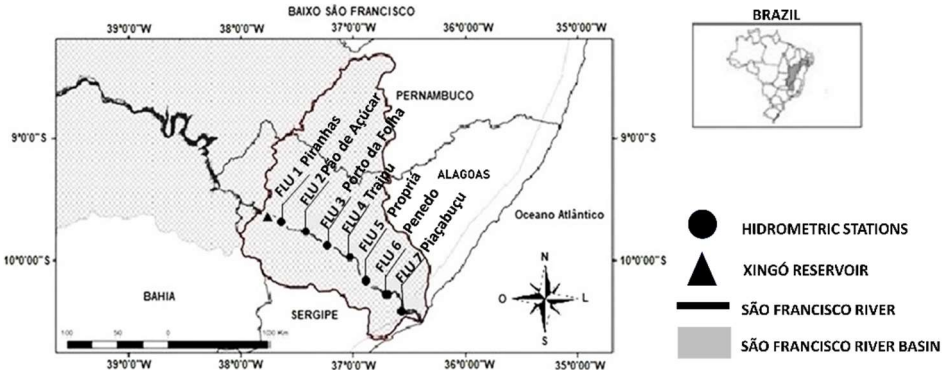

Figure 26: Study area location (Source: Authors, 2020).

The characterization of hydrodynamic changes and longitudinal salinity transport was performed with the one-dimensional hydrodynamic MIKE 11, which underwent the calibration and validation processes. The magnitudes of the Xingó reservoir outflows considered in the dry and wet periods were those simulated by Basto et al. (2020).

An evaluation of the water quality was performed according to the standards established by CONAMA Resolution No. 357/2005. In this step, the simulated values were compared to the existing condition in the stretch under analysis. The indicators used to evaluate the salinity parameter concentration, present in the CONAMA Resolution No. 357/2005, aimed at protecting the aquatic ecosystem (class 2). This resolution establishes that the salinity concentration for this water class must be equal to or less than 0.5 ‰.

3. Discussion

Figure 2A illustrates the salinity longitudinal distribution observed in the study stretch. It can be inferred that there was no significant variation in the concentration of this parameter over river stretch due to a higher flow present at the time. This magnitude flow was enough to dilute the salinity concentration to low levels. In Figure 2B, the simulation results were similar to the observed data.

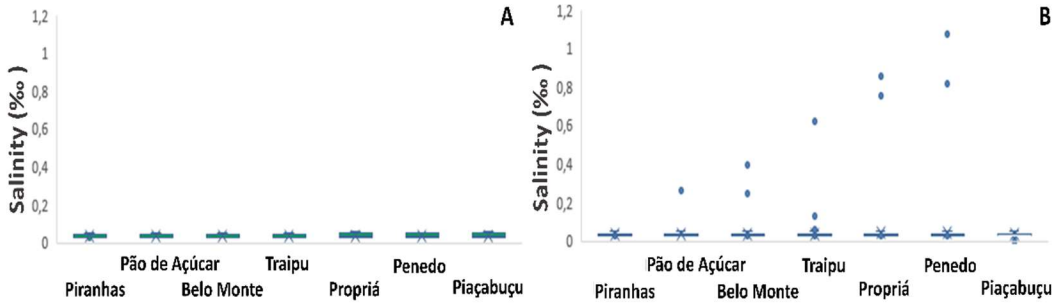

Figure *2*: Longitudinal salinity distribution (A)observed data; (B)simulation results- Dry Period.

However, for the dry period (Figure 3A), there is an increase in salinity concentration at the stations further downstream from Xingó, specifically in Penedo and Piaçabuçu. Figure 3B, also has an increase in salinity concentration, but the graphical representation shows that some values are not representative of the sample, indicating a possible limitation on the part of the model.

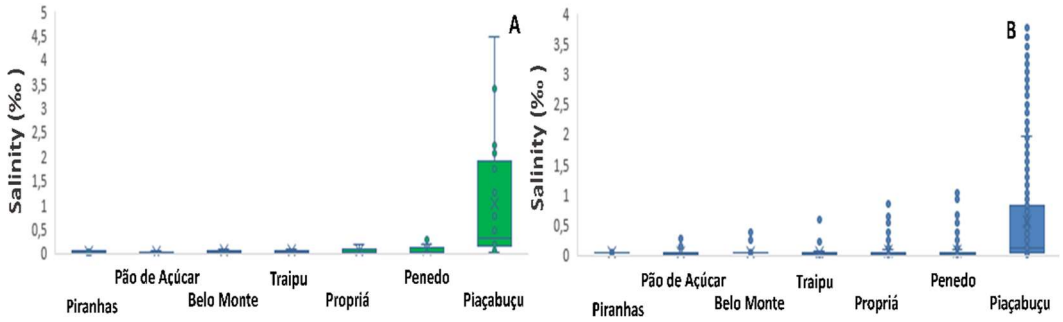

Figure 3: Longitudinal salinity distribution: (a) observed data; (b)simulation results- Wet Period.

Figure 4 illustrates the simulation results for the peak flow. In this figure, it is possible to notice that the salinity concentration is reduced considerably at all hydrometric stations.

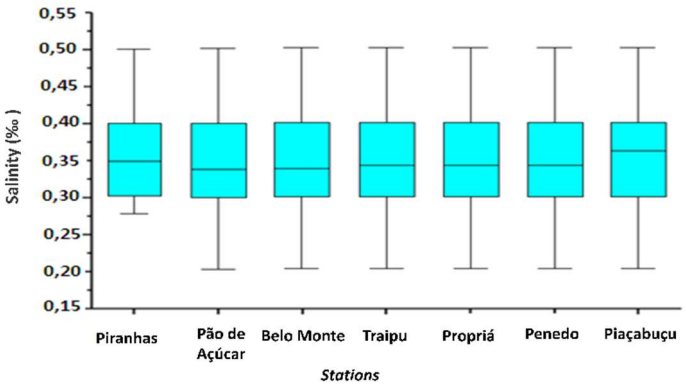

Figure 4**:** Longitudinal salinity distribution: (a) simulation results- Peak flow.

Comparing the results with the salinity concentration for class 2 freshwater, it is possible to point out that: in the wet period, the values are below the maximum limit, with a mean value of 0.037‰ and an upper limit of 0.5‰; in the dry period, there is increasing distribution of the salinity concentration from Piranhas to Piaçabuçu, with an average value of 0.12‰ and an upper limit of 1.7‰; and for the peak flow, the mean value was 0.034‰ and an upper limit of 0.5‰, meeting the class 2.

4. Conclusions

The simulations have shown for the wet period that the salinity concentration is below the maximum limit for class 2 freshwater. However, in the dry period, one notices an increase in salinity concentration from Piranhas to Piaçabuçu. Regarding the simulation of the peak flow, the model shows that the salinity concentration would meet the maximum limit for class 2, which could lead to human supply, after conventional treatment and protection of aquatic communities, considering them as the most restrictive uses of the lower São Francisco River.

From the results, it is possible to conclude that the alteration of the reservoir Xingó's outflows causes changes in the longitudinal distribution of the salinity, both when the salinity is acceptable (wet period and 3,000 m^3/s peak flow), and when it violates the limit adopted by CONAMA Resolution nº 357/2005 for class 2 (dry period).

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A novel and pragmatic methodology for scour risk assessment at bridge pier's vicinity

Ana Margarida Bento, Andreia Gomes, João Pêgo, Teresa Viseu,
Lúcia Couto

Abstract

Bridges crossing waterways are susceptible to collapse due to the local scour phenomenon, one of the greatest threats to the stability and safety of these hydraulic infrastructures worldwide. For the safe operation of bridges and their foundations it is of primordial importance to understand the inherent risk. However, the number of studies addressing scour risks and vulnerability is still reduced, which highlights the need for a systematic, coherent and straightforward methodology for assessing the scour risk of bridges.

A scour risk assessment involves the outcomes that could result from a combination of drivers, hazard events, and the performance of the bridge foundations when subject to those events. There are still many uncertainties affecting the design process of bridge foundations. Hydrological events, hydraulic conditions, bed morphodynamics and bridge pier characteristics are examples of the many underlying uncertainties that should be considered, in recognition of their influence on the scouring phenomenon and the resulting bridge scour risk.

Therefore, a new and pragmatic scour risk assessment methodology is herein presented. This is a three-step methodology that comprises: (i) the hydrological modelling of extreme events; (ii) the computation of flow and scour variables to model river behavior; and (iii) the assignment of a bridge scour qualitative risk rating based on the relation between relative scour depth and the vulnerability of the infrastructure in question. A Portuguese bridge case study was used to validate the proposed methodology, selected due to the changing bathymetry records over time at the bridge site and the availability of relevant flow monitoring data. The methodology has proved to constitute a useful tool for providing risk management measures and in assisting the prevention of catastrophic events.

Author Keywords. bridge piers, hydrological modelling, local scour, risk assessment.

1. Introduction

Bridges crossing waterways are susceptible to collapse due to the local scour phenomenon, one of the greatest threats to the stability and safety of these hydraulic infrastructures worldwide. However, the number of studies addressing scour risks and vulnerability is still reduced, which highlights the need for a systematic, coherent, and straightforward methodology for assessing the scour risk of bridges (Bento et al., 2020).

Scour risk assessment involves the outcomes that could result from a combination of drivers, hazard events, and the performance of the bridge foundations when subject to those events. There are still many uncertainties affecting the design process of bridge foundations. Hydrological events, hydraulic conditions, bed morphodynamics and bridge pier characteristics are examples of the many underlying uncertainties that should be considered, in recognition of their influence on the scouring phenomenon and the bridge scour risk.

Therefore, a new and pragmatic scour risk assessment methodology is herein presented. This is a three-step methodology that comprises: (i) the hydrological modelling of extreme events; (ii) the computation of flow and scour variables to model river behaviour; and (iii) the assignment of a

bridge scour qualitative risk rating based on the relation between relative scour depth and the vulnerability of the infrastructure in question. The proposed methodology was validated by a Portuguese bridge case study in Bento et al. (2020), selected due to the changing bathymetry records over time at the bridge site and the availability of relevant flow monitoring data.

2. Scour risk analysis

A. Proposed methodology

The present study addresses bridge scouring, through the development of a methodology to assess how it affects the bridge safety and level of risk. The proposed methodology aims to qualitatively evaluate the risks associated with scour at bridges, caused by extreme hydrological events. The methodology is based on numerical methods and comprises three distinct steps, schematized in Figure 27.

The first step of the methodology consists in obtaining the design floods (peak discharge and associated return period), through statistical analysis. In the second step, through computational hydraulic modeling (HEC-RAS), the river behavior is evaluated, resulting in the characterization of the flood in terms of water depths, velocities, and the maximum scour depth at bridge foundations. Finally, the last step of the methodology (step 3) is dedicated to the qualitative assessment of the scour risk level, through a scour risk rating.

Figure 27: Proposed methodology.

B. Hydrological modelling

In the proposed methodology, the hydrological modelling of the maximum annual flow discharge, at a given bridge site, is performed through a statistical method developed based on Okoli et. al (2018) studies, named modified averaging model (*modified MM*).

The *modified MM* method consists of applying the arithmetic mean to the design flood estimates, obtained by employing probability distribution functions that ensure good performance on both goodness-of-fit tests and graphical methods. Theoretically, this method allows the reduction of model uncertainties by not using a single best distribution function to represent the hydrological series and reduces data uncertainties by performing data reliability tests to assure the quality of the input data. Figure 2 presents a summary of the steps required to obtain the design floods by the *modified MM* method.

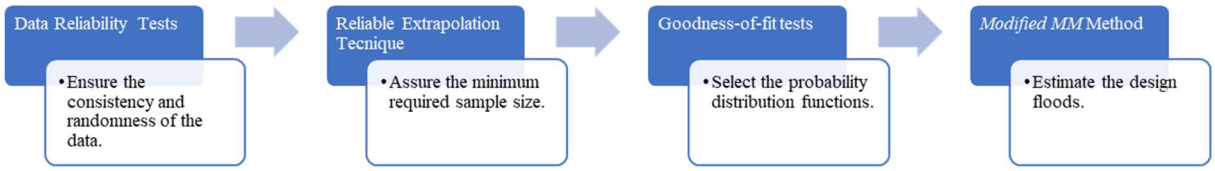

Figure 28: Proposed *Modified MM* method.

C. Hydraulic modelling and bridge scour analysis

The propagation of the design floods approaching a certain bridge section is performed using the HEC-RAS model. To maintain the proposed methodology simple and pragmatic, the simulations are performed in 1D and in steady flow conditions (Figure 3). The Digital Elevation Model (DEM) is

imported using the RAS Mapper routine. Then, the model requires the definition of the cross sections and bridge geometry, including Manning's roughness coefficient, the upstream and downstream boundary conditions (i.e., design floods), and the selection of the flow regime. Once the model is built, the water surface profiles can be computed.

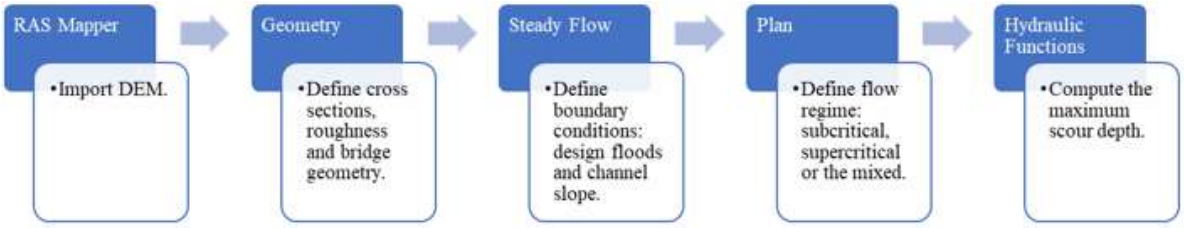

Figure 29: Modelling bridge scour depths using HEC-RAS.

HEC-RAS model also supports a bridge scour computation routine, which allows obtaining the maximum scour depth (sum of contraction and local scour) that can occur on a bridge foundation, through empirical prediction methods incorporated in the software. Other predictors of potential maximum scour depths are also considered, as stated in Bento et al. (2020).

D. Scour risk rating

The scour risk rating (Figure 30), given in Highways Agency (2012), allows a qualitative assessment of how the scouring phenomenon affects bridge vulnerability and its safety. The ratio between the maximum scour depth (D_T) and the foundation depth (D_F), expressed by a relative scour depth (D_R), provides the dominant parameter of the scour risk rating. The D_R is related to a priority factor (P_f) which is dependent on the type of foundation and material on which the bridge is founded, the history of scour problems, the type of river, and the importance of the bridge, as indicated by vehicle traffic volume and other factors. Bridges falling in band 5 have a very low risk of scour damage. In contrast, bridges with risk ratings of 1 and 2 are of greater concern and must be subject to strict monitoring and assessment.

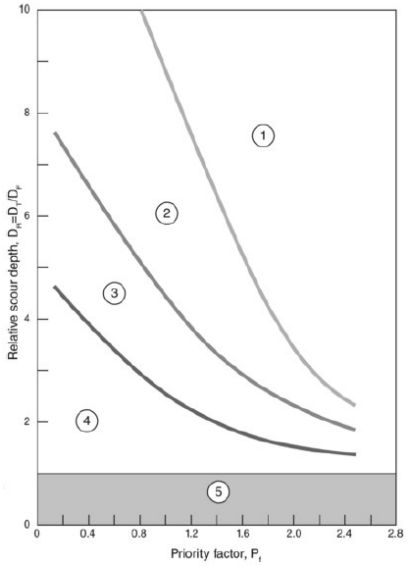

Figure 30: Scour risk rating (Highways Agency, 2012).

3. Conclusions

The proposed three main steps methodology provides a novel and pragmatic tool for rating and assessing scour risk to bridges using a semi-quantitative priority factor. It consists of the assessment of hydrological events, the modelling of the river behaviour, through the computation of flow and bridge scour variables, and the assessment of the bridge scour risk by associating its relative scour depth with the priority factor of such infrastructure and assigning a qualitative evaluation of the scour risk rating. Its applicability to a Portuguese case study bridge in Bento et al. (2020) has validated and made it a useful tool for being incorporated into regular inspection schedules and in the hydraulic design of new bridges.

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Site Production Management: Case Study of the Digitalization of Construction Companies in Portugal

Luís J. Sousa[1], Miguel C. Gonçalves[1], Pedro Pinto[2]

[1] Universidade do Porto, Faculdade de Engenharia, R. Dr. Roberto Frias, 4200-465 Porto, Portugal email: up201604212@edu.fe.up.pt, miguelcg@fe.up.pt
[2] ACA, S.A. email: pedro.pinto@grupo-aca.com

Abstract

Given that its low-skilled labour, low level of digitalization and information integration, characterizes the construction industry it suffers from low productivity and low efficiency compared to similar industries. (Calvetti 2021) (Martins 2009)

From this perspective, this work intends to explore alternatives and outline guides for obtaining data from the construction site, to improve production management on-site through the control of labour, considering the technical capacity of field-based workers. Through the application of technologies, namely mobile applications, is intended to accelerate the transmission of information and the perception of productivity in time to allow managers the power to make educated decisions, removing friction from the control process and the lack of knowledge.

Author Keywords. Building Construction, Mobile Application, Management, Raken, Procore, Integration

1. Introduction

Several technologies are already consolidated in the construction process, such as CAD, or have been gradually implemented, such as BIM. The truth is that they respond to the same theme: the digitalization of the design office. (Martins 2009) Ingenuity is needed to bring the digital world to the construction site. Companies have a crucial role in this technological development as critical players and activators of change. (Laudon 2010)

The use of management apps on mobile devices can solve this issue by bringing more information promptly and concisely to those involved on-site. With these technologies, we seek to remove friction from the production process, shorten cultural distances, and respond to today's trend. Managers want to have more control over the worksite, with fewer visits to it.

2. Methodology and Objectives

The authors approached the scope of this project through the analysis of different labour management applications. The Raken app was the preferred choice considering factors such as availability in Portuguese, other platforms readiness (smartphone, pc, tablet), access to the platform at different entry levels and cloud storage. Direct integration with the software offered by Procore was also decisive, as the reasons for this are explained in Conclusions.

A case study was carried out on one of the projects from the company that made this research possible, where the authors implemented the application.

The project aimed to verify if there was the ability to monitor employees' work by quickly checking whether deadlines are being met through production ratios (e.g., m^2/hr.). And by doing so enable managers to respond to delays through the thoughtful decision making and document errors to correct in the future.

The authors have implemented and adapted Raken's application with the existing general contractor company workflow and tested its ability to respond to the outlined objectives. It was possible to advance the digitalization of on-site processes, namely, obtaining information and sharing data with the administrative hierarchy promoting direct control and active, thoughtful, and sustained management.

3. Case study

A. Proceedings:

The method practised in the application of the software can be summarized in 3 phases:

i. Software Preparation.
ii. Data collection in the field.
iii. Data interpretation and processing.

By configuring the application in its computer version, it was possible to customize de mobile version for its use by a foreman on site. He had the function of gathering data about the job through photo and video collection, filling out daily surveys. But most importantly, by associating quantities with tasks and their cost codes (previously entered through excel sheets and MS project plans, with the option of manual input), thus allowing a comparison with the original planning and making forecasts and estimates of work performance. These actions result in a series of standardized pdf documents that can routinely be sent to management, the most relevant of which are the routine reports (daily, weekly, and monthly) and the production report (Figure 1).

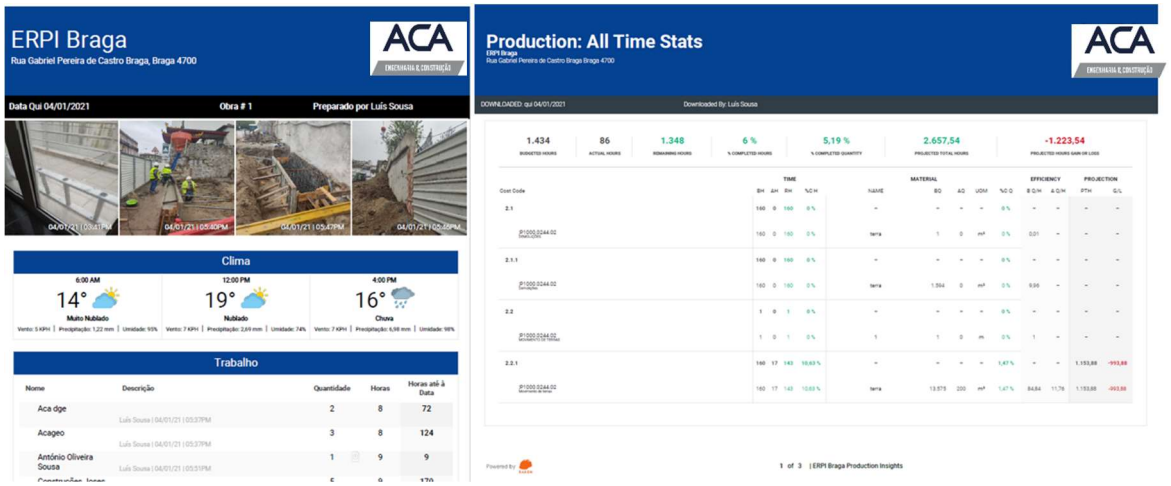

Figure 31: Example of the reports produced by the application during the case study. On the left a daily report, and on the right the production report.

B. System Analysis:

The goal that was initially proposed is answered by the app considering the sample application on-site. This software is a clear improvement to how reporting is currently done that involves written or orally communicated notes that support the weekly measurement reports.

In fact, in this work, it was noticed that the use of a mobile application on-site could be the answer that fits with the context of geographic dispersion, considering the ability of a smartphone to capture video, image and enter text, transforming it into the bridge between the site and the office. Moreover, there was general satisfaction and recognized value amongst the different levels of users, from the foreman on-site to the production manager.

The introduction of tasks with respective cost codes, questions that make up the daily survey, and the customization of the daily report format demonstrate the app's configuration capacity and the possibility to adapt to the specific situation of different companies. Also, sending an automatic e-mail with the daily report to the relevant people is a powerful tool for automatically transmitting the information.

Naturally, the program has some flaws, namely some errors in the translation to Portuguese (such as accents and tilde words). In the limited ability to read inputs, because although it reads CSV files, it only does so if they are in Raken's standardized format (a format that can be downloaded). As a result of this, is needed a considerable effort in terms of transforming the excel planning files typically used in the format which Raken can read.

4. Conclusions

The study concluded that, as expected, the application is a clear upgrade to the way reporting is currently done by the company.

It also concludes that there is a need for some training of employees on how to use the application. This training should not be too complex since the understanding of the software is elementary, with customer support readily available.

From a technological point of view, the study determines that to obtain lasting results for the transmission of information through the hierarchical project management team, a system that allows the integration of software is needed. This software should include all the documents associated with the project (drawings, schedules, reports) in one place and stored in an unlimited cloud service. It should also function as a tool for the collaborative work of the different intervenients in the construction process.

The study suggests Procore as this integration software because it meets the needs and compatibility requirements with the file formats used by the company (PDF and CSV), has unlimited cloud storage, is becoming a requirement in international project specifications, and has direct integration with Raken. This last point is essential in technological progress in the company, thus allowing a phased plan of transition between technologies. In the short term, we plan to use Raken for its simplicity and availability in Portuguese. In the medium term, prepare a team to work with Procore and integrate Raken's reports into its database. And in a long time, transact to the exclusive use of Procore, as it is a more complex software with no Portuguese version available yet. Following this phased plan, the adaptation by the company's staff will become more straightforward, and by then, a business case has been made for the translation into Portuguese by the Procore teams, a guarantee given in a meeting.

The need for further studies to determine the real and long-term impacts that the application of a cross-platform cloud-based integration software would have on a company's productivity is essential.

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Increasing Spatial Scales: Olympic Agenda 2020 and Portugal as Olympic Host

Gustavo Lopes dos Santos[1], Beatriz Condessa[1]

[1] CiTUA - Centre for Innovation in Territory, Urbanism, and Architecture, Instituto Superior Técnico (gustavosantos@tecnico.ulisboa.pt), (beatriz.condessa@tecnico.ulisboa.pt)

Abstract

Recent bidding cycles for hosting the Olympic Games have struggled to attract interested cities due to public opposition against the unsustainability of the event. To mitigate such problem, the International Olympic Committee (IOC) has recently adopted the Olympic Agenda 2020 (OA), which has already driven important changes regarding the Games' urban concept, including the possibility of countries being hosts. This paper compares a previous academic study regarding a hypothetical case of Lisbon bidding to host the event with a new study considering the entire country of Portugal as bidder. It pays especial attention to the country's existing venues, facilities, infrastructures, and planned interventions, as well as to the national territory planning policies in force. Findings show that the OA can generate greater opportunities for the country's territorial development, namely regarding issues of migration patterns, territorial diversity and inclusiveness, polycentrism, and mobility, but requiring larger infrastructure investment.

Author Keywords. Olympic Games, Olympic Agenda 2020, Mega-Event Planning, Spatial Planning, Transport Planning and Territory.

1. Introduction

With modern societies increasingly aware of sustainability issues, the Olympics became seen as excessive and ungovernable, producing weak legacies that highlight the costs of the event and outweigh previous cases of successful urban regenerations (Theodoraki, 2009). Thus, public opposition against the Games increased, resulting in the withdraw of several bids that left few candidate cities to host most recent editions (Hiller & Wanner, 2018). Consequently, the IOC adopted, in 2014, the OA, aimed at adapting the Games' concept to the new sustainability paradigms (Lopes dos Santos et al., 2021). One of the changes regards the possibility of cities, regions, or countries jointly bidding (IOC, 2020).

Prior to the OA, Santos (2015) developed an analysis of Lisbon's urban resources in the case the city was willing to bid, aimed at matching the requirements of the event with the city's existing facilities and planned interventions, highlighting the lack of sufficient high-quality sports venues in the city. Theoretically, the possibility of the entire territory of Portugal bidding for the event would increase the offer of venues, reducing the event's direct capital costs, and potentiating a more spatially equitable distribution of benefits. Possibly, it would also better match the long-term territorial plans of the country and its urban areas. Thus, the objective of this research is to investigate urban opportunities that the OA brings for potential bidders, using a comparison between hypothetical bids from Lisbon and Portugal, and taking in consideration the country's National Program for Spatial Planning Policy (PNPOT).

2. Methodology

Considering the criteria below and the Olympic Programme for Tokyo 2020, Santos (2015, p.45-46) has identified the most appropriate existing and planned sports venues in Lisbon's Metropolitan Area for hosting Olympic events.

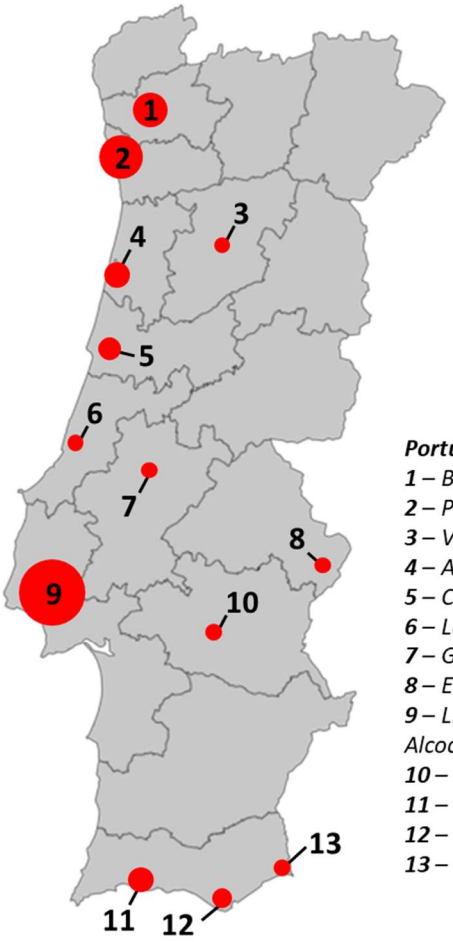
1. Dimension (field of play and spectator capacity)
2. Location (regarding Lisbon's city centre)
3. Relative location (to form clusters)
4. Competition history (national/international)
5. Uniqueness (stand-alone high-quality mono-functional venues)
6. Refurbishment opportunity (prioritizing renovation over new construction)
7. Surrounding spaces (for permanent/temporary works)

Regarding the changes induced by the OA, for the case of Portugal, criteria 2 and 3 are not relevant, making criterion 5 also irrelevant. Criteria 6 and 7 are not applicable, as this analysis aims to compare the case studies regarding existing resources or planned interventions. Both cases consider only stadiums, indoor arenas, exhibition centers, and specialized venues (swimming pools, special arenas, tracks, outdoor fields, and marinas), excluding routes for road events.

3. Results

Results for Portugal's case study are shown in Figure 32. Most venues are located in the largest cities of the western coastal line of mainland Portugal. The metropolitan areas of Lisbon and Oporto (including Braga) hold the majority of the venues. The longest distance by car between any two identified venues is 654kms (5h50, but close to 9h by land public transport).

There is a relatively good scattering of venues throughout the Portuguese territory. In particular for indoor arenas, 6 of the 17 identified venues are outside the metropolitan areas (36% of the spectator capacity). Among the TOP6 with the largest capacity, three are in the interior of the country. Compared to the TOP10 arenas in Lisbon, the TOP10 in Portugal represent an increase of capacity of 40,5%.



Portuguese municipalities with the identified venues *(and its number):*
1 *– Braga (3), Barcelos (1), Guimarães (1), and Vizela (1);*
2 *– Porto (4); Póvoa de Varzim (4); Gondomar (1), and Matosinhos (1);*
3 *– Viseu (1);*
4 *– Aveiro (2), and Anadia (2);*
5 *– Coimbra (1), Montemor-o-Velho (1), and Figueira da Foz (1);*
6 *– Leiria (1);*
7 *– Golegã (1);*
8 *– Elvas (1);*
9 *– Lisboa (9), Oeiras (4), Cascais (2), Benavente (2), Odivelas (1), Alcochete (1), Almada (1), and Barreiro (1);*
10 *– Évora (1);*
11 *– Portimão (3), and Silves (1);*
12 *– Faro/Loulé (2);*
13 *– Vila Real de Santo António (1).*

Figure 32: Map of municipalities with the most relevant venues to host Olympic Games events and media activities.

Comparing to Lisbon, the country's list suppresses the necessity of building new arenas, also leaving Feira Internacional de Lisboa free to host media and broadcasting activities. High-quality exhibition centers exist in almost all the five main venue clusters (except Coimbra). Also, as a legacy of the UEFA European Championship in 2004, half of the 14 identified stadiums are outside the metropolitan areas (43% of stadium's spectator capacity). 15 of the 21 specialized venues are too outside the metropolises.

4. The PNPOT

By analyzing the PNPOT (DGT, 2018, 2020), four strictly interdependent aspects with relevance for the context of this research prevailed, being described in Table 8.

	Diagnosis	Strategy
Migration	Demographic disequilibrium between cities is justified by outer international migrations for job opportunities, and by internal migrations from lower to higher density areas.	Facilitate investment in local development to intensify the connectivity, offer, and accessibility to public services (health, education, social support, justice, culture, sport). Take advantage of weather conditions, security, and hospitality to attract foreign residents.
Diversity	Alternative and collaborative economies, grounded on territorial diversity of local/regional resources, can reinforce the interurban and rural-urban relations, and contribute to mitigate the loss of population in low density areas.	Develop strategies to increase social inclusion and general services, dynamize the uniqueness of local/regional natural and cultural patrimony/resources and promote the development of cross-border interrelationships. Promote a more balanced and polycentric economic dynamic that values the complementarities of regions and their diversified functionalities.
Polycentrism	Very low level of polycentric development, as most urban centers present low density, connectivity, and territorial cooperation.	Focus on the articulation between urban areas, promoting competitivity and stimulating innovation, developing all regions rather than decreasing their differences. Cooperate to improve and capitalize the offer of facilities and transport to be distributed according to the specific needs and levels of specialization, promoting functional versatility and complementarity.
Mobility	Mobility is essential to attract residents and visitors, capturing investment and external income to develop polycentrism. It is necessary to reduce travel necessities and time distances, foster more sustainable modal split and integrated infrastructure networks.	Increase the network's sustainability, contributing for decarbonization, especially within metropolitan areas and in higher density coastal lines. Railways must play an important role and their integration with ports and airports has to be strengthened to enhance international economic dynamics and touristic attractiveness.

Table 8: Subjects in the PNPOT most relevant for the hosting of the Olympic Games in Portugal

5. Towards an Olympic country

The districts and municipalities of the identified venues account for more than 90 and 30%, respectively, of the country's population (INE, 2020), thus allowing almost the entire population to engage with, be part of, and benefit from the Olympics. That would contribute for the promotion of city culture, patrimony, and tradition, increasing site attractiveness for tourism, firm location, economic stimulation, job creation, and city competitiveness, mitigating 'glocalization' and potentiating desirable migration.

Many sports venues (especially outdoor) are outside the metropolitan areas bringing the opportunity for such territories to take advantage of natural resources, culture, and traditions to specialize and become the country's reference for outdoor activities. The territories with unique high-quality venues have the chance to enhance their offer for high-performance athletes.

A good mobility system is essential to mitigate undesirable migration, promote spatial diversity, allow efficient resource exploitation, improve territorial cohesion, inclusion, and polycentrism. It is

also vital for the delivery of the Games, especially if hosted at large spatial scales. With an event's transport demand between 1.5 and 2 million additional trips/day (Bovy, 2004), the country would have to develop some infrastructure projects planned for long and needed for the country's economic development and recovery, as the new Lisbon airport (see Costa Silva, 2020). Also, the high-speed rail (TGV) would decrease Lisbon-Oporto travel time to 93 minutes, with stops in Leiria and Coimbra (RAVE, 2009). Other planned TGV lines have stops in regions with identified venues (GIF & RAVE, 2004; RAVE & GIF, 2009), thus providing for a well-connected Olympic transport network (excluding only the venues in Algarve).

6. Conclusions

In comparison to Lisbon case study, Portugal case study provides the following opportunities:

- higher offer of facilities, in quantity and quality.
- increase cities and country's attractiveness, counteracting migration patterns.
- promote territorial diversity and sport specialization.
- improve the mobility system, accelerating planned interventions.
- increase polycentrism as a consequence of all the former.

The OA positively affects Portugal's potential to bid for the Games, allowing for a better match between the event's requirements and the country's resources and long-term plans. However, an increase in sustainability does not necessarily mean a decrease in costs, especially if interventions regard transport infrastructure. Nonetheless, these interventions have the potential for accelerating the country's economic, social, and urban development.

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Poster-papers

Concrete with coarse aggregates partially replaced by recycled construction and demolition waste

Nara Cangussu[1], Pollyana Ramos[2], Tulio Tolentino[3], Stephanie Rocha[4], Lino Maia[5]

[1]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; UNIMONTES, Center of Exact and Technological Sciences, State University of Montes Claros, Campus Prof. Darcy Ribeiro, 39401-089 Montes Claros, MG, Brazil, (naracan@gmail.com) ORCID 0000-0002-3442-6224

[2]Faculty of Santo Agostinho (FASA-MOC), Civil Engineering Course, 39400 Montes Claros, MG, Brazil, (pollyanalopesramos@gmail.com)

[3]Faculty of Santo Agostinho (FASA-MOC), Civil Engineering Course, 39400 Montes Claros, MG, Brazil, (tuliotolentinoeng@gmail.com)

[4]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (up202010607@g.uporto.pt) ORCID 0000-0002-0984-4897

[5]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; FCEE-UMa, Faculty of Exact Sciences and Engineering, University of Madeira, Campus da Penteada, 9020-105 Funchal, Portugal, (linomaia@fe.up.pt) ORCID 0000-0002-6371-0179

Abstract

The concern with solid wastes has been discussed for some decades in the national and international domains, due to the increase of collective awareness regarding to the environment. The current work aims to analyze the technical ability to produce concrete for non-structural purposes with the coarse aggregate coming from recycled concrete and other construction and demolition waste. Reference specimens were made without the addition of recycled aggregates, i.e. with natural crushed gravel was used as reference. The gravel was replaced by 25%, 50% and 75% coarse recycled aggregates. Concrete strength and workability testes were carried out. Results showed higher concrete strength values for concrete made with recycled aggregates. The replacement of 25% of the gravel by the recycled coarse aggregate resulted in a 21% increase in strength when compared to the reference mix. Then, for the materials tested, it was concluded that the replacement of the natural crushed gravel by recycled aggregate concrete can be carried out in fractions of at least 75% without loss in the compressive strength in the concrete.

Author Keywords. Recycling, Coarse Aggregate, Recycled Aggregate Concrete.

1. Introduction

In Brazil, the amount of waste disposed inappropriately grows with each year, bringing negative impacts on the environment and public health (MMA, 2019). Preserving natural resources and ensuring a decrease of the amount of waste discarded incorrectly, it is important reusing solid wastes and reintroducing them in the production process. Therefore, this work deals coarse

aggregates used in the concrete production, namely with the replacement of the natural crushed coarse aggregates by recycled concrete and construction and demolition aggregates. In this work the effect in the workability and in the compressive strength was evaluated.

2. Materials and Methods

The research was carried out at the Global Eco Environmental Treatment Plant, for the treatment of civil construction solid waste, in Montes Claros, Minas Gerais, Brazil. This plant receives, sorts and treats solid waste from civil construction. These wastes, after screening, they are segregated for treatment in a mobile impact crusher, which generates coarse aggregates (**Figure *1*** (a)), fine aggregates and recycled big stone.

The binder used in the production the concrete cylindrical specimens (**Figure *1*** (b)) was cement Portland CP IV-32. The mixing of the concrete was carried out mechanically, and the rate of the composition used was 1: 1.413: 2.196: 0.370, of cement, fine natural aggregate, aggregate coarse and water.

Figure *1*: (a) Coarse aggregate after treatment and (b) modeled specimen

Reference specimens were made without the addition of recycled aggregates, i.e. with natural crushed gravel was used as reference. The particle size distribution of the natural gravel was close to the recycled aggregate, this being classified commercially with DMC of 9.5 to 25 mm. The gravel was replaced by 25%, 50% and 75% coarse recycled aggregates. The slump test was done in all the mixes produced.

3. Discussion

It is observed that the substitution of the natural gravel for the recycled aggregates, affected the concrete workability negatively. There was a loss of workability between 75 and 90%. This effect was probably due to the greater absorption of the recycled aggregates, which removes part of the water available during concrete mixing. Therefore, it is necessary to add plasticizer additives to maintain the same workability than the concrete produced with natural gravel. Regarding to the compressive strength, the results of the reference mix presented the lower strength. The replacement of 25% of the gravel by the recycled coarse aggregate resulted in a 21% increase in strength when compared to the reference mix. This increase may be due to the greater absorption of recycled aggregates, causing a reduction in the water-to-cement ratio. The increase of the substitution content to 50%, a small reduction in strength was observed – only 4% compared to the 25% substitution mix. With 75% of replacement, there is still a strength increase regarding to the reference mix.

4. Conclusions

From the results, it is concluded that is possible to perform replacements of up to 75% of the natural gravel by the recycled aggregates and obtain concretes without loss of strength. However, these concretes must include higher plasticizer content to achieve similar workability.

The Brazilian standards do not allow the use of these aggregates for structural purposes, however finding of this research showed that possibility should be considered. This application would reduce the landfill disposal for the construction and demolition waste.

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Evaluation of concrete pavers using plastic as fine aggregate

Stéphanie Rocha[1], Jesse Lima[2], Pedro Quintino[3], Daniel Machado[4], Lino Maia[5]

[1]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; UNIMONTES, Postgraduate Program in Computational Modeling and Systems, State University of Montes Claros, Campus Prof. Darcy Ribeiro, 39401-089 Montes Claros, MG, Brazil, (up202010607@g.uporto.pt) ORCID 0000-0002-0984-4897

[2]Faculty of Santo Agostinho (FASA-MOC), Civil Engineering Course, 39400 Montes Claros, MG, Brazil

[3]Faculty of Santo Agostinho (FASA-MOC), Civil Engineering Course, 39400 Montes Claros, MG, Brazil

[4]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (up202010596@g.uporto.pt) ORCID 0000-0003-2082-6371

[5]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; FCEE-UMa, Faculty of Exact Sciences and Engineering, University of Madeira, Campus da Penteada, 9020-105 Funchal, Portugal, (linomaia@fe.up.pt) ORCID 0000-0002-6371-0179

Abstract

Polymers are manufactured in large scale, however, their recycling does not reach large proportions in countries like Brazil. This material can be incorporated into products used in civil construction, as this sector has been standing out in the use of waste, reducing the consumption of natural resources. The purpose of this study was to evaluate substitution of natural aggregate by plastic waste in pavers to decrease the amount of waste in landfills. Dimensional evaluation, water absorption tests, compressive strength and abrasion strength were carried out. According to analyzes carried out, the pavers with plastic did not reach values for the compression required in Brazilian norms, however, it is suggested that the strength found is suitable for walkways.

Author Keywords: pavers, sustainability, recycling, plastic waste, construction materials.

1. Introduction

The increase in solid waste, through the consumption of disposable products such as paper, plastic and glass, caused a decrease in the useful life of landfills, consequently impacting the environment (SANTOS E ROVARIS, 2017). In 2012, Brazil produced around 200 000 tons per day of solid waste, with 13.5% of this amount being composed of plastic (CEMPRE, 2015). The low cost of production and good durability makes its consumption increasing day after day. The incorrect disposal has consequence impacts on the environment due to the materials characteristics – decomposition is not in a short time.

Piatti and Rodrigues (2005) assert that plastics can be synthetic source or derived from natural substances. It is composed of polymers, macromolecules from smaller and repeated structural units. Among several types are Polyethylene (PE) and Polypropylene (PP).

Civil construction sector has caused major environmental impacts as large generators of waste. In addition, it is a large consumer of raw materials. According to data from ANEPAC

(2015), in 2015, approximately 519 million tons of aggregates were produced, in Brazil. Therefore, the search for alternatives to solve these problems is fundamental to reduce the impacts, making it necessary to development of new products.

The substitution of natural aggregates for solid urban waste such as metals, plastic and glass are studied in several investigations. Tiburcio (2018) reused plastic in masonry blocks. Gomes and Santos (2014) analyzed the glass in the manufacture of pavers. Therefore, the present work aimed to evaluate the plastic waste that cannot be recycled as aggregates when applied to pavers. Its viability can be an alternative in cases where the extraction and transport of natural aggregates is extremely reduced.

2. Material and Methods

Laboratory tests, dimensional evaluation, water absorption rate, compression strength and abrasion strength of the pavers, were carried out in accordance with the guidelines and procedures established by the NBR 9781 standard - Concrete pieces for paving, specifications and methods (ABNT, 2013).

2.1. Materials

Plastics used were Polyethylene (PE) and Polypropylene (PP) provided by a recycling company. The sand and gravel were made available by construction material stores. Portland cement used was the CP-V-ARI (NBR 16697), high early strength cement. The granulometric curve of the plastic waste was compared with that of the fine aggregate. About 52% of the tested material was retained in the 2.40 mm sieve and 48% in the 4.8 mm sieve. The fineness modulus was 6.45, higher common aggregate, because of the recycling process, presenting different distributions particle sizes.

The sand was retained in a greater proportion in the 0.3 mm sieve and 0.15 mm sieve, this being last in a volume greater than 50% of the total weight of the sample. The coarse aggregate was characterized as gravel zero, due to its small dimensions, being in a greater proportion between the 4.8 mm to 9.5 mm meshes, a usable value in the manufacture of artifacts of concrete.

2.2. Production of pavers

For the manufacture of the pavers, the mix 1:2.5:2.5 was used, with a water-to-cement ratio in 0.32. The substitution percentages of fine aggregate were 10% and 20%. The formwork for molding used was the segmented with 16 faces and dimensions of 20x10x6 cm. This format is classified as type 1 with a shape close to the rectangular.

3. Discussion

3.1. Dimensional Evaluation

After 28 days, dimensional evaluation test was performed. The values of the dimensions of the samples presented a difference in relation to the size of the formwork, but the variations between the samples of each mix were not greater than ± 3 mm, which is the value required by the standard.

3.2. Water absorption of pavers

The specimens must have a water absorption no higher than 6% to accomplish the specifications of the NBR 9781 (ABNT, 2013). The result indicates that specimens with plastic waste presented practically the same water absorption value than the reference mix, being 5.4% for the reference mix 5.63% and 5.76% for replacements of 10% and 20%. Regarding the percentages allowed, despite presenting values close to limit that standard requires for compositions made with substitution of fine aggregate by plastic waste to present a low permeability, demonstrating one of the main characteristics of polymers is impermeability. Therefore, it was noticed that increase in plastic in pavers increased slightly the water absorption, concluding that the more plastic, the greater the porosity of material, preventing to use of higher percentages of replacement of washed sand.

3.3. Compressive strength

The analyzes show that the reference mix reached a high strength already in first days with 25.11 MPa and had progressive strength increase reaching 35 MPa in 21 days. Therefore, on the twenty-eighth day the reference mix had a high strength gain reaching a value of 37.78 MPa, with an increase of 50.45% in relation to the strength value of the seventh day.

The 10% and 20% substitution mix for plastic also showed high strength values already on the seventh day, however, they showed a lower value in relation to reference mix. During the 7 days both mixes showed an average evolution of 1.77 MPa in their strength value reaching the twenty-eighth day at a value well below the benchmark. While the 10% mix had a compressive strength of 20.69 MPa, a strength 36.39% lower than the reference mix, the 20% mix had a compressive strength of 18.78 MPa, a value less 52.09% than the reference mix.

It was attributed the drop in strength after analyzing the adhesion of plastic in the binder, because it was noted the easy tearing of the fragments after rupture, a fact that implies in the viability of these pavers – there is no exception in the standard for a value less than 35 MPa. However, Fioriti (2007) when studying pavers using tire waste, concluded that values above 15 MPa are acceptable, as long as these blocks are used if only if in places where the predominance use is the pedestrian traffic.

3.4. Abrasion strength

The percentage of mark lost for the reference mix, mix with 10% and mix with 20% plastic aggregate, was 0.36%, 0.84% and 1.96% respectively. It is possible to identify that abrasion wear increases with the substitution of fine aggregates increases. The loss of material results from the adhesion between the plastic with the other components of the concrete, facilitating the material to be fragmented. According (FUSCO, 1995) the adhesion, attrition and interlocking of the connection or mechanical adhesion of the materials intervenes in connection with the other materials. Hypothetically the use of the plastic is greater than the fine aggregate, justifying the growth of the wear mass.

4. Conclusions

It can be concluded that as the percentage of plastic in the concrete mixture increased, there was variation in the values of the tests in comparation with the conventional concrete pavers. Pavers with plastic did not have compressive strength necessary to comply with the standard, because it was noticed that the plastic has little adherence to the concrete mixture. Compared to natural aggregate, the compressive strength of the reference pavers was higher due to the fine particle size of the aggregate, which facilitates adherence to mixtures of concrete. Water absorption and dimensions met the regulatory requirements. Regarding to abrasion strength, the more plastic waste the more loss of material. It was concluded that the pavers produced with plastic waste reduces the efficient use of the raw materials.

Acknowledgment

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BIM as a tool for Facility Management

Ana Thereza Carvalho[1], Lino Maia[2], José Santos[3]

[1]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (up202010594@g.uporto.com) ORCID 0000-0003-4013-6968

[2]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; FCEE-UMa, Faculty of Exact Sciences and Engineering, University of Madeira, Campus da Penteada, 9020-105 Funchal, Portugal, (linomaia@fe.up.pt) ORCID 0000-0002-6371-0179

[3]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; FCEE-UMa, Faculty of Exact Sciences and Engineering, University of Madeira, Campus da Penteada, 9020-105 Funchal, Portugal, (jmmns@fe.up.pt) ORCID 0000-0002-8134-0925

Abstract

Facility Management (FM) involves spaces, people, and processes to manage a built environment with or without technology. The use phase is the longest of the life cycle, which requires a high financial resource and all the building information generated during the life cycle should be stored reliably. Therefore, BIM (Building Information Modelling) technology has been associated with FM due to its ability to offer a reliable database regarding the components of the models, to have a digital representation of the building, which results in maintenance benefits and all building's life cycle. This study aims to show the benefits and some challenges to use BIM as a tool in FM. The results indicated that the use of BIM-FM brings benefits to the maintenance of a building. However, the adoption of this methodology requires changing the work process, maturity level, improve the accuracy of model information, and the adoption of new technologies.

Author Keywords. Operations, Maintenance, Life Cycle.

1. Introduction

In the past few years, some developed countries have been facing challenges in the construction sector due to the low number of new constructions, therefore, activities in this area are focused on modifications, retrofits, and deconstructions of existing buildings (PENTILLÄ; RAJALA; FREESE, 2007; VOLK; STENGEL; SCHULTMANN, 2014). Among the stages in the building life cycle, the use is the longest and can last for decades, therefore, the maintenance is a long process of planning and management required for the proper building operation (SANCHES, 2010).

Facilities Management associated with AEC (Architecture, Engineering, and Construction) are the main keys to efficient management and maintenance, and with less waste of materials and better health promotion for occupants and users of the building space (VOLK; STENGEL; SCHULTMANN, 2014). The association of AEC with FM came to be defined as AECO (Architecture, Engineering, Construction, and Operation). BIM technology emerges as a prototyping platform through three-dimensional modelling and management of building information from conception to the end of its useful life (WONG; SHOU, 2015). For this, the facility manager is responsible to manage the information, which depends on the accuracy and easy access to the data created in the design and construction phase that must remain during the maintenance and operation phase (MOREIRA; RUSCHEL, 2015).

Effective management depends on information, which is required and generated in the design phase, in the life cycle, and the operation and maintenance phase (EASTMAN et al, 2014). Thus, it

is clear how important the source, storage, reliability, veracity, and data handling by professionals involved are so what building development with BIM can facilitate the preservation and functionality of the built environment. In this sense, this article aims to identify through a bibliographic review the benefits of adopting the BIM platform as the main tool in facility management.

2. Materials and Methods

The study was based on a literature review on BIM for FM focus on the benefits, tools, and challenges. The search was performed on Google scholar to retrieve relevant papers and books. The search terms included "BIM", "Building Information Modeling", "Facility Management", "Advantages" and "Tools" limited from 2010 to 2020. In total, 30 papers were chosen. The content of each research paper was thematically analysed to identify its contribution.

3. Results and Discussion

a. Facility Management - FM

According to Brooks and Lucas (2014), facility management is a holistic approach that encompasses operation, maintenance, improvement, and adaptation of buildings to the built environment infrastructure, aiming to create an environment that can attend to the use of the building. Besides that, FM includes information related to the real estate assets, financial management, changes management, human resources, health and safety, contract management, maintenance, cleaning, and service provision. It has the potential to impact the performance and functioning of an edification. So, FM is resource management that attaches locations, people, and experiences in the process management to provide services to support the built environmental (Figure 1).

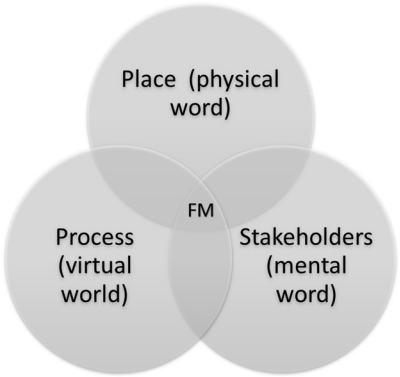

Figure 9: Resource management - FM

b. BIM maturity level and implementation

The project process still is developed linearly, in which the disciplines are not compatibilized and the stakeholders work separately. The change in this traditional process to dynamics for enterprises using BIM takes place gradually. Succar (2009) exposes a structure in which several stages characterize BIM maturity. According to the author, those stages can be divided into three, described as deep changes or transformations, divided

into incremental phases. The stages are implementation, collaboration, and collaboration with a virtual model.

c. Advantages and challenges of BIM-FM

BIM as a tool in FM can bring several benefits to the process such as stakeholders can structure and control the building information during all life cycle, only one model is necessary to manage all the intern systems (energy efficiency, flow of people, maintenance, and security), and 3D BIM model includes metadata. So, it is possible to plan the maintenance building according to the information in the virtual model. However, some challenges must be overcome as the identification of the critical information needed for sustainable operations, the management of information interchangeability between the BIM model and other FM tools, and the difficulty of dealing with lack of information if the construction documentation is incomplete (MCARTHUR, 2015).

4. Conclusions

BIM-based FM is increasing in AECO sector and its implementation should be done by steps until all processes, people, and tools are well integrated. In this implementation, the necessary information must be identified and updated so that the virtual model of the building has real data. The virtual model created can be shared and collaboratively maintained through life cycle so that the maintenance could be planned and done. However, information and data may be lacking in construction documentation, hindering the process of the development of the virtual model and maintenance plane. Despite this, it is possible to implement BIM-FM in existing or new buildings dealing with the challenges of each one.

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Application of silica fume in cored concrete blocks

Stéphanie Rocha[1], Ises da Silva[2], Izael Junior[3], Lino Maia[4]

[1]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; UNIMONTES, Postgraduate Program in Computational Modeling and Systems, State University of Montes Claros, Campus Prof. Darcy Ribeiro, 39401-089 Montes Claros, MG, Brazil, (up202010607@g.uporto.pt) ORCID 0000-0002-0984-4897

[2]Faculty of Santo Agostinho (FASA-MOC), Civil Engineering Course, 39400 Montes Claros, MG, Brazil, (isesjordana@gmail.com)

[3]Faculty of Santo Agostinho (FASA-MOC), Civil Engineering Course, 39400 Montes Claros, MG, Brazil, (izael207@gmail.com)

[4]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; FCEE-UMa, Faculty of Exact Sciences and Engineering, University of Madeira, Campus da Penteada, 9020-105 Funchal, Portugal, (linomaia@fe.up.pt) ORCID 0000-0002-6371-0179

Abstract

The present work proposed the partial replacement of the Portland cement by silica fume in cored concrete blocks with dimensions 14x19x39 cm. Silica fume is coming from the mining and metallurgical companies. Test specimen were produced for the reference mix and for mixes where the Portland cement was partially replaced by silica fume at the rates of 5%, 10%, 15% and 30%. Some physical and mechanical tests were carried out. All mixes reached the acceptance requirements for water absorption, net area and for dimensional stability. Compressive strength values were below the minimum required. The performance of silica fume was satisfactory for replacements of 10% and 15% mix with an increase of compressive strength at rates of 9% and 29% respectively.

Author Keywords: masonry, silica fume, sustainability, materials and construction.

1. Introduction

Structural masonry with cored concrete block provides the main structure and sealing function. It is crucial to use a good cored concrete block, from a new batching to reduce manufacturing costs and meet methods tests and requirements in production and quality control (INMETRO, 2013).

When hydrated cement produces hydrated calcium silicate (CSH) and calcium hydroxide ($Ca(OH)_2$), the latter who has low strength and is soluble in water. The use of silica corrects this deficiency, its reaction with calcium hydroxide ($Ca(OH)_2$) generates a resistant crystal for calcium silicate hydrated (CSH), which benefits concrete with increased strength, durability and impermeability (MEHTA; MONTEIRO, 1994 *apud* HOFFMANN, 2001).

According to Aïtcin (*apud* LEITE, 2015) it is advisable to use a batching between 3% at 10% addition of silica to the concrete. A survey idealized by Fornasier (1995), the most common ones presented in research vary between 5% to 30%, with the percentages of 10% to 15% being the most indicated for improving the mechanical qualities without increasing its cost.

Therefore, this project proposed the partial replacement of Portland cement by silica fume in cored concrete blocks. The silica fume was supplied by the company Minasligas, in the city of Pirapora, state of Minas Gerais, Brazil. This company have four decades of activity, producing silicon iron, silicon metallic and silica fume, meeting the demands of the national

and international markets. This is an exploratory study to discover its potential for application in cored concrete blocks, since in the state of Minas Gerais the cost of silica is 60% that of Portland cement.

2. Materials and Methods

The cement, coarse sand and gravel used were according to NBR 16697 (ABNT, 2018) and NBR 7211 (ABNT, 2009), respectively. Considering the base line, the proportions of replacement of Portland cement by silica fume were 5%, 10%, 15% and 30%.

2.1. Laboratory Tests in blocks leaks of the plain concrete

All tests carried out on the concrete cored blocks were carried out in accordance with procedures described in NBR 12118 (ABNT, 2013). The steps of the water absorption and net area testes are illustrated in Figure 1.

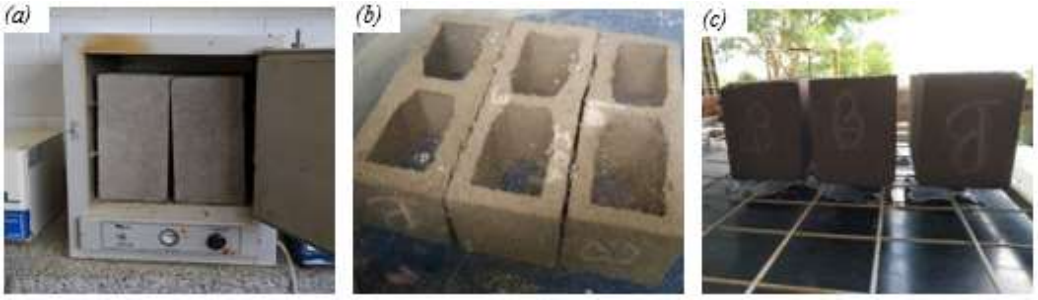

Figure 1: (a) specimens in a stove; (b) specimens immersed in water; (c) drainage.

3. Discussion

3.1. Dimensional Analysis

According to NBR 6136 (ABNT, 2016), the tolerances permitted are ± 2 mm for width and ± 3 mm for length and height. The dimensions of length and width were satisfactory, except for length the reference mix. Regarding to the height dimensions found outside the specified for all mixes, where the value found was above the allowed value, a fact that possibly it occurred because to the molding and manual densification of the specimens.

For minimum thickness of specimen web and face shell the tolerance allowed in the dimensions is -1mm for each individual value. Considering class C, the minimum reference for wall thickness is 18 mm and equivalent thickness is 135 mm – all requirements were met. In the ears dimension, all samples met the specification, since the minimum radius must be 20 mm and considering the width of 140 mm of the block the smallest dimension of the core must be ≥ 70 mm.

3.2. Water absorption and net area

Water absorption index of the concrete block must be checked because a high content outside the levels indicated in NBR 6136 (ABNT, 2016) may result in an increase in the weight of the block, causing pathologies in construction such as cracks, overpressure of foundation, detachment of the mortar and collapse.

The results of the water absorption tests were 9.56% for the base mix and 10.16%, 9.27%, 11.34% and 11.63% for the mixes with 5%, 10%, 15% and 30% replacement of the binder

by silica fume. Already for the net area for reference mix obtained a percentage of 7.3% and the mixes with 5%, 10%, 15% and 30% replacement of cement was 8.67%, 7.9%, 9.59% and 9.74%, respectively. According to NBR 6136 (ABNT, 2016), average water absorption must be ≤ 13% for blocks with or without structural function when lightweight aggregates are used. Furthermore, the concrete cored block, cast in the face lower and upper, must have a net area ≤ 75% of the gross area. Therefore, all requirements have been met.

3.3. Compressive Strength

Compressive strength test can only be considered if the result of relative humidity test of the blocks is between 10% to 40% according to NBR 12118 (ABNT, 2013). The relative humidity for all mixes was between 17.55% and 27.95%. The compressive strength test was: 1.2 MPa for the reference mix, and 1.2 MPa, 1.7 MPa, 2.0 MPa and 1.4MPa for mixes with 5%, 10%, 15% and 30% of replacement, respectively.

The mixes of substitution of Portland cement silica fume at the levels of 10% and 15% obtained respectively 42% and 67% increase in strength when compared to the reference mix. With the hydration of cement produces calcium hydroxide ($Ca(OH)_2$) which causes a decrease in strength, durability and impermeability, silica reacting with calcium hydroxide forms the calcium silicate (CSH) that corrects this strength deficiency (MEHTA; MONTEIRO, 1994 apud HOFFMANN, 2001). Replacements of 5% and 30% presented similar results than to the base mix.

However, the classification of specimens by compressive strength, NBR 6136 (ABNT, 2016) specifies that for blocks with or without structural function of must be ≥ 3MPa. None of the blocks achieved that satisfactory result.

4. **Conclusions**

It is concluded that the replacement of Portland cement by a by-product like the silica fume from the manufacture of iron silicon found in metallurgical and mining companies the in cored concrete blocks in the proportions of 10% and 15% is interesting. In this research some limits specified in standards were not accomplished. Further research on the subject should be carried out, since it is an economical alternative, since the cost of silica fume in the region of Minas Gerais (Brazil) is 2/3 the cost of Portland cement.

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Uses and benefits of BIM in construction management

Daniel Machado[1], Ana Thereza Carvalho[2], Lino Maia[3], José Santos[4]

[1]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (up202010596@g.uporto.pt) ORCID 0000-0003-2082-6371

[2]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (up202010594@g.uporto.pt) ORCID 0000-0003-4013-6968

[3]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; FCEE-UMa, Faculty of Exact Sciences and Engineering, University of Madeira, Campus da Penteada, 9020-105 Funchal, Portugal, (linomaia@fe.up.pt) ORCID 0000-0002-6371-0179

[4]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; FCEE-UMa, Faculty of Exact Sciences and Engineering, University of Madeira, Campus da Penteada, 9020-105 Funchal, Portugal, (jmmns@fe.up.pt) ORCID 0000-0002-8134-0925

Abstract

In the past few years, in the AECO (Architecture, Engineering, Construction, Operations) industry is possible to observe the ineffective planning or missing planning in the project development process is a common problem, which brings on to errors, delays, and undesirable expenses in the budget. It can happen due to the processes is not being well defined, lack of information and definition of the assignment process, or the non-implementation of technological tools to help solve those problems. In this context, the present paper aims to identify the benefits of using Building Information Modelling (BIM) technology in construction management and construction management brings in the stages of a project. The results showed that the knowledge of the process, the standardization of steps, the training of the team, the definition of the level of detail (LOD), and the flow of information are required for 4D planning.

Author Keywords. BIM, 4D Planning, Construction Management.

Introduction

The use of BIM technology as an auxiliary tool to development of projects in the construction industry was introduced in the '70s in the works of Charles M. Eastman, however, this methodology only started to be used later (YESSIOS, 2004). It was possible to observe that some BIM concepts have been improved over the time, however the implementation of BIM in a building is presented in a segmented and paper dependent (EASTMAN et al., 2011).

The AECO industry is seeking for new technologies to obtain better results in productivity, quality, and development in the construction sector, so BIM can represent a potential solution. This technology is a virtual process to encompasses all aspects related to disciplines and systems of a building in a single model, allowing all members of the design team (owners, architects, engineers, contractors, subcontractors, and suppliers) to collaborate more accurately and efficiently than using traditional processes. (AZHAR, 2011). This paper aims to analyse the uses and benefits of adopting BIM methodology for construction management.

Materials and Methods

The literature review aimed to reveal the meaning, uses, benefits, and obstacles of BIM 4D for the process of management and planning of projects and undertakings under construction. A bibliographic survey was carried out during January and February 2020, in the databases of the

CAPES periodical portal. 44 papers and documents were found, having as descriptors: Planning and management, BIM and BIM 4D.

Results and discussion

Project planning is the process that aims to determine the objectives of a project identifying the activities to be performed, methods and resources to be used to complete the pre-established tasks (AACE, 2011). The fourth dimension (4D) of the BIM is the planning process that seeks to link construction activities represented in schedules and the 3D models performing, and the graphic representation of the construction process against time (ABDI, 2017).

A. Uses of BIM 4D

BIM 4D approximates the design in real construction, not only in space but also in time. It is being used to correlate planning activities to objects and/or terrain (SHEINA et al., 2018). This dimension allows the participants to extract and visualize the sequence of activities that will happen in the works or throughout the life cycle project (SHEINA et al., 2018). The schedules used traditionally by AECO companies do not provide sufficient information about the spatial context and the complexity of the components of a project, causing an abstract representation of the planning (BIOTTO; FORMOSO; ISATTO, 2015). The 4D model is created from a 3D model linked to a detailed work plan, so the elements or groups of elements, as shown in Figure 1. This association can combine tasks and deadlines (SHEINA et al., 2018).

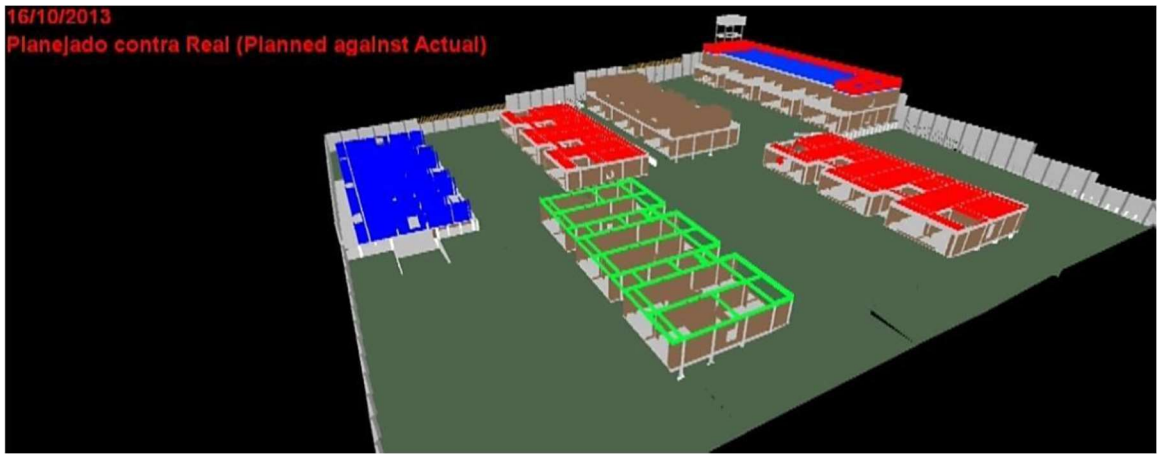

Figure 33: Representation and analysis of the planning and control of works using the BIM (BRITO; FERREIRA (2019)

This is a powerful resource that can guarantee a high level of understanding and alignment between the main stages of a project and the construction (CBIC, 2016). The adoption of this system the occupation plans can be dynamized and propose multiple options and solutions for space conflicts. Moreover, aligning the model with the planning and estimated cost of the material, there are cost reductions in the integration between human resources planning, equipment, and materials management (Pennsylvania State University, 2019).

B. Benefits of 4D BIM

A 4D BIM model is a powerful resource that can guarantee a high level of understanding and alignment between the main stages of a project and the construction (CBIC, 2016). With the adoption of this system the occupation plans can be dynamized and propose multiple options and

solutions for space conflicts. BIM can improve this area providing technological support with innovative uses of the processes, also can improve the development of construction cost planning and management (ABDI, 2017). The correct use can serve to generate information of high added value for the planning activities of the construction phases, quantitative survey, study of logistics, organization of the construction site, definition of deadlines, presentation of the actual stage versus planned progress, cost estimation, financial and economic management and, finally, support for work safety (ABDI, 2017).

Conclusions

The BIM platform in 4D planning can improve the management of information, the planning of construction stages, the organization of the construction site, the survey of materials required in each stage, etc. However, successful 4D planning requires, for example, knowledge of the process, standardization of construction steps, and team training.

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Advantages of using of BIM methodology in civil construction

Ana Thereza Carvalho[1], Daniel Machado[2], Lino Maia[3], José Santos[4]

[1]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (up202010594@g.uporto.com) ORCID 0000-0003-4013-6968

[2]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal, (up202010596@g.uporto.com) ORCID 0000-0003-2082-6371

[3]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; FCEE-UMa, Faculty of Exact Sciences and Engineering, University of Madeira, Campus da Penteada, 9020-105 Funchal, Portugal, (linomaia@fe.up.pt) ORCID 0000-0002-6371-0179

[4]CONSTRUCT-LABEST, Faculty of Engineering (FEUP), University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; FCEE-UMa, Faculty of Exact Sciences and Engineering, University of Madeira, Campus da Penteada, 9020-105 Funchal, Portugal, (jmmns@fe.up.pt) ORCID 0000-0002-8134-0925

Abstract

AECO (Architecture, Engineering, Construction, and Operation) sector evolution requires the introduction of computational technologies that assist in the development of new virtual building processes. In this sense, BIM (Building Information Modeling) technology has been increasingly used as the main tool in the development of building design. This study presents a review of publications on BIM adoption in AECO industry and a simulation of a virtual building model and aimed: showing the benefits of using BIM as a design tool; analysing the virtual simulation according to a defined schedule; evaluating the clashes between the disciplines in a unique model; evaluating the quality of the design and incompatibilities among them; and evaluate the practicality and the automation process. According to the results, BIM facilitates the development of all disciplines, reduces time spent, and detects issues in the design stage.

Author Keywords. Technology, Efficiency, Building Information Modeling.

Introduction

The traditional building design approach is divided into several parts and involves different professionals who do not usually communicate with each other. In this process, the design disciplines are developed separately at different times, which results in disciplines incompatible, lost information, cost increase, issues during the building, etc. However, the AECO sector has been more demanding, and the use of building technology tools is increasingly frequent to comply with the requirements. For this, BIM emerged to improve the project process. It is an efficient building information management system that exchanges and storage data (AYRES; SCHEER, 2007). This technological tool uses a 3D building model to simulate a real building and unify all building phases, from conception to execution, including maintenance, monitoring, and management (EASTMAN et al., 2008). The BIM model works as a single database that stakeholders can access, use, and share the same design (TARRAFA, 2012). However, unlike the traditional design approach, the tool requires team integration which is the primary influence on results obtained (SOUZA et al., 2009). The present work aimed to analyse the advantages of using BIM in building development from a virtual model.

Materials and Methods

This study presents a review of publications on BIM adoption as a tool in AECO industry and a simulation of a virtual building model. It aims to evaluate the benefits, available tools, and challenges in BIM adoption. The scope of this research includes papers and books searched on Google Scholar. The search terms included "BIM", "Building Information Modeling", "BIM uses", "BIM tools" limited from 2002 to 2016. Twenty-three papers were chosen and analysed to identify their contribution.

The virtual building model has four identical floors, each with two apartments containing two rooms, one living room, one kitchen, and a service area. The architectural design was initially developed in AutoCAD, even though it is not BIM software. The BIM modeling software chosen was Autodesk Revit due to easy handling, interoperability, parametric modeling, bidirectional associativity, i.e., automatic changes across the model. Besides that, this software has several extensions that allow modeling architectural, structural, and plumbing disciplines, but only two disciplines were developed in Revit. The structural design was developed in TQS software due to its plug-in inside Revit, therefore it was not necessary to use the IFC format. Then, the structural elements were scaled considering the user loads and the minimum dimensions of each. After that, all disciplines were imported to Revit to obtain a unique model to detect clashes between the disciplines (Figure 1), even though this software is not the most suitable for it.

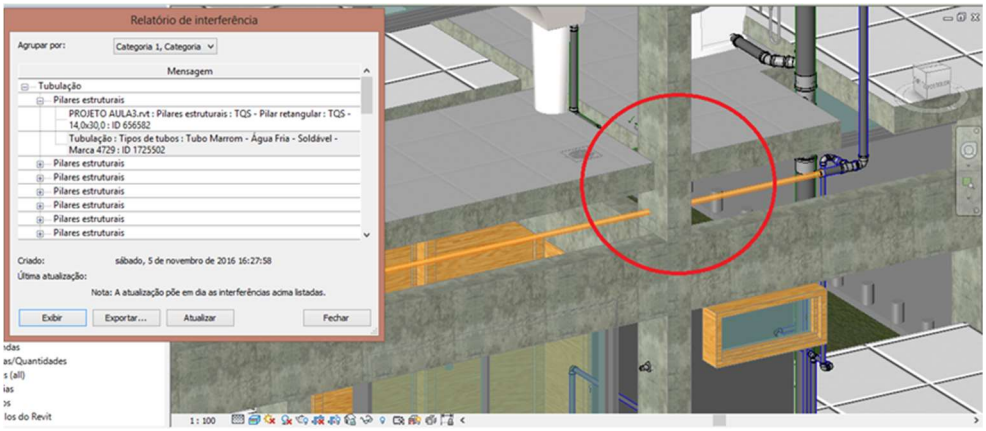

Figure 1: Clash detection

Results and Discussion

Concerning the time spent, the architecture design developed in AutoCAD took more time than the same design developed in Revit. This BIM tool has parametric objects, i.e., the components are dynamically changed instance-based objects (HILGENBERG et al., 2012; EASTMAN et al., 2008). During the design development, all parts (plan, façade, sections, views, 3D model, etc.) are developed simultaneously. The architectural design was used as a bond to develop the other disciplines, which assures its automatic update. Then, all disciplines clashed in Revit and 38 clashes between structural and plumbing disciplines were reported. The software shows those clashes through report format, Table 1, which includes the element ID, name element, and discipline. It was realized some clashes are not always a mistake, as a hole an unplanned hole in a beam for the pipe to go through. This technology also allows association between 3D models and building schedules, i.e., 4D planning. Thus, it is possible to follow and view the building steps virtually (SUZUKI; SANTOS, 2015).

Clash	Plumbing Element	Structural Element
01	Brown tube – Cold water: ID 1726345	Rectangular pillar: TQS – 14,0x30,0: ID 656579
02	Brown tube – Cold water: ID 1726552	Rectangular pillar: TQS – 14,0x30,0: ID 656582
…	…	…
38	Brown tube – Cold water: ID 1765881	Rectangular pillar: TQS – 14,0 x 40,0: ID 659371

Table 1: Report clashes

Conclusions

Design compatibilization is a process not widespread in AECO sector and many issues are solved during the building. The 3D model BIM and clashes report facilitates the issue identification even in the design stage, reducing cost and building rework. BIM allowed a better and faster development of all design disciplines, even though all BIM features were not explored. However, it is necessary high initial investment in software, structure, and training, but this expense is compensated over time. The 4D planning showed a virtual simulation of each building stage according to a defined schedule.

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