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8TH AECEF SYMPOSIUM

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FOREWORD

Sustainability of the world has become a pressing concern for Society, especially for younger generations. Energy is becoming scarce and expensive and the tendency is that these characteristics will worsen in the near future. The Civil Engineering profession has a major responsibility in addressing these two global issues. Civil engineers have the knowledge, attitudes and skills to help the World becoming a better place with positive prospects for the future.

These are the main motivations for the AECEF Symposium in Porto in 2015. Stakeholders of Civil Engineering (teachers, researchers, engineers, companies, government agencies, professional associations, NGOs) are invited to participate, share and debate innovative ideas, experimental results and education curriculum. The AECEF Symposium 2015 is the perfect Forum to get together and prepare proposals for a better endeavor to Civil Engineering.

Porto, November 2015

SCIENTIFIC TOPICS

DEALING WITH ENERGY

New materials for sustainable construction with eco-friendly properties and durability for building of the 21st century

Energy efficient solutions for new buildings

New generation of material and energy efficient systems

INNOVATION IN CONSTRUCTION

Rehabilitation, renovation and reconstruction for a sustainable built-environment

BIM and sustainable construction: engineering education and practice

Innovation in education and training processes in sustainable construction

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Water and waste sustainable management

Quality evaluation in sustainable construction

Life-cycle analysis in civil engineering

BUILDING FOR FUTURE GENERATIONS

Construction site waste minimization and management

Civil engineering in a sustained world

Responsible retrofitting of built environment

CONTENTS

BUILDING INSPECTION AND PATHOLOGY DIAGNOSIS IN BUILDING RESTORATION. CASE STUDY.

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Abstract

The legal framework for urban development and building in Portugal, revised and updated in the past year, calls for mandatory conservation works every 8 years. This statutory requirement stems from the Portuguese culture for building restoration, which consists of intervening the buildings only when anomalies arise, rather than consistently over time, through premeditated maintenance schedules.

The role of the designer in the restoration of buildings is not yet mandatory, either legally or from the users' point of view. This leads to a general market practice which tends to favor unplanned and sporadic interventions, which more often than not, leave the main issues unresolved. Still, the essential role of a reflective anomaly diagnosis and comprehensive restoration project is widely accepted by both scientists and professionals alike.

CEES, which stands for Study Center for Building Maintenance, arose from the belief in the role of technological and scientific development in the search for effective and lasting solutions for the maintenance of the Portuguese built heritage. The accumulated knowledge of CEES is intended to be an asset for all professionals in several sectors relating to building maintenance and restoration.

This paper focuses on the inspection and diagnosis study developed by the researchers at CEES on a housing development in a coastal village from northern Portugal.

The paper will introduce the CEES method for inspection and diagnosis and concisely present the work carried out by CEES, structured by the following stages: Current state evaluation; Anomaly description for each maintenance source element; Exam (Constructive reconstitution, Similar events, Tests and measurements); Possible causes; Proposed repair approach; Cost estimation.

Keywords: building maintenance, building restoration, building pathology.

1 INTRODUCTION

The present paper will focus on an actual inspection and diagnosis study requested by the building's management team in order to assess its main anomalies and propose a method for repair.

The buildings constitute a gated housing development with 19 entrances and consists of 156 apartments, five stores, one show hall and three restaurants (Fig. 1). Its construction began in 1997 and ended in 2003.

Fig. 1 – General exterior view of the housing development under study.

The development is located on the waterfront, in a small coastal village from northern Portugal (Fig. 2).

Fig. 2 – Spatial context of the housing development under study [1].

2 METHODOLOGY

The inspection and diagnosis study begins with an evaluation of the building's users perception of its anomalies, as well as its distribution throughout the buildings, made by means of a survey.

With the survey as a guide, a round of preliminary technical visits is conducted to infer the conditions of the buildings' main components – structure, envelope, power grid, etc. – which leads to the recommended stages for an inspection and diagnosis study:

- Current state evaluation – this stage serves as a preliminary screening for further diagnosis. It is often based on the accounts of residents, the building's manager and the original developer, on visual observation, and the consultation of the building's design projects. It also provides for restricting the scope of constructive elements for further investigation;
- Anomaly description for each maintenance source element;
- Exam – set of procedures carried out in order to understand the phenomenon in its entirety and identify the "cause-effect" mechanism in question. These steps should be performed iteratively and without any chronological sequence [2];
    - Constructive reconstitution – aims to achieve the knowledge of the solution of the constructive element in which the anomaly has developed. This information is to be further assembled into a detailed drawing [2];
    - Visual inspection – this step aims to understand the spatial development of the anomaly, checking not only the area directly observable, but also, when necessary, other adjacent compartments or floors on the same building [2];
    - History – at this stage, we intend to gather useful information about the pathological phenomenon under study, such as the time on which it first became noticeable, how it developed over time, if it reveals any cyclical characteristics and whether or not it coincides with any specific activities or events [2];
    - Similar events – this procedure aims to identify, by visual observation and inspection of the building, other anomalous events whose behavior is analogous and suggests the same "cause-effect" mechanism, which may help diagnose the anomaly's cause [2],

    - Tests and measurements – in order to establish and support a certain diagnosis, it is sometimes necessary to use experimental tests in order to investigate certain behavioral hypotheses [2];
- Possible causes (diagnosis);
- Proposed repair approach – this chapter aims to constitute a proposal to be built on in the design stage;
- Cost estimation – this is an essential stage when conducting this sort of study. The estimation of costs allows the building's managers and owners to make decisions for further detailing of the repair intervention.

3 ANOMALIES LISTING

Following the preliminary evaluation conducted on the Current State Evaluation phase, the diagnosis efforts focused on the following maintenance source elements: exterior walls, interior walls, balconies, terraces, roofs, windows and basement.

The following anomalies were found on exterior walls: cracking of the exterior coating, degradation of the grouting on ceramic tiles, degradation of the expansion joints, visible dampness on the base of the wall's interior face, stains from drippings on salient structures, cracking in the vicinity of some expansion joints.

The following anomaly was found on interior walls: cracking of the coating plasters.

The following anomalies were found on balconies: Degradation on jambs and outer links of glass brick panels, degradation of the stone sills which cap the balconies parapets, puddles of water accumulating on balconies' floors, corrosion of metal guards, corrosion on the metallic panels in suspended ceilings, cracking and calcareous spots on the floor's ceramic tiling, drippings on outer walls of planter elements.

The following anomalies were found on terraces: deficiencies on the waterproofing of the floors due to past modification (ceramic tiled roofs became terraces) and calcareous spots on the floor's ceramic tiling.

The following anomalies were found on roofs: deficiencies in the capping of parapets, general degradation and sealing deficiencies on the bituminous waterproofing membranes, and extensive cracking on chimney masonry elements.

The following anomalies were found on windows: cracking and excessive wear on stone window sills, extensive corrosion on window profiles, and dampness in the vicinity of glass brick windows.

The following anomalies were found on the basement: rising damp on floors and sporadic signs of water infiltration on ceilings.

Given the extent of the present study, this paper will focus only on one of the anomalies.

4 DIAGNOSIS EXAMPLE - DAMPNESS IN THE VICINITY OF GLASS BRICK WINDOWS

There were clear signs of degradation from dampness on the coatings in the vicinity of these window elements. Some of the glass bricks were cracked and/or broken. Several interior reparations had been made, but the anomaly was recurring.

Moisture levels were measured to establish the moist boundaries around the windows. The moisture presence wasn't coincident with the cracks on the glass bricks

The constructive reconstitution was reproduced from the reports of the building's developer, as shown on Fig. 3.

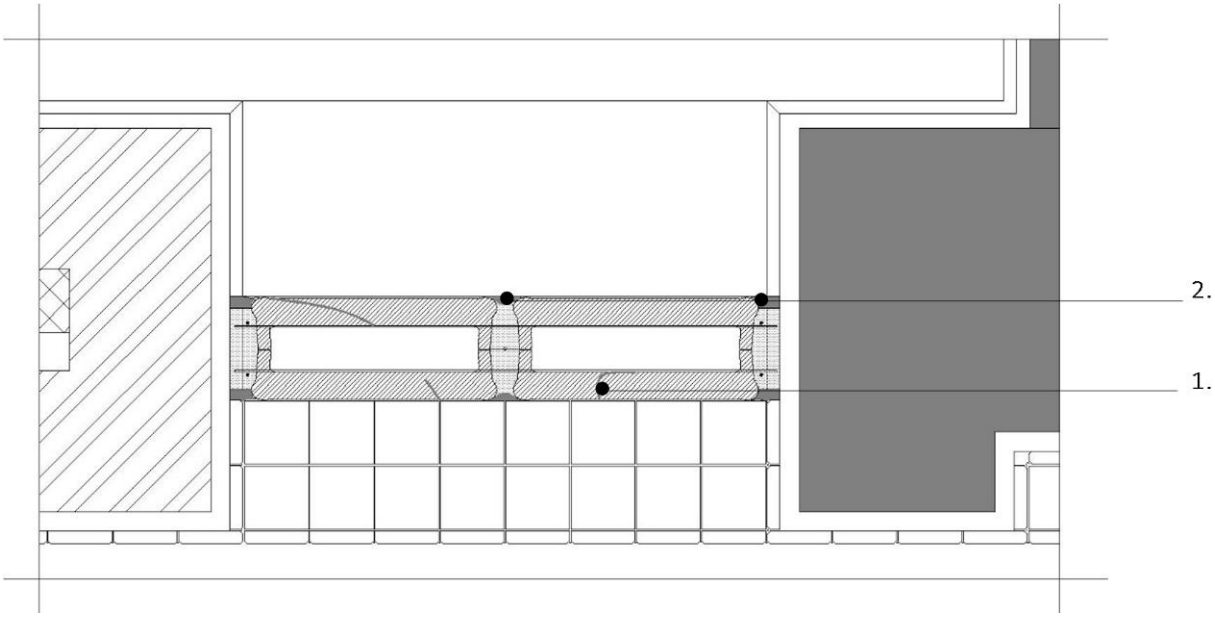

Fig. 3 – Detailed drawing of the constructive reconstitution of the glass brick windows [3].
Figure legend – 1. Cracked and / or broken glass brick; 2. Deficiencies in mastics.

In addition to being very large panels, the vast majority of these glazed elements were supported by cantilevered slabs (Fig. 4), which meant increased stress on the glass structure.

Fig. 4 – Configuration of the glass brick structures under study.

Glass brick structures demand for rigorous movement restraint in order to prevent cracking and/or collapse, particularly in larger panels, as was the case. These restraints are traditionally achieved by two methods: continuous restraint along the entire vertical edge of the glass brick structure, obtained by using metal sections or “U” section channels; or dowel restraint obtained by extending the reinforcement bars, which are used in all horizontal joints, into holes in the adjacent loadbearing vertical structures. In order to avoid friction with the surface, a slip joint should be provided for at the base of the wall, as well as expansion joints on all connections (Fig. 5).

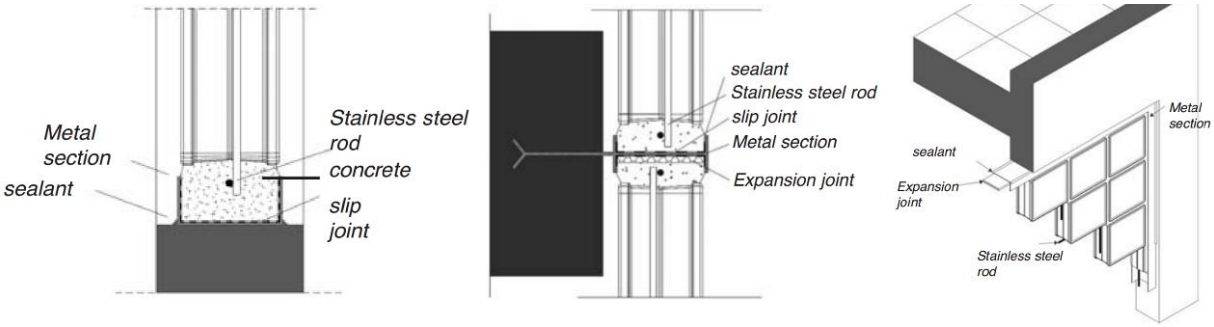

Fig. 5 – Restraining detail examples for glass brick installation with the traditional system (cement mortar) [4].

The glass brick panels found on the building lacked most of these restraining elements, namely reinforcing bars on joints, anchoring devices on edges or stiffeners on intermediate floors. All connections were achieved by means of simple mastic joints.

The movement of the building when submitted to the strong coastal winds, adding to the creep effect on the base slabs, led to increased cracking on the glass brick structure, as well as on its surroundings, due to the existence of adjacent concrete reinforcements. These concrete reinforcements provided a link between the exterior and interior masonry panels, which by means of the exterior cracking provided a direct path for rain waters that ran down the façade and penetrated the cracks.

The proposed repair approach includes the complete demolition of the glass brick wall, along with the removal of the coatings and ceramic tiles on the interior and exterior of the window jambs. A meshcloth reinforced render shall enclosure all of the glazing's jambs. The reconstruction of the glass brick structure shall include adequate movement restriction, as previously mentioned. The architectural integrity of the facade will be compensated through the application of a lacquered sheet aluminum rim profile (Fig. 6).

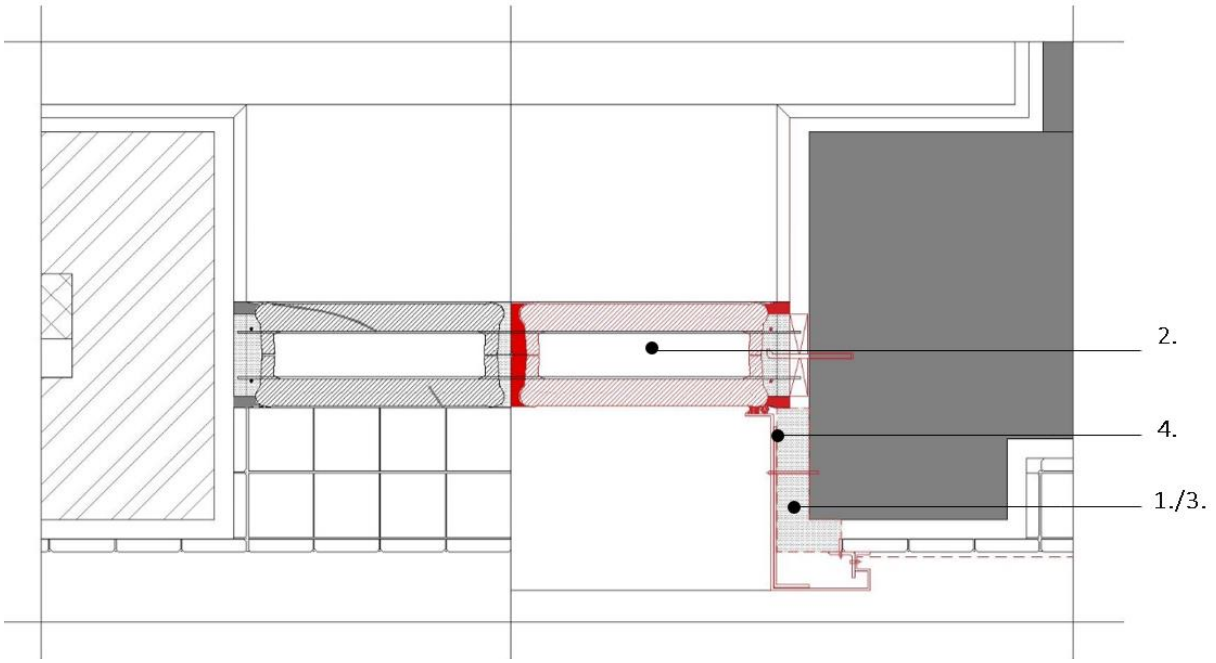

Fig. 6 – Proposed repair approach for glass brick window anomaly [3].
Figure legend – 1. Remove the outer coating of ceramic tiles and grout on the perimeter of glass brick window. 2. Demolition and reconstruction of glass brick panel; 3. Application of glass fibre mesh reinforced polymer render; 4. Application of outer aluminum rim.

5 CONCLUSIONS

Research findings indicate that buildings account for one third of global greenhouse gas emissions [5], which leads to growing concerns for sustainability and cost effectiveness on every aspect of building management.

Building restoration can be a major factor of spending on a building's lifespan, whereby the durability of these kinds of interventions are paramount. Thus, trial and error is not an acceptable approach for repairing constructive anomalies, which calls for a preliminary diagnosis that points the intervention in the right direction.

The findings of an elaborate and conclusive inspection and diagnosis study restrict the scope for both design and construction phases of a repair intervention, while also providing valuable information for the building's maintenance tasks and their efficient scheduling.

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ACOUSTIC BEHAVIOR OF TRADITIONAL BUILDINGS

ACOUSTICS CHARACTERISTICS SUPPORTED BY SITE MEASUREMENTS

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Abstract

Buildings are part of a country's national heritage, they are part of a community culture and so they must be well cared-for and restored. In particular traditional buildings that regularly characterize the center of our cities, present us the challenge of being updated without losing their uniqueness. Acousticians frequently are in the center of that challenge facing traditional solutions that must fulfill present acoustical requirements.

This paper presents the research carried out by the NI&DEA group focused in the development of acoustical constructive solutions for the rehabilitation of traditional XIX century buildings.

Original constructive solutions are typified regarding both architectonic and acoustic characteristics supported by site measurements.

In order to apply technical improvements to enhance the performance of traditional constructive solutions, we first need to understand how these solutions work and perform in real life conditions.

This paper aims to characterize the acoustics parameters of original constructive solutions in order to enhance the rehabilitation of these solutions.

Airborne sound insulation ($D_{nT,w}$, $D_{2m,nT,w}$) and impact sound insulation ($L'_{nT,w}$) tests were performed on external walls with windows or doors, wooden slabs and interior partitions.

The potential demonstrated by these enhanced traditional solutions predicted a shift in current paradigms of building rehabilitation and will allow acousticians to support the heritage challenge for buildings.

Key Words: Building Acoustics, Building Rehabilitation, Site measurements.

1 INTRODUCTION

The focus on rehabilitation of the historic cores of cities led to an increasing demand for properties for different activities. The operation hours and characteristics of these activities added performance requirements of buildings that take place.

Currently the rehabilitation operations that take place in the oldest urban centers of our cities tend to replace all the interior solutions and preserve only the facade elements.

Adapt the traditional solutions to current standards of comfort can become arduous since the information on the performance of these solutions is unknown.

Some studies have been conducted in this area, generally centered on concerns inherent to the aesthetic and architectural restoration of buildings.

In "Acoustique et réhabilitation" (Acoustics and Cultural Heritage Management), Christine Simonin-Adam [1] deals with the problems of adequacy of new constructive solutions for existing buildings as well as the requirements of acoustic comfort, thus presenting a range of technological solutions to improve the acoustics in the restoration of existing buildings.

The restoration of historic buildings involves specific requirements arising from their patrimonial value. Architectural elements such as the facades and flooring are the most significant part of its aesthetic and historic value.

This paper aims to characterize the acoustics parameters of original constructive solutions in order to enhance the rehabilitation of these solutions.

2 BUILDING UNDER STUDY

This paper addresses the heritage buildings on the old city of Porto built on the time period between the 19th century and the late 20th century. The historical core of Porto is home to a set of buildings of undeniable historical value.

The most charismatic element of these buildings are the facades, mostly composed by stone masonry, with thicknesses that can reach the 80 centimetre mark. The final coating of these walls are painted or ceramic tiling. Stone artwork is not unusual on elements like windows, balconies or cornices.

The glazed areas complementing these facades include iron or wooden framing with single pane windows with thicknesses around four millimetres. The window-framing connections are made by the use of studs with a special paste sealing. Solar protection is guaranteed by interior wooden shutters.

It is ordinary on some buildings the use of wood and plaster on exterior walls on floors added after the construction, which is a solution usually applied on interior walls. These walls are composed by vertical and horizontal rows of wooden boards which served as a base for thinner wooden tyers on trapezoid shape. This thinner wooden framing provides for the adherence of the coating plaster. Externally the walls are covered in ceramic tiling, slates or undulant zinc plate.

The wooden structural pavements are another vital element in these buildings. These floors consist of main beams arranged parallel to each other, spacing and dimensions of sections dependent on the span. The sections of the beams are usually rectangular, or in some cases with the trunk wood.

The beams sat on resistant walls and their connection was performed by means of bolted plates directly on the wall or by means of a belt wooden beam which distributed the loads onto the resilient walls.

As flooring, the use of wooden floorboards was the preferred solution. The ceilings were performed by placing a lining consisting of lath nailed to wooden planks that were nailed to the main beams. The lining of ceilings was performed by filling and regularization with mortar and stucco finish. The ornamentation of ceilings and walls in prime areas such as living rooms and hallways through perimeter frames, and sometimes in the centre of the compartment, was frequent.

3 METHOD

In order to understand up to what point the improvement of traditional solutions favours acoustic insulation of spaces, it is important to assess the acoustic behaviour of traditional buildings.

Our main objective is to understand the performance of traditional solutions on centennial buildings. In order to achieve this goal we begin by running some site measurements on different constructive solutions on Portuguese centennial buildings. In order to apply technical improvements in these solutions we first need to understand the real performance of these solutions.

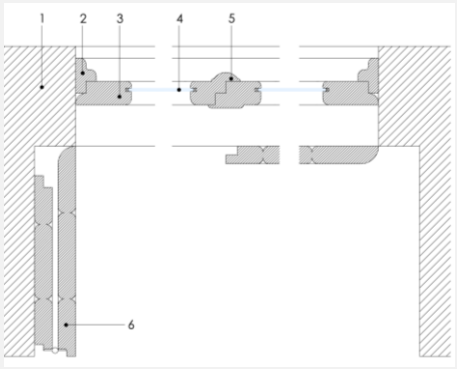
The tests were performed in accordance with the NP EN ISO 140-4, EN ISO 140-5, EN ISO 140-7, EN ISO 717-1 and EN ISO 717-2.

3.1 Site measurements

Keeping as an objective the prioritisation of rehabilitation activity for historic buildings, the following figures present the results obtained from measuring operations.

Table 1 – Obtained results for external walls by site measurements.

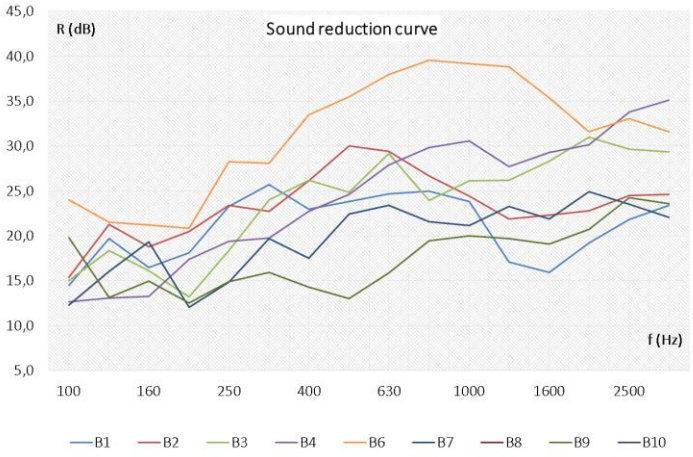
Traditional solutions for external walls



Source and receiving room

Key:
1 – Stonemasonry with thickness higher of 20 cm; 2, 3, 5 – Wood Window; 4 – Glass with thickness of 4 mm; 6 – Shutters.

Site measurements curves by building under study



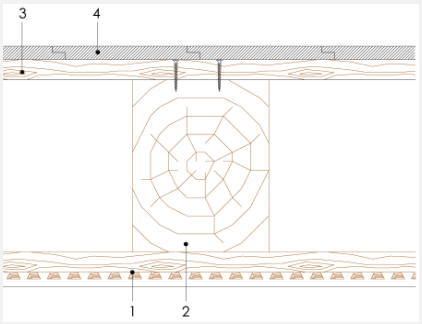
	S (m^2)	V (m^3)
B1	25,80	116,20
B2	18,10	116,00
B3	9,80	62,10
B4	29,10	70,00
B5	20,90	156,75
B6	13,00	32,50

S – Area of the test element

V – Receiving room volume
B – Building under study

Table 2 – Obtained results for structural pavements by site measurements.

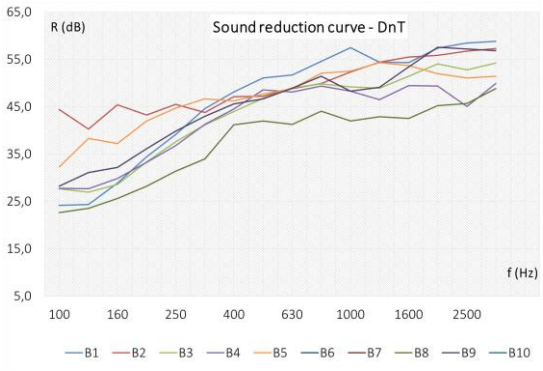
Traditional solutions for structural pavements

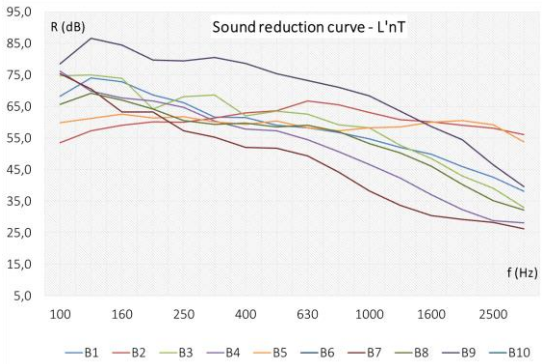


Source and receiving room

Key:
1 – Ceiling (Wooden planking (≈ 20mm); Lath (≈ 20mm); Mortar filling, stuccoed and painted); 2 - Structural wooden beam (≈ 25cm); 3 – Wooden planking (≈ 20mm); 4 - Surface casing in wood (≈ 20mm).

Site measurements curves by building under study





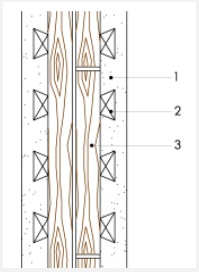
	S (m^2)	V (m^3)		S (m^2)	V (m^3)
B1	28,40	116,20	**B6**	41,25	156,75
B2	28,20	116,00	**B7**	7,80	32,50
B3	31,00	62,10	**B8**	-	-
B4	15,00	70,00	**B9**	17,40	32,50
B5	6,9	20,7	**B10**	-	-

S – Area of the test element

V – Receiving room volume
B – Building under study

Table 3 – Obtained results for interior partitions by site measurements.

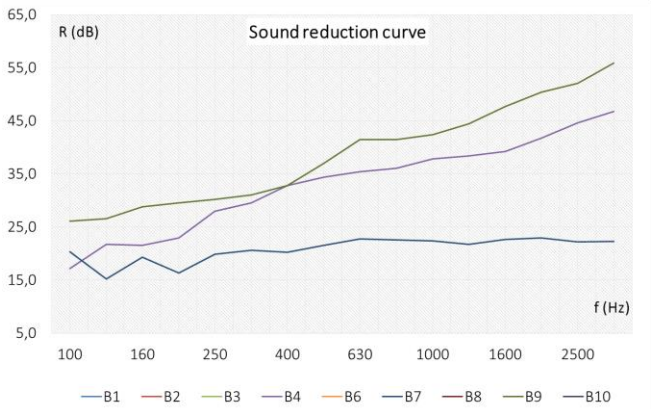
Traditional solutions for interior partitions



Source and receiving room

Key:
1 - Mortar filling; 2 - Lath (≈ 15mm); 3 - Wooden planking (≈ 20mm).

Site measurements curves by building under study



	S (m^2)	V (m^3)
B1	-	-
B2	-	-
B3	-	-
B4	18,20	70,00
B5	-	-
B6	-	-
B7	7,80	32,50
B8	-	-
B9	10,40	26,00
B10	-	-

S – Area of the test element

V – Receiving room volume
B – Building under study

4 RESULTS

Table 4 – Results obtained for measurements made.

	Site measurements (dB)								
Element	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**
External walls ($D_{2m,nT,w}$)	21	24	27	28	-	34	22	-	19
Flooring ($D_{nT,w}$)	49	52	47	46	51	27	-	42	49
Flooring ($L´_{nT,w}$)	62	65	44	51	62	-	46	58	70
Interior partitions ($D_{nT,w}$)	-	-	-	37	-	-	22	-	41

Table 5 – Legal regulatory criteria for buildings.

Element	**Legal regulatory criteria (dB)**
External walls	$D_{2m,nT,w} \geq 33$ dB
Flooring	$D_{nT,w} - t \geq 47$ dB
Flooring	$L´_{nT,w} + t \leq 63$ dB
Interior partitions	-

t – tolerance for buildings in historic centre

5 DISCUSSION OF RESULTS

Building rehabilitation will only be possible if we are able to adapt the existing solutions to the requirements of contemporary comfort, by making use of technological development.

The first step on the path to achieve this purpose is the study of the performance of traditional solutions. Thus, the evaluation of a considerable amount of different solutions will allow us the definition of characteristic intervals of sound insulation for each of these standard solutions in order to learn if the existing solutions become competitive.

The results show that there is great potential in the use of traditional solutions.

Wooden flooring solution aerial sound insulation index values range mostly between 49 to 52 dB and for impact sound insulation indexes site measurements vary between 58 and 62 dB.

The results of sound reduction index show that in the case of floors, more than 50% of the studied solutions fulfill legal requirements. This finding is particularly important as it provides the improvement traditional flooring and contributes to a more sustainable construction.

In this case air sound insulation index values depend mostly on the absorption of the floor materials, while impact sounds are subject to the binding between layers. And both are influenced by marginal transmissions that take place on the various links between the pavement and other elements.

Site measurement results for air sound insulation index values and impact sound insulation index values are satisfactory, since it leads us to conclude that an intervention for the improvement of these elements can ensure compliance with contemporary legal standards.

Results for air sound insulation on exterior walling vary substantially from case to case. The values range from 19 to 34 dB.

The results obtained for the facades are low in almost all cases studied. This is explained by the existence of a large percentage of glazed areas with very low sound reduction index. We must be aware that 45% of these facades consist of glazed area which has a great influence on the solution's overall sound insulation.

The study shows that interior walls can function as interior partitioning walls, or even be associated with lightweight plasterboard structures so as to be used as separation elements for adjoining dwellings.

This study aims the optimization of rehabilitation actions in traditional buildings with outdated construction methods, in such a way that the rehabilitation actions prioritize the improvement of existing solutions, maximizing the use of existing materials and minimizing the implicit costs on rehabilitation actions.

This study precedes the development of a manual which contains a wide range of rehabilitation solutions with the restoration and improvement of existing solutions as its primary objective in order to make them compliant with the current legal requirements and providing of well-being and comfort to its occupants.

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SUSTAINABILITY IN THE PERSPECTIVE OF MAINTENANCE AS LIFE CYCLICAL MANAGEMENT FACTOR OF BUILDINGS

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Abstract

There is broad consensus about the need to define policies and strategies that ensure the sustainable development of buildings. As such, it has been incremented the development of methods to assess sustainability and respective tools based on Life Cycle Analysis Systems (ACV) for the sectors of industry and construction. Whereas, buildings have a determinate service life, in which must meet or exceed a set of requirements and respective topics, so must be guaranteed that they perform their functions without having to expend additional costs for such unforeseen maintenance.

This paper aims to reflect on the importance of including maintenance from the preliminary design stages, but also be a factor in managing the cyclical life of buildings. From the design stage, it should be possible to find rational and constructive solutions optimized from an economic point of view, through the choice of materials, improved energy and water consumption and greenhouse gas emissions.

Sustainable development must therefore consider maintenance as a factor in managing the cyclical life of buildings, for this allow keeping or returning to the elements and components a state that let them to perform the functions for which they were designed. Thus, it can be say that the maintenance contributes, not only to ensure performance during the life cycle of the various elements and components of buildings, but also to prolong them in time beyond the expected.

With this paper is possible to conclude about the importance of building maintenance in the life cycle cost (LCC), the definition of policies and strategies for implementation, and on the need to do more research content that support decision-making.

Keywords: Sustainable Development, Building Maintenance, Life cycle, Design Process, Building Management.

1 INTRODUCTION

The concept of sustainable development was delivered in the Brundtland Report [1], where has been defended that "*humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*". The idea of sustainability arises, in part, as a "cause" that relocates the human being and its present and future needs as a priority.

Subsequently, and in order to continue to establish international principles and national sustainable development were prepared several documents, approved in the Rio Declaration on Environment and Development, such as the Statement of Principles on Forests, as well as the Convention on Climate Change, the Convention on Biological Diversity and Agenda 21. [2]

In Portugal, in the context of Agenda 21, was produced a document entitled - National Strategy for Sustainable Development. [3]. This document consists of a set of coordinated performances that, starting from the current situation of Portugal, with their weaknesses and potential, ensure an economic growth faster, greater social cohesion, and a high and growing level of protection and enhancement of the environment.

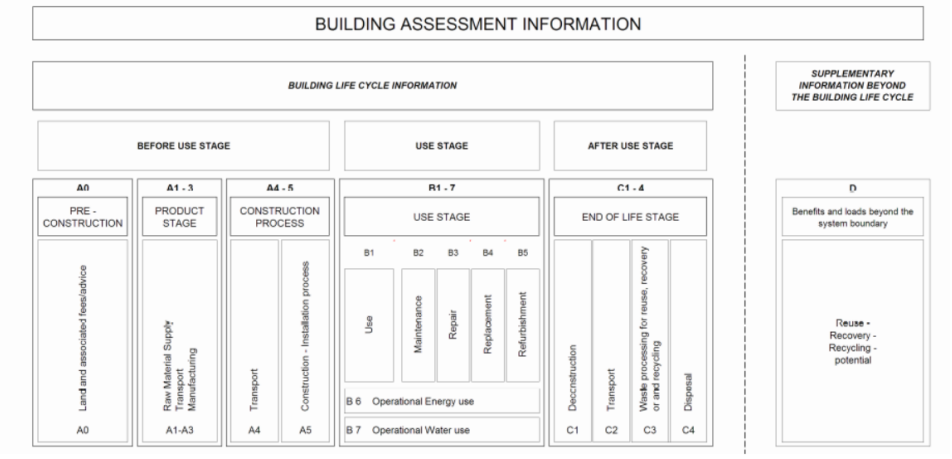
Thus, the need arises for a sustainable framework also at the level of construction, as well as the definition of methods and tools for the assessment of sustainability. In the case of architecture and construction, demand-materialize this concept through a set of indicators, standards and rules that must be subjected to a constant review, in order to achieve a sustainable development. Some tools were developed in order to evaluate and recognize the sustainability in construction, based on three levels: environmental, social and economic, which stand out: the BREEAM (environmental), the LEED (environmental), the SBTool (environmental and economic), the CASBEE (environmental), the NABERS (environmental), the CEEQUAL (environmental and social), and the LiderA (environmental, economic and social), the latter developed in Portugal.

It has also been developed a set of standards - ISO standards - about the sustainability of buildings, such as: the ISO 15392 [5] laying down the general principles of sustainability for the construction of buildings and the ISO 21929-1 [6] which sets out the indicators of sustainability for use in the assessment of economic, social and environmental impacts of buildings.

The technical Committee CEN/TC 350 [4] shall be responsible for the development of standardized methods for the evaluation of aspects of the sustainability of buildings and the rules for the environmental statement of construction products. One of the standards recently developed was the EN 15643 - Sustainability of Construction Works. Assessment of the Sustainability of Buildings [11] [12] [13] [14] which allows to set the assumptions underlying the concept of assessing the sustainability of building.

These standard sets out the general principles and requirements for an assessment of the buildings in terms of environmental, social and economic performance, also taking into account the technical and functional characteristics. In compliance with these requirements it must be considered that there are impacts and aspects that are influenced by actions taken throughout the life cycle of the building. Table 1. presents a summary of the information of the life cycle of the building in several stages:

Table 1 – Building Assessment Information. EN 15643-4. [14]

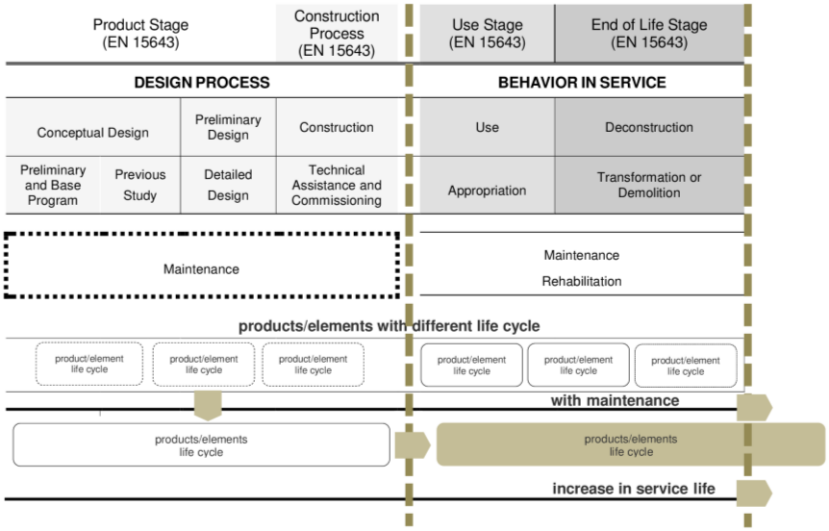


Maintenance appears as an aspect to be considered in the framework of the evaluation of social, and economic performance in the Use Stage.

In what concerns, social aspects and impacts maintenance is considered as a category, whose aspects are evaluated from the user point of view, that is, by means of the maintenance operations it is possible to assess the consequences for users and neighborhood of maintenance activities necessary to maintain the building in a state where it can carry out its functions.

Indeed, it is a purpose of building maintenance through a set of actions and procedures ensure that a certain building hold the initial conditions provided for in the project, so it must be included in constructive process since the early stages. The maintenance is an important feature for the sustainable development, because it lets make a set of guidelines in order to ensure the sustainability of constructive solutions. (Table 2.)

Table 2 – Inclusion of building maintenance in the design process.



Constructive solutions defined for the various elements of the building, should be based on sustainable construction, in other words, the "*creation and maintenance of a healthy built environment, based on efficient use of resources and ecological principles"* [7], being that involves the consideration of the whole life cycle of the building.

As the various elements and components have different life cycles, including maintenance since the early design stages, allows ensuring and extending the building service life. Constructive solutions should be designed bearing in mind that some pathological manifestations that may occur and accelerate the process of degradation can be analyzed, and in some way, even foreseen during the design process, that is, it may be anticipated the future of the degradation process.

2 LIFE CYCLE ANALYSIS

The life cycle analysis is based on the three pillars of sustainable development model and can be divided into three types of evaluation: Evaluation of Life Cycle (LCA LCA (Life Cycle Assessment); Life Cycle Costs (LCC LCC (Life Cycle Cost) and functional performance of the product.

The evaluation of life cycle (LCA) was originally defined by the SETAC- Society for Environmental Toxicology and Chemistry1 - as a *"process to assess the environmental implications of a product, process or activity, through the identification and quantification of uses of energy, materials and environmental emissions; assess the environmental impact of these uses of energy and matter and emissions; and to identify and evaluate opportunities to carry out environmental improvements*". [8]

Being the evaluation of life cycle (LCA) directed to the evaluation of the environmental performance of a product or material, the construction can be used for the evaluation of materials, elements of construction and the entire building. The Life Cycle costs (LCC) are based on an analysis predominantly economic of the product throughout its life.

The functional performance evaluates the entire system (constituents/product and materials) considering the whole set of requirements by which they have to respond. The life cycle analysis corresponds to a long-term analysis that want to monitorize the building´s behavior covering the areas referred to.

It has also been developed a set of standards - ISO standards - on the evaluation of life cycle, such as: the ISO 14040 [9] and ISO 14044 [10] which set out the main objectives, the data and life cycle inventory, among others.

Due to the complexity and need for systematization of information, were developed several specific tools, in recent years, based on LCA method, such as: InVest (United Kingdom), the Eco-Quantum (Netherlands), the EQUER (France) the ECOPT- ECOPRO-ECOREAL (Germany), Gabi (Germany), ATHENA (Canada), among others.

3 INTEGRATED APPROACH TO THE DESIGN PROCESS AND THE SERVICE BEHAVIOR

In accordance with the EN 15643-1 [11] the information of the building life cycle is divided into several stages (Table 1.) and *begins with the acquisition of raw materials.*

Sequentially encompasses *"the manufacture of products, the processes of construction, use, including maintenance, rehabilitation, and operation of the building and, at the end of life, the deconstruction or demolition, waste processing in preparation for re-use of energy and other recovery operations and deposition of materials of construction*." Being that, maintenance is introduced in the use/operation stage and from the user's perspective. [12]

In this process of LCA there are several stakeholders, being the responsibility of the project´s author the decision-making in the design process and construction. As it happens, many of the problems relating to building service behavior, at use stage, assigned to not intentional options during the design process, and this situation has implications underlying the level of building maintenance. Thus, maintenance should be considered as a life cyclical management factor of buildings, and should also be considered since the conceptual design stage accompanying all the following phases.

In short, sustainability based on three levels: environmental, economic and social, must include the maintenance as an integral factor of performance guarantee of the various elements and components that are part of the building, in which the various indicators should be analyzed and evaluated from the initial phases of project.

During the design process, and as regards the environmental level, the decisions taken in the choice and selection of materials and components of constructive solutions must take into account - a use and adjustment of resources, maximising performance in service, the use of eco-efficient and recyclable materials and the use of energy-saving systems and mechanisms. On the social level should take into account - the fairness of enjoyment of the needs of the individual(s) and the refitting of the damage caused by an activity or inappropriate use (the answer should be proportional to the responsibility). On the economic level should take into account - a use and management of resources, a guarantee of economic viability and concern in the optimization of costs over the service life.

For that since the conceptual phase, the project´s author will be able to ensure the performance expected of the elements that constitute the building, and need to bear in mind the existence of a set of functional performance requirements, which the various elements should respond. And also, that this will be subject to the appearance of a set of possible pathological manifestations, during its service life.

It is through the definition of the various needs of the functional performance requirements and the compliance with the various levels of environmental, social and economic assessment that must sustain the integrated vision of the life cycle building management, including the maintenance since the early design stages.

This need is embodied on the observation that the procedures more advanced of building maintenance are based on interventions in the use stage, away from the intervention in more premature stages of the construction process.

It is considered that the ISO 15686-1 [15] is the one that currently best defines the concept of building maintenance, and that is defined as the *"combination of all technical and associated administrative actions during the service life to retain a building or its parts in a state in which it can perform its required functions".*

In ISO 15686-10 [16], are defined the various stages and phases assigned to the building information model. Building maintenance and management appeared in the occupation and use stage. However, during the phases of the design process and implementation are defined parameters that include the maintenance, as being, to assess the capacity and needs of the various components to be maintained, repaired and replaced, as well as a verification of the life of components, depending on the building service life and the setting of a Maintenance Plan (already present in brief, conceptual and initial design, and detailed design phases).

3.1 Design Process - guidelines for sustainability in the perspective of maintenance

During the research work developed in the doctoral thesis, Fernandes Rocha [17] developed a decision support model that allows the project´s author include maintenance during the design process. Was defined a set of guidelines for the various maintenance operations, where had been also considered the sustainability in the perspective of maintenance. Were assigned some parameters of evaluation:

- **1. [Planning the sustainability process**] - Allows to determine a prediction of actions required for a good behavior of the main materials and components of the element (define the main characteristics of environmental impact factors for its operation and use);
- **2. [Shortage and rarity of materials]** - Ensure minimization of employment of raw materials and difficult to replace;
- **3. [Use of resources]** - Allows to make sure that the majority of components and materials have the ability to reuse or recycling;
- **4. [Causality of choices]** - Allows to determine alternative strategies, by correcting the unintended consequences of performance;
- **5. [Sustainability Initial Plan]** Allows to determine a Plan of principles and good practice for a sustainable development, with the mechanisms of monitoring required.

The definition of guidelines intended to demonstrate how the sustainability in the perspective of maintenance can and should be included in the preliminary design stages, and how his contribution can be decisive in order to allow secure and extend the life cycle of the elements and components of the building.

The scope was to get through a weighting assess the sustainability in the perspective of maintenance of a given constructive solution and with this, their suitability for the performance of maintenance operations.

The assumptions on which it based the various parameters of evaluation were:

3.1.1 Planning the sustainability process

In the preliminary design phase, it should be possible to find constructive solutions streamlined and optimized from an economic point of view, through the choice of materials, better energy consumption, water and pollutant emissions. In the construction phase should be possible to obtain a reduction in the consumption of resources, vibrations and noise, and also a reduction in the production of waste, as well as the absence of pressures and waterproofing of soils that cause severe environmental impacts. The plan should define the main characteristics of environmental impact factors for its operation and use. [17]

3.1.2 Shortage and rarity of materials and Use of resources

These aspects concerning maintenance, are based on the extent that are oriented with the objective that the activities are easy to deploy and of highly efficient sustainable, avoiding the use of short raw materials and difficult to replace **[schortage and rarity of materials]** and ensuring that the majority of components and materials have the ability to reuse or reuse **[use of resources]**.

As an example, between synthetic materials more recommendable, are polyethylene and the polypropylene, which are simple synthetic materials and has a low production energy cost, compared with other materials. It must be possible to ensure that the majority of the raw materials are not rare and difficult to replace and which allow, in general, recycling or reuse. [17]

3.1.3 Causality of choices

One of the introduced actions is the determination of alternative strategies to correct the unintended consequences of performance, and decrease a risk (preventive measures). The project´s author must considered the precautionary principle, [18] which can limit the decisions in the way of existing knowledge about the consequences, that so measures must be taken in order to predict the relationship of cause and effect that can exist in a particular solution and what are its implications for the future, and get to the conclusion of another alternative.

The choices defined in the design stage shall thereafter, during the service life be monitored (check the impact on individual/user and the level of health, social relations, environmental and economic).

3.1.4 Sustainability Initial Plan

The Sustainability Initial Plan must be provided in accordance with the needs, but without compromising the ability of future generations and must contemplate: a plan of principles of good practice for sustainable development, with the mechanisms of monitoring required. The Plan of principles of good practice should be based on assessment parameters established in accordance with the phases stipulated in ISO 15686. [15]

4 CONCLUSIONS

In fact, there is an urgent need to define contents for maintenance, which allows established concepts and concerted strategies. In the present communication proved that the existence of standards that support and regulate the sustainable construction are fundamental, but these must be in parallel and in coherence with the content whose concepts are present.

As regards, the standard EN 15643 - Sustainability of Construction Works - maintenance is considered in use stage and in general by the user´s perspective. The standard ISO 15686 – Building and Constructed Assets. Service Life Planning - considers maintenance at occupation and use stage, however includes aspects that must be taken into account during the design stage.

The building maintenance contributes to ensure and extend the life cycle of elements and components and, thus, is necessary to define policies and strategies for their implementation in line with a policy of sustainable development.

Currently, given the complexity of the projects and the need for multidisciplinary teams, the decision-making by the project´s author are also more complex and difficult, while the greater number of instruments and tools that they can assist.

In the context of the building maintenance is still a way to go, thus, there´s the need to do research on maintenance contents that integrate as a life cyclical management factor of buildings and consider as a common denominator the sustainable development of the construction.

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THE SUSTAINABLE CITY OF TOMORROW THROUGH CO-DESIGN. AN INNOVATIVE TRAINING APPROACH FOR (CIVIL) ENGINEER STUDENTS

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Abstract

An engineer's technical know-how positions him as a major stakeholder in shaping the society we live in. Furthermore the increasing complexity of environmental projects means that these same engineers have to develop new skills, include new working methods; taking into account the different stakeholders and to work outwith their comfort zone.

Our article details a seminar aimed principally at civil engineering students. This seminar offers them the opportunity to design the sustainable city of tomorrow taking inspiration from Jeremy Rifkin's Third Industrial Revolution (TIR). It is based around a practical project on the regeneration of a neighbourhood, with input from external sources, for example, visits, experts or users; covering a variety of themes such as mobility, renewable energy, thermal simulations and bioclimatic architecture.

Inspired by architecture workshops and by exploring innovative co-design activities, techniques and methods; it encourages an iterative approach to the creation, where the future engineer can imagine, test, try, analyse and redo.The activities foster a creative attitude and collaborative behaviour. These activities allow the engineers to confront and take onboard other points of view and favour the emergence of collective intelligence. This seminar brings the students to an innovative and integrated design, through bridging the abstract of the project ideals and intentions and the actual design models.

This type of learning is based on animation by the authors where their role is not that of content deliverer, but that of facilitator and guarantor of the correct running of the proceedings and the maximisation of the process. This learning protocol is through a predetermined sequence of activities targeted to develop an attitude or behaviour of the participants, or an element of group work. This method of teaching is pedagogically very effective because it encourages the student engineer to take responsibility, engage and participate. Valuable skills he needs for future professional projects.

After a short presentation of the seminar outline and the pedagogical methods used such as creative forums, world cafés, roving files or Bono's Hats, the article will then analyse how this seminar encourages participants to use their technical expertise to benefit responsible development.

Keywords: Co-design, project work, multi-disciplinary, sustainable development, model, architecture, innovation, eco-neighbourhood, complexity, technical creativity

1 ENGINEERS ROLES AND NEW ROLES

In 1970, the civil engineer Sir Ove Arup in The Key Speech said: "Engineering is not a science. Sciences study particular events to find general laws. Engineering design makes use of the laws to solve particular practical problems. In this it is more closely related to art or craft; as in art, its problems are under defined; there are many solutions, good, bad and indifferent" [Tonks, 2012].

We sadly see that often students of civil engineering are not encouraged to take an active interest in design despite the fact that this may be their principal activity after graduation. Most of these students are engaged in these studies because of their mathematics and physics talents and not because of their enthusiasm in finding or producing solutions, designs or innovation. There is also a gap between the way subjects are taught in civil engineering schools and the engineering work methods. Training often consists of studying a large numbers of subjects deeply in an unconnected and isolated manner in contrast to the use of apprenticeship style learning that allows students to develop a capacity to mobilize different understandings and to transform them and produce something. Traditional teaching promotes knowledge expertise lectures over project workshops.

This does not mean that an engineer should not pay attention to all these highly useful scientific subjects. The innovative civil engineer Peter Rice (Pompidou Center) who innovated the use of cast steel into structures against conventional industrial practice. When evoking team work he said: “The structural engineer has no right to make mistakes. When innovating, as we were, by how we used cast steel, it is essential to be able to rely on accurate analysis of highly qualified people more emotionally indifferent to the outcome of the project: a clear look, logical and objective about the structure and materials to ensure they comply with laws and requirements.“ [Rice, 1994]

If we take into account the visions of Sir Ove Arup and Peter Rice, the desirable qualities for a civil engineer will include good scientific knowledge but also imagination, vision, flexibility, the ability to address complex problems. An engineer should be able to take into account all the parameters regardless of the order. Ove Arup, as an engineer, used the term « total architecture » [Arup, 1970] and for him this term implies that relevant design decisions have been considered together and have been integrated into a whole by a well-organized team empowered to determine priorities. This purpose seems to be still valid today more than ever.

To be an engineer nowadays, concerned by sustainability and energy reinforces even more these qualities that an engineer should possess. The increasing number of matters to take into account in a construction project multiplies the number of actors who intervene which in turn increases project complexity. Engineers have to develop new skills, include new working methods; taking into account the different stakeholders and to work outside their comfort zone.

The act of building requires the multiple skills of many actors who must work together. We believe that modern, efficient training which combines architecture and engineering, must produce professionals capable of this collective work, where personal opinion and specific knowledge become complementary. This way of working is now at the heart of the issues and stakes related to project complexity and aesthetic quality, construction, energy and economic buildings.

Today the area of construction is so complex that a single discipline cannot meet all the emerging technical, social and economic needs.

2 THE CITY TOMORROW SEMINAR: CONTEXT AND SUBJECT

The OT-EHE (Technical Option - Energy Habitat Environment) seminar was set up for Master 1, to enable an informed choice on the EHE Master 2 in the civil engineering school HEI (“Haute Etude d’Ingénieur) in France. EHE aims to train engineers capable of managing an urban development project taking into account the energy efficiency of housing, the use of new energy sources and the environmental management of the space. The pedagogical field EHE is built around a practical project of the renovation of a neighborhood, complimented by theoretical learning on transversal issues (mobility, renewable energies, thermal simulations, bioclimatic architecture ...). The authors of this article have taken inspiration from architecture schools pedagogy and Co-design [Roche, 2014] experience to create the EHE OT workshops.

The OT (Technical Option) is an educational unit that brings together approximately 20 students during a 4 day seminar (2x2 days) to explore a wide range of themes. The authors wished to create a specific OT project that would allow the students to confront both the problems of a working project and those of the city of tomorrow. The aim of the OT EHE is to undertake a complex project in a limited time. Using a "protocol" of activities, as used in Co-design, is expected to provide a framework for this workshop. It will include the creative atmosphere of an architectural workshop, while structuring the approach to what can be achieved in 4 days. The OT EHE has been performed three times since October 2013 based around the objective pretext "Building a neighborhood in the town of 2030 in the context of the Third Industrial Revolution (TIR) in the Region NPdC (North Pas de Calais).” It can deal with a global hot topic [Rifkin, 2012] but also regional [Nord-Pas de Calais Region, 2014]. The TIR provides an initial approach through structuring of Rifkin’s 5 pillars (renewable energy, smart grids, energy storage, energy producing building, electric mobility) and 3 themes added by the NPdC region (energy efficiency , circular and functionality economies).

3 WORKSHOP, CODESIGN

3.1 General organization and influences

The OT-EHE programme is inspired by building workshops, practiced in architecture schools, and a seminar for the Third Industrial Revolution stakeholders in Nord Pas de Calais in a lively co-design approach. It promotes the expression of different points of view. Care is taken to blend the skills of students, professionals or invited experts. Models are used as a representation that allows the passage from the abstract to the concrete. Facilitation will be provided by the authors whose role is not that of knowledge giver, but to guarantee a smooth process and its maximisation. The protocol defines the sequence of activities throughout the process and whose aims are to foster an attitude or behavior or to enable a group production. From a pedagogical point of view the teacher-facilitator's attitude is very effective even if it is not totally understood by the students at first. Deeper knowledge in the students' project comes only through their own research and discussion with experts.

3.2 Protocol and activities

The explicit aim of the seminar is to make a proposal for development of an existing city district in 2030 as part of the Third Industrial Revolution. This project is a "pretext" that will address the contents of the EHE field. The twenty students are divided into three or four teams that will work on their projects. These teams stay together for the four days but different activities may lead them to exchange with other groups. By the second day the teams undertake a model and a presentation of the project, which will be regularly reworked, and will be the ongoing theme up until the final submission.

The days start with a welcome coffee and a "ice-breaker" or "warm-up". This has a twofold objective: a rapid creation of group dynamics and an expression of diverse views that enable team members to think out of the box. Warm-ups, such as a photo-language or performing a skit, allow explicit dimensions that rarely appear in PowerPoint presentations.

The days end with a debriefing. The debriefings are essential to the process because they allow the adaption of the course to each seminar. They also establish a relationship of trust between the facilitators and students. They allow validation or questioning of the actions of students and facilitators.

Due to the limited length of this article we cannot present the full protocol and details of the four days. Instead we have chosen to present (Tab. 1) a simplified protocol

Table 1 – The simplified 4 day protocol.

	Jour 1	Jour 2	Jour 3	Jour 4
	Welcome, coffee Warm-up and ice-breaker	Welcome, coffee Warm-up and ice-breaker	Welcome, coffee Warm-up and ice-breaker	Welcome, coffee Warm-up and ice-breaker
Morning	photo language get to know people;	design a neighbourhood (model V1)	back to the perfect model	cross fertilization of project ideas **Bono's hats**
	design a perfect neighbourhood (model V0)	prepartation for experts' visits	design a neighbourhood (model V2)	design a neighbourhood (model V3)
Lunch	site visit	On site	On site	On site
Afternoon	Third Industrial Revolution	Working with experts. Learning tables	**Pre panels** **Pre evaluation**	**Panels and Forum Evaluation**
	Debriefing	Debriefing	Debriefing	Debriefing

The seminar lasts for 4 days during which everyone will work all together and in the same space. The protocol sequences are pre-determined but not definitive activities. It encourages an iterative approach (Fig .1) to the creation, where the future engineer can imagine, test, try, analyse and redo.

This seminar brings the students to an innovative and integrated design, through bridging the abstract of the project ideals and intentions and the actual design models.

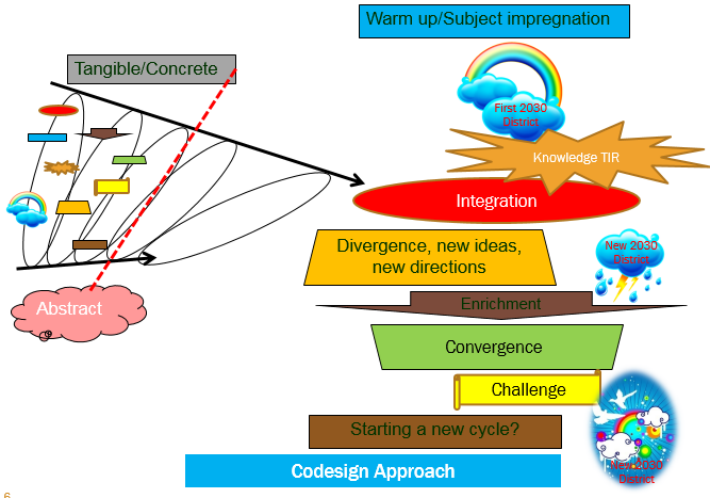

Fig. 1 – The iterative approach.

3.2.1 Examples of educational activities: Bono's Hat, Analyze differently.

By this activity, students have already worked for three days on their project. Each team will "lend" their project to other teams, who will analyze it using Bono's Hat [Bono E. 1985]. This method allows a structured analysis with a different approach to traditional functional or organizational approaches. Each team plays a different role symbolized by colored hats. Red (emotion, intuition), Black (Critical Thinking), Yellow (Optimism), Green (Creativity). The result is returned to the initial project team in order that it can draw lessons about the perception of its work and areas for improvement. By performing this exercise the team takes on the Blue hat which is one of synthesis. This exercise allows us to offer or receive observations from different vantage points. Students realize that even at the end of the project, this exercise helps to raise many points accurately or highlight areas for improvement.

3.2.2 Examples of educational activities: Pre panel presentation work or learning tables.

Project groups have to work several times with different experts during the afternoons of day 2 and 3. These experts are engineers, architects, urban planners, sociologists, users, research professors. As advisors, they transmit their knowledge on their practices, which students can then apply to the project. They do not make specific presentations or conferences but they give a real exchange of applied expertise. Each project team has its "stand" that allows them to work on their project with one or two professionals for 20 to 30 minutes (Fig. 2).

Fig. 2 – The learning tables and spiderweb graphics.

The experts attitude has to be different, depending on the sequence and project progress. For example, on the second day we want kindness, enrichment and advice and on the third day we ask them for a constructive project evaluation according to criteria defined by the animators. The origins of the experts are very different, their outlooks on the project vary and may even be contradictory. We can observe the ability of the different groups to accept constructive criticism or not, to include a compromise or affirm a conviction or originality. The general debriefing which follows, gathering all groups, allows them to locate and identify lines of advancement. This learning from errors will allow students to list the "right questions" to be asked in a design phase, before making the "right answers".

3.2.3 Examples of educational activities: Evaluation and assessment

The first formal evaluation of day 3, is established from the criteria defined by the facilitators. For this a "spiderweb" of each project will show the strengths and weaknesses of the team project. This form of feedback is very popular among students. At the end, they will collectively produce criteria applicable to all the groups that is then used to evaluate the final project: connectivity / mobility; Flow management; Economy; Well-being and living together; Integration of the habitat and ecology; Type feasible project / innovative / inspired. Two end of seminar evaluation forums are designed (Fig.3), with both expert and student panels. The joint project is equally weighted between students and experts. The final assessment of the OT will integrate both the collective projects and an individual impression report.

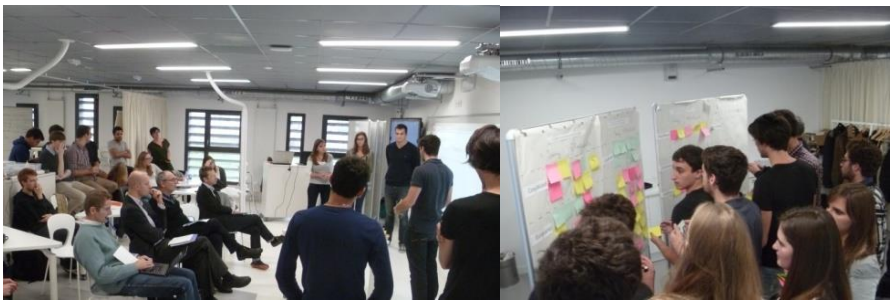

Fig. 3 – The "forums" evaluations.

4 DIFFERENT ROLES, ACTORS BEHAVIOUR AND IMPLICATION

In this method, as participants, whether as lecturer, student or visiting professional we assume different roles from that of convention.

We have the student as an individual learner and project producer, but also as part of a team, whereby the team is an entity where knowledge and collective intelligence can emerge. The student is an active participant, well-meaning towards himself and to his peers. The project result and conclusion depends on collective involvement. Learner implication in their own learning and training by the topic, the innovative training, the work space and the « ecosystem » (fig. 4)

Fig. 4 – The students behaviour and implication.

Academics have also different roles. The authors are the facilitators of the seminar and are responsible for the regulation of the groups. They are available to the groups to support them however they may need. This might be through coaching or encouragement. However, they do not actually provide the project content. They are the "vessel". That is, they determine the workshop protocol and they ensure the activities undertaken are matched to the learning outcomes required. If necessary, they adapt materials and activities during the programme in order to reach the goals.

Other roles are undertaken by « experts », who could be industry professionals, researchers, or building users. These experts are engineers, architects, town planners, sociologists, users and school staff. They will challenge the projects during the 4 days and they will bring their own expertise but not through a conference format rather by working directly with the students. Their contributions will create changes through the course of the seminar. In the beginning they will act as project advisors, but will become project critics at the final presentations.

5 CONCLUSION

The objective of the EHE OT (Energy Habitat Environment) was to introduce students through the Master 1, to the EHE domain Master 2. This required not only the presentation of subject content but also the inclusion of the working methods that would be used in this area. The design of a neighborhood or building taking into account its environment requires a multidisciplinary and global approach. While it is difficult to establish a cause-effect relationship, participation in the EHE domain increased from 13 students in 2013 to 22 students in 2014, 50% come from the OT EHE. Similarly Master 2 lecturers have perceived positive changes in the dynamics of the domain EHE group between 2013 and 2014. The strudents' impression reports have led us to think that the OT teaching EHE formula increases their interest for two reasons. The first is the wealth of experience of multidisciplinary working and the diversity of solutions it provides. They understand that some of this wealth comes from the real expertise of stakeholders and a certain empathy that allows challenging solutions. The second is the recognition by the student of their own ability to make a personal and original contribution to the solutions proposed. This second realization is possible only because the student is a real partner in the process, a confident, and responsible player.

The OT EHE will be repeated in the coming months. Many questions, some raised by the students themselves, remain unresolved. Students are interested in receiving more technical knowledge and skills in order to design a better final project. This students' wish provides the authors both frustration – we do not have 6 days and satisfaction that the students want to deepen their knowledge and produce more complete. We also find ourselves in a paradox: we motivate the students in the field EHE through the working methods and the meaning given to designs carried out; against the assessment, which is based on, as in our schools on the result, the final draft, and few of the skills acquired throughout the process. The OT EHE and its programme will therefore have to change the terms of technical input during the seminar and the evaluation method.

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PROGRESSIVE RESEARCHING THE EFFECTIVENESS OF INTEGRATING COMBINED SYSTEMS OF RENEWABLE ENERGY SOURCES

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Abstract

The paper describes the excellent laboratory centre of Civil Engineering faculty, Technical university of Kosice called "VUKONZE" that is orientated towards the integrated design of intelligent systems in building service technology environments and renewable energy sources based on the synergistic combination. This new multivalent laboratory for optimization and the use of renewable energy is constantly monitored by temperature sensors, pressure and heat meters. When complete they will represent a complex matrix monitoring the building envelope, building environment, storage devices and service systems. The purpose is to analyse the performance of the building and its services systems under varying dynamic climate conditions and evaluating life cycle management risks for renewable energy, an activity consistent with established laboratories. The analysis focuses on current legal requirements, evaluation and assessment in specific fields of industry, current methods and procedures which could be used for analysis, evaluation and assessment of emerging risks with priority on new technologies for renewable energy.

Keywords: House in house, building service, renewable energy sources, intelligent systems

1 INTRODUCTION

A team from Technical University of Kosice (TUKE) has in the last years created a new high profile project called VUKONZE, which is a Slovak acronym for a Centre for researching the effectiveness of integrating combined systems of renewable energy sources, financed by the Ministry of Education of the Slovak Republic, and the European Regional Development Fund.

This progressive project in the area of Civil Engineering is orientated towards the integrated design of intelligent systems in building service technology environments and renewable energy sources based on the synergistic combination and development of the following goals:

- The development of modern technology system environments made of advanced materials with the use of modern terminal and distribution elements and their application in real terms
- The creation of non-linear time-dependent transformations of calculation models in order to assess changes in time-variable properties of building structures and their environmental status
- Verification of physical characteristics of the in-situ internal environment in real conditions; exploitation for the purpose of application in simulation methods
- Creation of regulatory, management and control methods for complex systems in environmental engineering
- The conversion of the building's energy supply from fossil-based fuels to locally accessed renewable resources
- The creation of models to transform buildings into zero net energy balance structures
- Preparing conditions for the transfer of technology and its inception in R&D innovations in Slovakia.

2 APPLIED RESEARCH IN A DEVELOPMENT OF INTELLIGENT BUILDING SERVICE SYSTEMS

The R&D of intelligent buildings service systems is focused on achieving a zero net energy balance by implementing the following hierarchic strategy (Fig. 1):

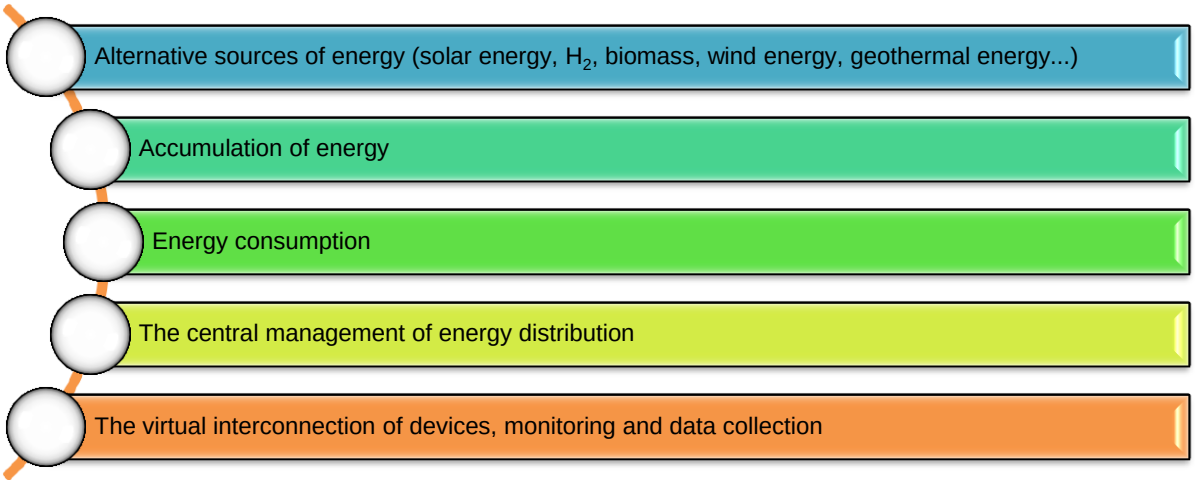


Fig.1 – Strategic hierarchy for the applied research and development of intelligent building service systems

2.1 Elucidation of the Strategic Hierarchy

The used hierarchy will create a platform to research the efficiency and interoperability of components and renewable energy technologies which will be based on experimental analysis. The facility is designed to ensure the independent operation of each of the energy sources or a combination thereof. Therefore, the storage system is realized as a sum of different energy potentials (See Fig. 2).

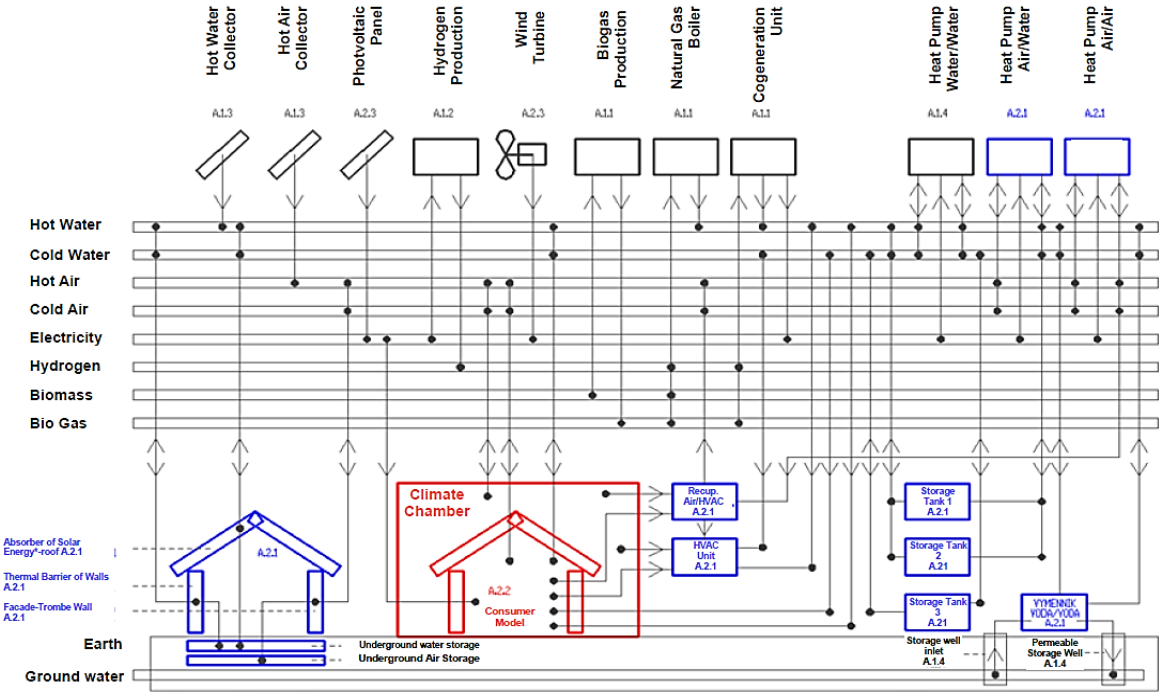


Fig.2 – Schematic description of the VUKONZE experimental platform.

2.1.1 Storage and accumulation of energy

The storage/ accumulation part consists of three underground tanks with a total capacity of 150 m^3 of water. The main source of heat are solar hot water collectors covering a roof area of 150 m^2, which ensure a year-round supply of heat to the tank for long-term accumulation. Estimated temperatures in

the tanks are designed to range between 15 - 85 °C. For a short-term accumulation, heat and coolth are stored in above ground steel tanks each with a volume of 2,000 litres. The system is designed for maximum efficiency and the source of heat or coolth can be actively adjusted to suit consumer needs (see Fig. 3).

Fig.3 – Storage/ accumulation of energy in the VUKONZE.

2.1.2 Consumer model

Generated energy will be expended by a purpose built consumer model which is located in what will be a future climate chamber (see Fig. 4). The model incorporates low temperature cooling and heating in the form of capillary tubes located in the ceiling and walls, floor heating and highly efficient HVAC and cogeneration units to ensure that renewable energy is consumed responsibly.

Fig. 4 illustrates a five zone partially transparent climate chamber which has been proposed for the consumer model. One zone simulates the roof while the other four zones are used to simulate cardinal environments and can be changed i.e. NE, NW, SE, SW with the ability to alter temperature, humidity and pressure based on experimental boundary conditions for the environment. The effect is that the building can be transposed to almost any climate, altitude and cardinal position dependant on the performance limitations of the chamber's unit. The chamber will be used to verify the performance of the consumer model subjected to predefined environmental boundary conditions.

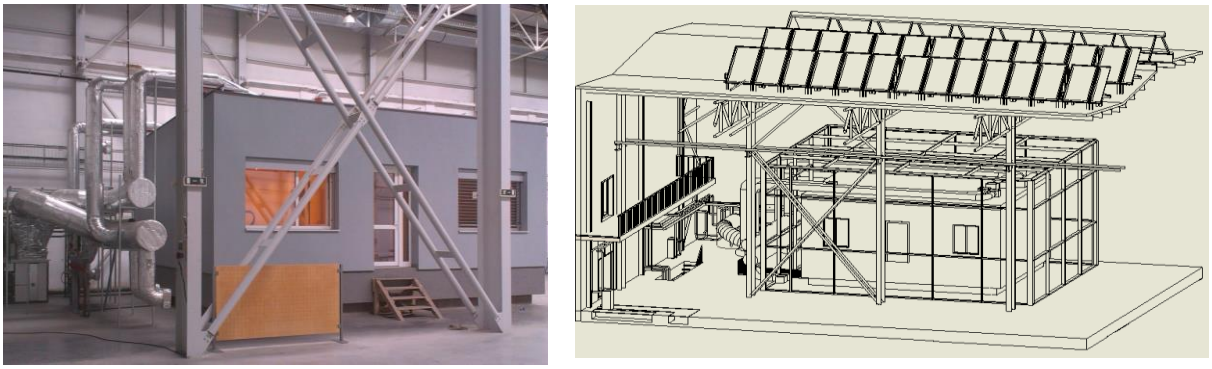


Fig.5 – The 55 m^2VUKONZE full scale consumer model of house with two rooms.

Half of the model features walls that are made from externally insulated rammed earth CS0108 (Stone, C., 2014) while the diametrically opposite walls are made of externally insulated fired brick, both with thermal transmittances of 0,15 W/m^2.K fulfilling passive house requirements. The building envelope features triple glazing in the windows and doors 250 mm of mineral wool insulation in the walls. The internal floor is raised by 965 mm above ground level and is ventilated. The floor and lightweight flat roof are both insulated with 400 mm of thermal insulation.

Additional properties of the house envelope (Fig. 6-8):

- 250 mm of contact mineral wool insulation fixed to the building envelope
- Low temperature heating and cooling wall system which use the heat sink properties of the mass walls to maintain thermal comfort

Fig.6 – Erection of the VUKONZE Climate chamber envelope.

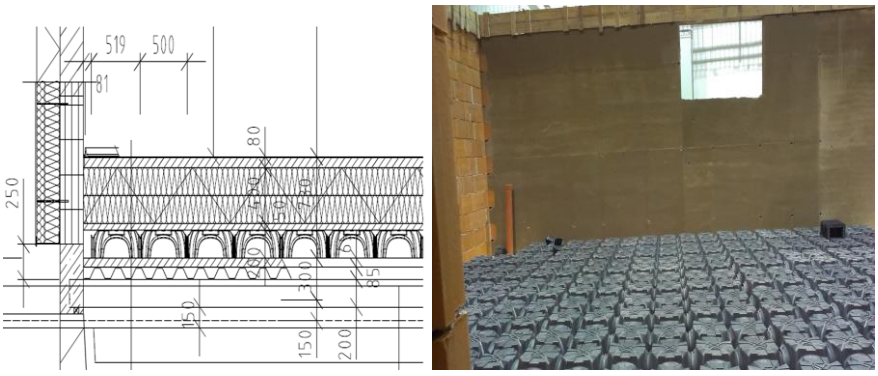


Fig.7 – Proposal and real construction of the VUKONZE Climate chamber floor.

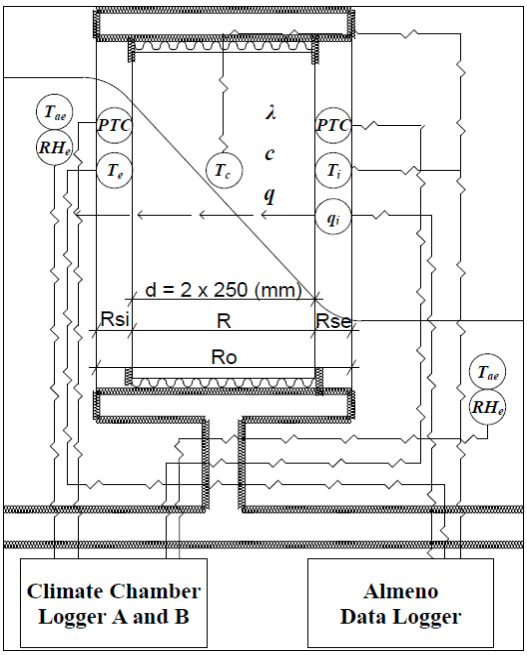
Fig.8 – Details of the VUKONZE Climate chamber additional insulation and wall heating system.

2.1.3 Management of Energy Distribution

The central management of energy distribution is designed to demonstrate the effectiveness of combined alternative energy potentials. Feedback is sent to a central control room via communication interfaces that also facilitates online monitoring in a virtual research area as a progressive means of applied informatics in the application and development of advanced methods of automatic control (see Fig. 9), (Stone, C., Vranay, F., 2015).

The multivalent laboratory for optimization and the use of renewable energy will be constantly monitored by temperature sensors, pressure and heat meters. When complete they will represent a complex matrix monitoring the building envelope, building environment, storage devices and service systems. Their purpose is to analyse the performance of the building and its services systems under varying dynamic climate conditions and evaluating life cycle management risks for renewable energy, an activity consistent with established laboratories. The analysis focuses on current legal requirements, evaluation and assessment in specific fields of industry, current methods and

procedures which could be used for analysis, evaluation and assessment of emerging risks with priority on new technologies for renewable energy.



Legend	Description	Legend	Sensor description
	Insulated barrier	*PTC*	Product temperature control
	Connection line	*q*	Heat flow density
	Thermal gradient	*RH*	Relative humidity
	Direction of heat flow	$T_{i/c/e}$	Temperature in./centre/ex.
	Construction foam		

Fig. 9 – Detailed schematic of sensors for the consumer model building envelope & data-logger - Adapted form [1]

3 RESULTS

The output of the scientific research will be used in energy efficient proposals, the provision and dissemination of knowledge and verification of simulated models or numerical methods.

The results will focus on:

- The implementation and operation of the distribution of all forms of energy used in the system, auxiliary pumps regulatory nodes
- Separate testing of individual system elements
- Management of production , distribution and consumption of energy in the management and operation of multivalent combined sources
- Optimum use of the energy produced in relation to its potential temperature, and the possibility of testing and researching principles of short and long term storage of energy
- Operation and testing of the use of underground tanks for the purpose of accumulation of thermal energy to research the impact of the environment (soil characteristics, depth of the deposit, the influence of humidity and temperature gradient at different timescales)
- Examining the principles of stratification (temperature stratification in the tank),
- In situ simulation and testing conditions of energy and process controls subjected to dynamic environmental conditions,
- The creation of a virtual space where it is possible with remote supervision to simulate and test the interoperability of physical connections and virtual machines,
- Other activities include outputs of control algorithms that increase the efficiency of heat and its distribution.

The total annual thermal capacity of the permanent storage tanks is 290 GJ or 87 MW/h. The peak performances of the individual renewable sources of energy are presented in the table below.

Manipulation of these energy resources will be accessible via a cloud computing network so that registered institutions may conduct experiments for their desired climatic conditions remotely.

Table 1 – Output of different sources in kW.

Source	Heat [kW]	Electricity [kW]
Solar Collector 128m^2	90	0
Hot Air Collector	3	0
Photovoltaic	0	5
Hydrogen	3	3
Wind turbine	0	1.5
Bio gas	90	0
Natural gas	25	0
cogeneration	37	30
Heat pump water/water	43	0
Heat pump air/water	15	0
Heat pump air/air	3.5	0
Total	312.5	39.5

4 CONCLUSIONS

The paper outlines the concept for the implementation of coupled renewable energy sources and their operation. The output is a proposal to motivate the energy market and building industry, through recommendations, economic viability and legislation, to reduce their dependency on fossil based fuels. This achieved by defining the most appropriate renewable energy source combinations, their application optimized operation in practical implementations.

ACKNOWLEDGEMENT

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ANALYSIS OF PERFOMANCE STANDARD ABNT NBR 15575:2008 WITH EMPHASIS ON THE LUMINIC PERFORMANCE, IN THE CONTEXT OF BRASILIA

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Abstract

This study is a review based on the theoretical analysis of the Performance Standard ABNT NBR 15575:2008 focused lighting and in the performance standards or other national and international sources relevant to the topic, as well as discussion of possible applications or difficulties of implementation in accordance with the criteria of the standard and its likely consequences, especially for users and professional construction of Brasilia, Brazil. Aims to produce a consultation document, the undergraduate and graduate students on luminous performance, based on the ABNT NBR 15575:2008, emphasizing the reality brasiliense through examples of buildings that have some type of control element for natural lighting. Ramble on possible impacts of implementing the standard in the professional, the market and for customers.

Keywords: Performance Standard ABNT NBR 15575, luminic performance, the control element.

1 INTRODUCTION

The performance of Brazilian buildings as well as its constituents has been the subject of discussions by experts in the areas of construction and the like, for a long time, having an approach from the middle of 2002 when there was the first attempt to generate a standard containing evaluative parameters suitable to Brazilian reality. Since then, the documents and work from these meetings resulted in the performance Standard ABNT NBR 15575:2008 [2] through (qualitative) requirements, criteria (quantitative) evaluation methods and includes topics such as: acoustic performance, thermal performance, luminic performance, tightness, fire safety, accessibility and functionality/other.

This article has an emphasis on luminic performance, emphasizing the requirements, criteria and evaluation methods applied in general way, since the standard does not cover the application of that item separately as systems: structural systems, floor systems, internal and external seals systems, hydro systems and roofing systems.

The article also seeks to make a merge between what is exposed in the norm, in other sources about this kind of performance and the reality of the city of Brasilia aimed for the use and control of natural lighting.

2 OBJECTIVES

- Produce a consultation paper to undergraduate and postgraduate degrees on Luminic Performance, based on the Standard ABNT NBR 15575:2008 [2], emphasizing the reality brasiliense through examples of buildings that have some type of control element for natural lighting;
- Rambling about possible impacts of the application of the standard in professional, in-market and for customers.

3 LITERATURE REVIEW

The pursuit of energy efficiency in the world is a result of that reality in which there is a shortage of energy and material resources available.

According to Galasiu and Veitch [7] in 2006, the literature shows a strong preference for the use of daylight with a wide acceptance on the part of users and professionals, as has been recognized by the construction research community, for example, in the creation of the Subtask: perspectives and user requirements, under the IEA Task 31, "Daylighting Buildings in the 21 century", according to the International Energy Agency-IEA [9].

According to the USA Department of Energy, as part of the effort to reduce the production of greenhouse gases and preserving the natural environment, office buildings should consume less power. In USA commercial buildings share the electricity consumption was reported in 2002 in 35%, according to the U.S. Department of Energy [13]. And in Canada, offices and other institutional buildings, were harvested in consumption values 30% [12]. The lighting in these buildings represents about 15% of the total energy consumed and which can be reduced with the adoption of good lighting control elements designed to take advantage of available natural light. Ideally, these elements provide a correct level of light transmittance in relation to solar orientation so that these gaps affect the minimum thermal performance by avoiding the increase of energy by the need to increase cooling or heating systems.

Chocos [4] applied questionnaires in England and New Zealand to investigate the perception of users regarding the importance of the existence of openings that take advantage of natural lighting. Were asked if they considered the Windows an important feature of a workplace and, if so, how it was important to them and why. Almost all respondents (99%) thought that the offices should have openings (windows) and 86% considered the natural lighting as your favorite luminic source. The preference for natural lighting was attributed to the belief that working with daylight results in less stress and discomfort than working with electric light, but as the author has observed this belief does not define the use of artificial lighting is harmful to your health. College students surveyed in Canada by Veitch et al. [10] about their knowledge, beliefs and preferences for lighting presented similar data. When Veitch and Gifford [11] refined their questionnaires and examined the question again through a mixed sample of office workers and college students once again observed that people believed that daylight is preferable.

In the research of Butler and Biner of 1989 [5] held in Indiana, USA, it was found that the preference of users by the size of the openings (windows) varied according to the type of space. Contrary to previous research that showed a general preference for large windows, this study provided evidence that large windows were not the preferred choice for most spaces.

Rubin et al. [1] in 1978 found that most occupants of offices equipped with shutters closed settings that prefer had little to do with the position of the Sun or the daily and seasonal weather conditions. The experiment was performed over three periods of 10 days in October, February and July. The results showed that the incidence of closed shutters was higher on the South side (about 80%) than in the North (about 50%), which suggests that the occupants were using their shutters to prevent the penetration of sunlight and overheating of their offices. However, most of the blinds or brises were designed with the tabs open and not closed, which suggests a preference for a view from the outside.

3.1 Energy Eficiency Law in Brazil

Law No. 10,295, October 17, 2001, discusses the maximum values of the energy consumption or energy efficiency minimums for machinery manufactured or marketed in the country and that contributes to combat waste.

According to Haddad in 2002 [8], despite the current circumstances, it is important to stress that

energy efficiency cannot be linked only to short-term issues, but should be a practical purpose of National Energy Policy, through actions aimed at, for example, add value and develop technology, preserving the environment and introducing, in the domestic market, products of greater energy efficiency.

The actions of the Government have contributed to advances in the area of energy production when they created the regulatory agencies (ANEEL – National Electric Energy Agency and ANP – National Petroleum Agency), and forced the public utilities to adopt contractual measures and combating waste as well as technological development.

3.2 Procel

According to Eletrobrás in 2011 [6], the Procel Stamp aims to guide the consumer in the Act of purchase, indicating the products that present the highest levels of energy efficiency within each category, providing thus saving on your electric bill. Also stimulates the manufacture and marketing of products more efficient, contributing to the technological development and the preservation of the environment.

The seal has a voluntary character and all products must be analyzed and tested in laboratories recognised and reputable indicated by the PROCEL. The criteria set out in the regulation of energy economy Procel Stamp-2011.

3.3 Performance Standard ABNT NBR 15575:2008

The benchmarking of lighting in buildings take into account natural and artificial lighting. In both cases, should be observed the human visual comfort requirements, which include factors such as appropriate to the activity exercised illuminates and ofuscamentos free visual field.

According to ABNT NBR 15575-1:2008 [2] during the day the building housing dependencies should receive natural lighting from outside should be, directly or indirectly, through adjacent enclosures.

And at night, the lighting system must provide satisfactory internal conditions for occupying the precincts and circulation in environments with comfort and safety.

Set these two basic conditions of illumination, the standard addresses separately for each of these situations, criteria and methods of evaluation.

3.3.1 Nature Lighting

The natural lighting requirement established by the standard is the need that all environments receive amounts of natural light, obviously, during the day. As a criterion, the ABNT NBR 15575-1:2008, page 22 [2], presents satisfactory minimum illuminated environments just by natural lighting.

As a way of evaluating the natural lighting includes three standard methods. The first consists in the analysis of the project through established premises, the second is through the method of calculation and the third through on-the-spot measurement.

3.3.2 Artificial Lighting

The requirement for artificial lighting according to ABNT NBR 15575-1:2008 [2] consists of providing artificial lighting conditions satisfactory, according to the internal regulations applicable to other Brazilian occupation of premises and movement in environments with comfort and safety.

As a criterion, the standard puts minimum levels, intermediaries and of artificial lighting for the environments must be in accordance with ABNT NBR 15575-1:2008, page 23 [2].

The methods of evaluating compliance with stipulated in standard consists of the same applied to natural lighting. Project analysis, method of calculation and measurement in situ.

The concern made explicit by the standard of performance is not the only attempt aimed at prioritizing the quality in construction, as well as meeting the needs and comfort of the users. In the same line, but directed the use of natural light can cite the ABNT Standard Project 02:135.02-001 [3] that arose from the requirement, established by the society of projects and buildings that implement the concept of energy efficiency and visual comfort, overlooking the use of renewable resources and reduced environmental degradation and its inputs or raw materials.

This project has as standard order publicize and sort the information, providing the professionals

related to construction area the instruments for the implementation of mechanisms to control and enjoy natural lighting, increasing luminic performance without compromising thermal performance.

The scope of this standard design is divided into:

General terms and conditions, which are determined or confirmed the nomenclatures used in academia as azimuth, artificial sky, zenithal lighting, area or time zone among others.

Lighting components in which is divided into general and qualifiers. The item is informed way of penetration of light in the building if it's zenith, global, driving, etc. In the qualifying item is put the type of the element in which there are penetration, for example, windows, skylights, domes, sun ducts, lobby, etc. Defining the characteristics of each of them.

Control elements consisting of protectors or of entry totes natural lighting to the interior of the building. Normally transmit the light diffuse or with less intensity, decreasing the thermal impact and consequently the use of artificial refrigeration. Include light shelf, ledge, venetian blinds, awnings, leaked element and others.

4 STANDARD CONTEXTUALIZATION

Brasília, with only 50 years old, considered a symbol of modernist architecture and urbanism of the 20th century, renowned for its organization and planning intended for the concern with the well-being and quality of life of its inhabitants, comes problems common to older cities, linked mainly to the performance in the construction is related to the quality of the materials or the services provided both in the design phase as of execution.

One of the great dilemmas faced has been the adoption, economic and commercial reasons, of architectural styles originating in countries with temperate climates which cause disorder in the environmental comfort item as well as increase energy consumption by making buildings less efficient and cooling systems are deficient. The blame for this can be attributed to the lack of a correct process of design and implementation of legislation has that force a serious study of the use of artificial light and natural light with correct choice of control elements and without prejudice to the thermal performance.

In order to resolve such issues in a manner that is objective and based on measurable parameters there is an effort on the part of local and national professional, to regulate and approve the ABNT NBR 15575-1:2008 [2].

In this order, despite the constant increase of fully glazed facades, in Brasilia, there are examples of application of elements of lighting control in older buildings that demonstrate the feasibility of using them without cosmetic damage and executives in what actually transpires is the opposite where these elements are essential and integral part of your body and conception of buildable project.

Examples of such architectural works the following inserts:

a) Esplanada dos Ministérios

Predominant control element on the west facade of the ministries, presented in the Fig. 1, are the vertical blinds, commonly called brises. This element aims to partially or completely block the entrance of natural light, being mostly adjustable. The concern with the solar incidence became intrinsic feature of the building.

Fig. 1 – Vertical venetian blinds (brise), control element on the west facade of the ministries in Brasília-DF (ARAÚJO, SIMÕES & SPOSTO, 2012) [14].

b)SCS (Setor Comercial Sul) - Edifício Morro Vermelho in Brasília - Distrito Federal

The predominant control element on the north facade of the building, presented Fig. 2, are mobile, but if eaves are positioned perpendicular form openings can play also the role of light shelf, leading to diffuse the light way to the interior of the rooms. On the south facade, Fig. 3, by receiving less insolation has only a brise to block or divert light occasionally, probably in the summer.

Fig. 2 – Mobile eaves in the north facade of the Building Red Hill in Brasília-DF (ARAÚJO, SIMÕES & SPOSTO, 2012) [14].

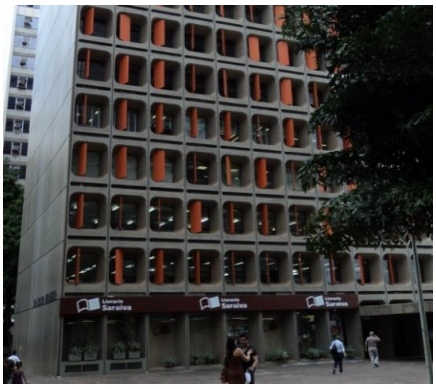

Fig. 3 – Mobile brises in the south facade of the Building Red Hill in Brasília-DF (ARAÚJO, SIMÕES & SPOSTO, 2012) [14].

c) SQN (Super Quadra Norte) 206 in Brasília-Distrito Federal

On the block there are two types of control elements made in concrete. The first, Figure 4, is classified as leaked, popularly called cobogó, and is in the service facade. The second, Figure 5, is the eaves and there is presence of the same both in front of service as the main facade. The interesting of both is in the peculiar way in which they were designed and how sets all perception and composition of facades.

Fig. 4 – Cobogó on front of block services 206, Super Block North – Brasília – Distrito Federal (ARAÚJO, SIMÕES & SPOSTO, 2012) [14].

Fig. 5 – Eaves on the main facade of the block 206, Super Block North in Brasília-DF (ARAÚJO, SIMÕES & SPOSTO, 2012) [14].

d) DNIT (National Department of Transportation Infrastructure)

The building of the local government Sector North DNIT in Brasilia-Distrito Federal, Figures 6 and 7, has elements venetian type concrete made fixed which probably were rented in accordance with the solar orientation, protecting from direct impact and allowing natural ventilation.

Fig. 6 – Fixed venetian view open in the Building of the DNIT in Brasília-DF (ARAÚJO, SIMÕES & SPOSTO, 2012) [14]

Fig. 7 – Fixed venetian view closed in the Building of the DNIT in Brasília – DF (ARAÚJO, SIMÕES & SPOSTO, 2012) [14].

e) W3 North - Brasília Shopping

The building of Brasilia Mall in Brasilia - Federal District, Fig. 8, is composed basically by a skin of glass without any barrier enabling shadowing the internal spaces, the only existing control element is the smoked tempered glass which is best suited to the climatic profile of Brasilia.

Fig. 8 – Tempered glass smoked in the Building of the Brasilia Mall (ARAÚJO, SIMÕES & SPOSTO, 2012) [14].

From what was observed in the Brasilia buildings, noted that market demand is still a primary factor for implementation of control elements on the facades, because there was a larger presence in the most ancient buildings made of concrete, sometimes with metal inserts and typological modernist trends. Unlike more recent constructions that mostly have smooth translucent facade without any feeder component of sunlight which refer to an aesthetic as bold, contemporary and technological.

5 FINAL CONSIDERATION

The problematics of energy in the world and in Brazil, besides being guided in discussions or congresses, now has to be tackled thinking of creative solutions and alternatives. It is necessary that both the construction and the use of this be soon adapted to the new paradigms characterized by the limitations of energy sources.

The Brazil has a climate that enables the reduction of energy consumption of buildings. Due to the existence of his celestial dome between the brighter the world, allowing you to dispense with the use of artificial lighting on most of the day, and because the thermal differences between summer and winter in most of the Brazilian territory are small, providing a comfortable operation of buildings with minimal energy expenditure.

But, it is essential to note that the lighting should be designed for the user of the building. For the right sizing of a natural lighting system must pay attention to:

a) The right sizing of openings buildings, considering the amount and type of light that enters the same, leading to visual comfort;

b) Exercise caution especially with the thermal efficiency of the surface area of the window that is limited in luminous efficiency. So, the ideal is to use only the illuminating surface required, in addition to the use of elements of control against direct sunlight;

c) As clearer are the surrounding surfaces and the inside of the building, the better will be the performance of the lighting system;

d) Right-sizing of the lighting system, by establishing right of visual activities and characteristics of who performs;

e) Still consider the quality and the energy capacity of lamps, the sizing system of artificial lighting.

So with the application of sustainability concepts increasingly disseminated around the world and the growing technological development of construction components is assumed that the market trend of Brasilia as well as changing global, even if it takes a few years, and value beyond aesthetics, concepts like the functionality, durability, recyclability and the performance.

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ANALYSIS OF DEMOLITION AGGREGATES IN CONSTRUCTION

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Abstract

All over the years, and in what construction industry concerns, the types of used materials, as well as the applied building processes, have been gradually modified, in order to achieve the purpose that was intended to attain, economic contingencies of the moment, and also the existing market technological availabilities. Over the last century there were no specific demolition processes, since the needs of those times were considered zero or of less importance, using up, for some specific purpose very simple existing methods. Meanwhile, the need to find new and faster demolition processes began to take shape as indispensable in the construction industry.

Due to several factors, the art of demolishing, with advancing time, acquires increasing importance, giving rise to a specific type of highly specialized services, which today goes by the name of Demolition Industry. The advancement of technology gives rise to alternative methods of buildings demolition for the replacement of damaged structures with new buildings, integrated into a social network, essential to the development and progress of the modern world.

The demolition industry and the materials recycling are presented as essential elements in the constant struggle for change and integration of human conditions to the surrounding environment. Structures, after a certain period of time, will deteriorate. Sometimes, when they reach a point where they no longer can be used or are considered unsafe, demolition is less expensive than restoration.

Demolishing of an old building and construction of a modern one in its place, will be safer and will improve the zone outlook. Thus, the demolition emerges as one of the tools to maintain the good performance of the cities contributing to a sustainable development.

This research aims to analyze the existence of inert in a specific demolition process and to identify the presence of potentially hazard materials that may put in risk people's health and safety.

Keywords: Rehabilitation, demolition, hazard materials.

1 INTRODUCTION

The demolition is the act of deliberately destroying some construction in order to give another destination to the space formerly occupied by it. To make a demolition there must be some causes for its occurrence, which are divided into buildings with a few years of use, due for example: long-term deformation, regulatory constraints, anomalies and durability of materials, structural reinforcement, etc, In newly built buildings demolition may happen due to design change, incompatibility between projects and different specialties, errors in design deficiencies and/or construction, etc.

The demolitions should be carried out by companies specialized in this type of work because they are high risk operations. The demolition process begins by making a detailed study of the structure which will be demolished, the existing infrastructures, possible neighboring buildings, procedures for execution and inspection, the possible existence of hazardous products/materials (eg: asbestos, concrete pre-stressing), and by protecting the public service features likely to be affected, so that none of these procedures put at risk the safety of workers, the surrounding buildings and the public that circulates in the immediate area to be demolished. This plan should include placing protections, collective and/or individual, to be implemented during the process.

The demolition should also assess the strength and stability of each of the parts of the building (especially the floors), in order to predict the type of demolition plan to adopt, without jeopardizing the safety of workers and the neighboring buildings. The following step, after the site recognition, is the choice of the demolition process.

This research aims to investigate which materials, used in the demolition procedure, may be harmful to the health of workers. So, in this a case study, a sample was collected from a demolished building,

analyzed it through to its chemical/morphological composition and the results were correlated with the materials used in the reconstruction.

2 METHODOLOGY

The work in question was basement on a building, ground floor and 1st floor, located in Vila Real. This building was demolished, and only the fronts were kept, as shown in Fig. 1. The purpose was to build the Headquarters of the Latin Quarter and the Artists House.

Fig.1 – Building facade with the respective containment.

When the workers were dismantling the stone to lower the quota threshold, with the aid of manual pneumatic drills, the material was being crushed and reduced to dust. This dust was collected on site, at several distinct points with the aid of a shovel. The sample was then observed using Scanning Electronic Microscope, SEM, in order to obtain morphological and chemical composition. The samples were mounted on aluminium supports for placing the microscope. In Fig. 2 one of obtained SEM photomicrographs may be observed.

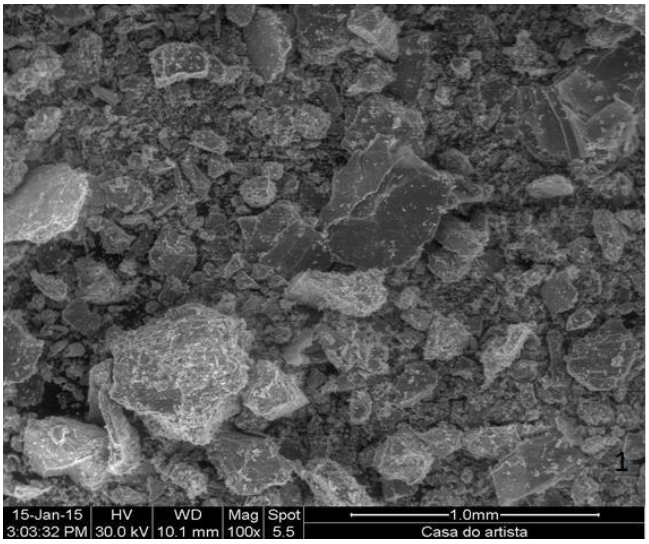

Fig. 2 – SEM photomicrograph of a collected sample.

The sample appears to be more crumbled, with finer powders. Powders are practically all of angular shape. The sample varies greatly with regard to the degree of heterogeneity, since the powder shape and size are very dissimilar.

Fig. 3 shows the results of Energy Dispersive Spectrometry, EDS, analysis. Through the spectrum observations, and WDS analysis, it may be seen that:

- The sample main constituent is oxygen (O_2), silicon (Si) and aluminium (Al), although the aluminium may be misleading, because aluminium supports were used as a support for samples placing,

- It also comprises potassium (K), sodium (Na), iron (Fe) and Calcium (Ca), although in lower percentages;

- Magnesium (Mg) and Titanium (Ti) were also present, but in very low percentages, nearly zero.

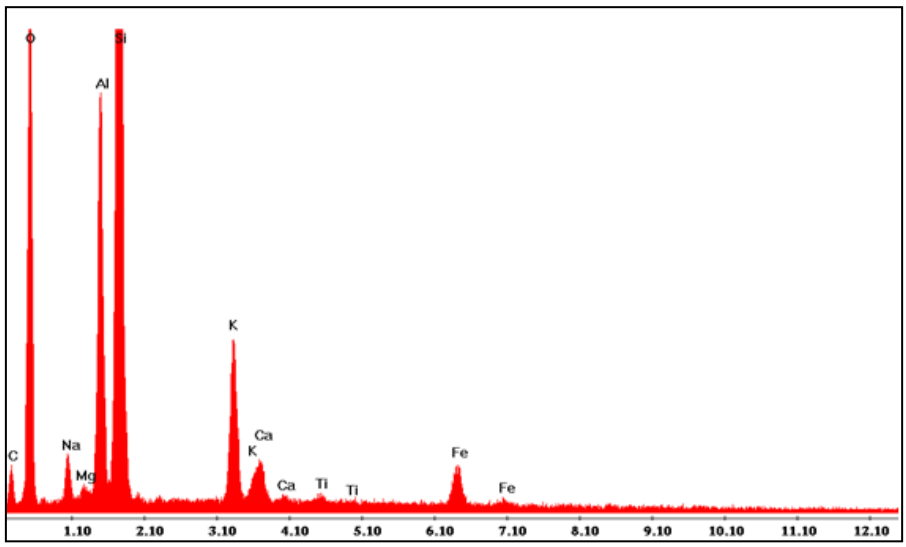

Fig. 3 – Samples EDS analysis.

3 CONCLUSIONS

The materials used were those used at the time of construction, partition walls in “tabique”, wooden slabs and beams, and ceramic coatings. However in this work was only possible to analyze the dismantling of stone. This disassembles served to lower the quota threshold. The remaining materials had already been removed and disposed in landfill, according to the legislation indication

Since one does not know the chemical composition of the stone (used to remove inert) prior to the construction work, it was not possible to correlate the chemical composition before the beginning of the work, with the inert current analysis results.

Apparently chemical elements that have emerged in stone demolished are not harmful and so they seem to have no negative interference in the workers’ health. Often these hazard materials are present people involved with the demolition process may even Apparently chemical elements that have emerged in stone demolished this work does not have harmful materials that might interfere the health of workers. Because often these harmful materials exist and may appear in the demolition process it is important to make studies like this, or others of similar nature, to realize in what extent they can affect workers or residents of these rehabilitated buildings.

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MASTER STUDY ON ENERGY EFFICIENCY AND RENEWABLE ENERGY SOURCES

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Abstract

Renewable energy sources are expected to play a greater role in the future based on the rich natural potential of the region. In addition, appropriate efforts to formulate strategic reasonable use of energy policies are initiated for assuring buildings sustainability and providing guidelines for future architecture. This paper includes an review of the current RES and RUE development status in the West Balkan region, giving special emphasis to the common EU project outcomes, especially innovative education programme as well as some identified particularities of new technological applications.

Keywords: Renewable energy, Rationale use of energy, study programme, bioeconomy.

1 INTRODUCTION

The development of renewable energy sources (RES) and rationale use of energy (RUE) present a central aim of the world energy policy in the last years. International studies raised crucial concerns about increasing the share of renewable sources in the energy balance that could contribute to improve the security of energy supply by reducing dependence on imported energy sources during the last decade. Considering the above, the ultimate goal of this paper is to present in a coherent and integrated way a review of the current status regarding the development. It is noted that the review presented is based on collected information especially from Tempus project ENERESE [1] and the possible sources.

The first section presents the energy outlook of the west Balkan countries, given emphasis to the energy indicators that especially have an impact on climate changes issues. The next sections are devoted to the review of the implemented activities regarding RES and rational use of energy RUE development in master study programmes in WB countries.

2 CURRENT ENERGY ATTITUDE

It is well known that in the Western Balkan countries the efficiency of energy use is approximately three times less than in EU countries. The average energy consumption in residential buildings is over 150 kWh/m^2 per year, while in EU countries it is only abou 50 kWh/m^2. Furthermore, public buildings in WB show less sustainable measures in terms of energy features, energy performance, environmental features and privacy. Because of the population growth and rapid development in countries, the demand for electrical energy in recent years is approaching the power generated, mainly during the winter months. More specifically, the electrical energy consumption in the residential sector is at the highest levels compared to the industrial and agricultural sectors. Thus, in this region almost 20% of great domestic product was spent on energy, compared to about 5% of GDP in EU countries. Issues considered in the assessment of buildings such as energy use per square meter and CO_2 emission are alarming [2].

Electrical energy saving can be nowadays achieved through the use of efficient electrical equipment, application of passive energy technology in buildings such as insulation, evaporative cooling, ventilation and solar heating. In addition to energy efficiency measures, the other way that citizens and government can offset rising energy costs is increases public awareness about the benefits of energy efficiency, targeting all the key energy sector stakeholders on the benefits of using energy efficient methodologies and codes, regulations, energy information and databases.

The need for a study programme in this field became evident during many contacts among teaching staff in universities involved in this project. These needs are also expressed by non-academic partners. During the reorganization of universities according to Bologna suggestion many contacts with EU universities have been established. These contacts made clear that appropriate study

programs are missing in several countries. As an output of the common activities in the above ENERESE project [1], the applicable curricula and the training programmes for integral sustainable energy design were developed. Project aims was also to train qualified master engineers in relatively new and broad interdisciplinary field of reasonable use of energy in partner countries. Also modern teaching materials have been prepared. The training material can be used as a methodology to solve new problems concerning energy efficiency and energy economics. The material contains state of the art knowledge and is with the necessary degree of detail, yet at the same comprehensive and attractive.

3 NEW TWO YEARS MASTER PROGRAMME

The major objective of the project activities was to structure the development of the new master programme at energy efficiency, renewable energy sources and environmental impacts at WB universities in accordance with the European standards. The completion of the master programme, which corresponds to 120 European credit transfer system (ECTS) has to be done in two years.

No.	Subject code	Subject title	S	Subject status	Classes of active teaching			ECTS
					L	E	SRW	
1st semester								
1	EERES11	Energy sources	1	OB	2	2	0	6
2	EERES12	Concept of energy efficiency and management - EU and national legislation prospective	1	OB	2	2	0	6
3	EERES13	Energy efficiency in buildings	1	OB	2	2	0	6
4	EERES14	Digital systems of automatic control	1	OB	2	2	0	6
5		Optional subject 1	1	EL	2	2	0	6
Optional subject 1 (chosing 1 subject out of 3 offered)								
5a	EERES15	Energetic impacts on environment	1	EL	2	2	0	6
5b	EERES16	Energy efficiency in transport	1	EL	2	2	0	6
5c	EERES17	Urban and architectural aspects of energy efficiency						
Classes of active teaching in total in 1st semester					**10**	**10**	**0**	**30**
2nd semester								
6	EERES21	Energy efficient, environmental friendly construction materials	2	OB	2	2	0	6
7	EERES22	HVAC	2	Ob	2	2	0	6
8	EERES23	Energy efficiency in municipal services	2	OB	2	2	0	6
9	EERES24	Use of renewable energy sources	2	OB	2	2	0	6
10		Optional subject 2	2	EL	2	2	0	6
Optional subject 2 (chosing 1 subject out of 2 offered)								
10a	EERES25	Use of solar and wind energy	2	EL	2	2	0	6
10b	EERES26	Geothermal and biomass energy	2	EL	2	2	0	6

Classes of active teaching in total in the 2nd semester					**10**	**10**	**0**	**30**
Classes of active teaching in total in the 1st study year					**20**	**20**	**0**	**60**
3rd semester								
11	EERES31	Energy monitoring and system control	3	OB	2	2	0	6
12	EERES32	Economical and environmental aspects of energy efficiency and renewable energy sources – cost-effectiveness and CO_2 emission	3	OB	2	2	0	6
13		Optional subject 3	3	EL	0	0	12	18
Optional subject 3 (chosing 1 subject out of 2 offered)								
13a	EERES33	Profesional practice – energy efficiency in construction sector	3	EL	0	0	12	18
13б	EERES34	Profesional practice – energy efficiency of mechanical systems	3	EL	0	0	12	18
Classes of active teaching in total in the 3rd semester					**4**	**4**	**12**	**30**
4th semester								
Optional master thesis (chosing 1 subject out of 2 offered)								
14a	EERES41	Preparation and defense of master thesis – energy efficiency in construction sector	4	EL	0	0	20	30
14б	EERES42	Preparation and defense of master thesis – energy efficiency of mechanical systems	4	EL	0	0	20	30
Classes of active teaching in total in 4th semester					**0**	**0**	**20**	**30**
Classes of active teaching in total in the 2nd study year					**4**	**4**	**32**	**60**
Classes of active teaching in total in the whole study					**24**	**24**	**32**	**120**

S- semester; OB – obligatory ; EL – elective ; L – lecture ; E – exercise ; SRW – study research work

Another main aim is for the students to gain additional skills in topics that have not been widespread in the existing curricula, such as economics, management, professional communication, usage of state of the art software packages in their work, dealing with modern technologies and ability to handle professional communication in English. This was particularly important as it is a prerequisite in order to enhance the students' chances for employment and to help them to take a proper place in the regional and international society and economy. It is very expected that such professionals will become highly competitive on the local and regional labour market.Students have the choice of two modules of technologies to specialise in Energy efficiency in buildings and RES or Heating, Ventilating, and Air Conditioning (HVAC) and hybrid systems as the technology of indoor environmental comfort using RES. A common mode for both modules includes subjects related to civil engineering, mechanical engineering and electrical engineering as well as to the subjects devoted to environmental science and technologies and management skills. Previously developed set of electives attempt to establish a uniform level of knowledge on RUE. Each WB partner university is free to add to its syllabus some topics of its choice, as long as the learning outcomes are respected. Special set of electives have been developed for masters to continue with the improvement of their skills in the rapidly changing field of RUE. Quality control of master programme study is conducted regularly and systematically through self-assessment and external verification of quality.

Within the scope of this study programme, and in the frame of the deliverable, emphasis was also placed on information referring to:

- economy and investments, namely on macroeconomics, capital cost, debt and equity structure, inflation, fiscal policy,
- economic features of an investment, namely on capital expenses, depreciation, revenues and expenses, cash flows, salvage values,
- energy investment plans and time, namely on the time value of money, lead and implementation time, cost concepts and identification,
- investment appraisal methods for energy production and energy conservation investments, namely on net present value, internal rate or return, life cycle cost, levelled cost of energy, depreciated payback period,
- tools to promote energy policies and renewable energy sources, namely on feed in tariffs, net metering, alternative subsidies schemes,
- costing and pricing of energy, namely on fixed and variable cost of power generation, sensitivity analysis, break-even point,
- life cycle analysis of energy projects,
- sustainability certification schemes and tools,
- large and small scale energy business structures,
- financing schemes, namely banking, equity financing, crowd funding,
- legal aspects of energy projects, focusing on large scale building refurbishment and renovation schemes, district heating systems.

The lecture teaching materials with abundant information and presented in a very comprehensive way have focused on energy monitoring systems, biomass perspectives as well as wind and solar energy and the respective markets. They covered a broad set of environmental economics issues in order to provide students with an insight into the subject. The main courses provided a well-balanced insight into the topics of energy and buildings, by presenting the technological aspects in a concise and comprehensive way.

4 CURRENT CHALLENGES

The relevant study estimated that a saving of the electrical energy in the industrial sector could be achieved by applying *solar thermal systems*, using flat plate collectors. Solar thermal absorption systems are ideal ones to be adopted and implemented for cooling and refrigeration. The solar water heaters may reduce electricity consumption in water heating sectors for many hot water domestic and industrial applications. Furthermore, the high temperature water could be used to generate electricity. The electrical energy could be used immediately or stored through the production of hydrogen via electrolysers.

Until 2006 application of *photovoltaic* panels was limited by high prices to special applications. Great demand for ecological energy and government subsidies have driven the research and nowadays, price of panels was reduced significantly, photovoltaics is applicable for general use, but still expensive. Photovoltaic panel can be effective in environment with large portion of diffuse light. More specifically, adoption of solar technology is very advantageous in WB and small capacity projects were conducted. However, the main drawback of using such technology is the decrease of the photovoltaic cells efficiency because of the high temperatures, which in turn reduces the efficiency. Daily production is very *unstable*. In case of an off grid system, large accumulation is needed. Local generation decreases the *voltage drop* on a power line, reducing the current flowing from network to distribution transformers, causing significant changes of nodal voltages, often oscillating from -10 % of nominal voltage to +10 %. Of course, the still high cost of the cells, energy storage and short operating lifetime are other disadvantages. However, wider use of solar energy, supported by *state subsidies* leads to significant increase of electricity prices. Moreover, the *mixture* of dust and humidity plays an important role in limiting the efficiency of the solar cells [3].

According to the relevant estimations, the *wind power* is not encouraging, nevertheless during the last decade, the installed capacity has grown. The turbine converts the kinetic energy of moving air to mechanical energy on the shaft. The power of a wind turbine is given by the square of rotor diameter and the third power of wind speed. Even relative small change in wind speed results in big change of output power. Moreover, the operation of this type of turbine is reasonable only if the average wind speed in the location of operation is higher than $4 m \cdot s^{-1}$. Typical localities for wind generation are seasides and hills or mountains. Inland localities have in general much worse conditions for wind generation. Wind generation is often called as distributed generation. In fact, most of installations is concentrated in relative big wind parks with overall installed capacity of several tenths or hundreds of megawatts. Such a wind parks behave from grid point of view as one big power plant. In countries with

high installed capacity in wind power plants, generation in wind parks significantly influences the operation of national power grid, often also power grids of neighbouring countries. Unfortunately, it is possible to *regulate* output power of a wind power plant, but only *downwards* by changing the aerodynamics of rotor blades. In a power grid, consumption and generation must be always in balance. In order to keep this balance, it is necessary to have a qualified forecast, so the transmission system operator can reserve enough *regulation capacities* to eliminate the fluctuation of wind power. If the operator fails to keep the balance, in the interconnected network, this disturbance will spread to neighbouring states. This affects scheduled power flows and potentially can cause massive *outages* or black-out. Thus, large installed capacity in wind in a system with not enough regulation capacities and limited transmission capacity significantly decreases system safety. More wind power is not automatically more ecological, if the fluctuation of wind generation is high and *regulated with fossil* power plants. Furthermore, *noise* from the wind turbine is another problem. If windmills are installed in the areas now considered to be isolated, in future, they could become inhabited, thereby reducing the local wind kinetic energy because of the obstruction by buildings.

A good solution that is under construction is a mobile *hybrid system* consisting of wind generators and solar panels to produce 1.5 kW of alternating current electricity for rural areas. This system utilizes solar power and wind power and is suitable for many applications, such as mini mobile clinics, small schools, libraries and camping sites. Furthermore, contribution to RUE is achieved by installing energy efficient motors instead of standard efficiency motors. This transition becomes a necessity as a direct result of limitation in energy sources and escalating energy prices.

In addition, a possible *hydrogen energy* system was studied. The only remedy to the above problem is to exploit solar energy and to produce hydrogen through an electrolysis process, in order to satisfy the gap between demand and fossil fuel productions.

Regarding *tidal power* this type of energy is possible, but it has the disadvantage that it is very cost-ineffective, because maximum tidal height does not exceed 3 m. Unless a location with a tidal height larger than 6 m is chosen, it is not recommended to invest money on such a project.

According to the appropriate, adopting *water technology* can cause a disturbance for fishermen. This does not hold out a worthwhile promise as a practical source of energy. A very large number of turbines is estimated possible to be installed from this type of RES in the near future.

Companies have implemented a number of RES projects, mostly consisting of solar applications in the WB region, especially using photovoltaic solar systems. A number of other enterprises specialize in alternative power solutions, meeting the energy requirements of the region with solar, wind energy and power backup systems. Universities in the region have carried out demonstration small scale RES and RUE projects as well as feasibility studies for the viability of such RES and RUE applications.

However, since two decades, CO_2 emissions have increased and the contribution of RES and RUE in these countries is relatively low. More specifically, till now, only minor RES and RUE activities such as pilot, research and real life projects were conducted and as a result, some small and medium capacity projects were installed and tested. The main reasons can be identified as:

- the greater competitiveness of conventional energy supply technologies based on oil and gas,
- the high initial cost of RES and RUE projects in relation with the long time period of depreciation of the investment,
- the lack of available funds of the enterprises for the implementation of these projects,
- the financial, technological and performance risks of these projects, which are often high for an enterprise related to the expected results,
- the lack of awareness regarding the performance of modern and innovative technologies.

Oil and gas are sure to remain the major energy sources in the foreseeable future. Their use as primary fuels is expected to further expand, due to the accelerated developments in the respective technologies, which lead to more efficient processes in all aspects of exploration and development equipment. Oil demand is expected to grow somewhat faster in the future than over the past two decades. This is due, primarily, to the continuing increase in world demand and to the lack of commercially viable and easily storable alternative non-fossil energy resources. Consequently, contribution of RES is almost small till now and is estimated to be relatively low in the foreseeable future.

But then again *sustainable development* is development that meets the needs of the present without compromising the ability of future generations to meet their own needs [4]. The challenge of a green economy is to improve the standard of living in developing countries without increasing their carbon

footprint and in the same time maintain the standard of living, while reducing their footprint. The notion *biobased economy* is recently announced and used on international levels and defined as an economy that uses renewable bio-resources, efficient bioprocesses and eco-industrial clusters to produce sustainable bio-products, jobs and income. *Bioeconomy* is no more limited to research but has developed into a *strategy* and *policy* with heavy emphasis on innovation. This has not yet been successfully acknowledged by all stakeholders as well as policy makers and has not reached the level of mass acknowledgement. There is a threat that outside Europe these rules will be quicker implemented than in the old continent, in particular because of more courageous and speedier decision taking in building or industrial bioeconomy complexes and using new innovative ways of funding, including the potentials of available public funds and investment in the format of state funds.

5 CONCLUDING REMARKS

Use of renewable energy sources is not just technical problem, but also economical and legal. Nowadays, the countries of WB region are keenly interested in taking a more active part in the development of RES and RUE technologies, because the region has significant especially solar potential. These countries have many remote villages and settlements that can benefit from the friendly environmental energy applications. In addition, the demand for electricity is expanding as an inevitable outcome of social and economic development. Consequently, their major challenge for the near future needs to be the commercialisation and industrial use of large scale RES and RUE applications. These technologies are estimated to play a greater role in the future, in order to contribute to the reduction of the climate changes effects. In this framework, we should be aware that is not possible to remain reliant on oil and gas for forever. Thus, energy management and promotion of RUE will be a prerequisite for meeting the future energy demands.

Higher Education is one of the few “industries” where single or quite a few persons, the teachers, can design, develop, deliver and adjust the quality of a “product”, the student. Hence, to achieve and improve the quality of education in the field of renewable energy sources and rationale use of energy, integrated study master programme was implemented, as principal output of project activities. The actions also aimed to contribute to the dissemination and increasing public awareness in energy efficient technologies. The efforts have been focused to promotion of mutually beneficial technological cooperation between organizations and professionals for innovative efficient technologies.

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FARMER PARTICIPATION'S MODEL IN IRRIGATION SYSTEM MAINTENANCE
CASE STUDY: KHUN DAN PRAKARNCHON DAM, THAILAND

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Abstract

User participation is the one of several succeed keys in sustainable development. This research aimed to develop the simple regression model for evaluate Farmer Participation's level (FPL)in the Irrigation System Maintenance (ISM). Total 339 samples were used in this study these are water users in the service area of Khun Dan Prakarnchon dam of operation and maintenance's project, Nakorn Nayok province, Thailand. The analysis shows that there are the three main activities help to promote the FPG activities, those were 1) Dredging cannel, 2) Donation for ISM activities and 3) Development operation and maintenance of ISM plan. The models could be analysis the relationship between individual socio-economic factors, FPG factors related with ISM activities and participation level. Final analysis model shows that increase in the water-user role in FPG status, land holding and information received from irrigation office these indicated the high value of FPL. In the opposite way, decrease in the crop cultivation type, and the farmer's education level, these indicated the low value of FPL.

Keywords: Farmer's Participation, Maintenance, Irrigation System, Khun Dan Prakarnchon Dam, Royal Irrigation Department.

1 INTRODUCTION

Water is a limited natural resource that is vital to the survival of mankind while the water consumption demand is increasing dramatically. According to the activities of various sectors such as agriculture, household consumption, industry and ecosystem maintenance. Total 65 percent of water consumption demand is in agriculture sector [1] resulting in a shortage of water.

In the past, the water resources projects in Thailand were focus on the construction hydrologic infrastructure such as construction canals, irrigate building, large scale multi-purpose water reservoir (eg. Bhumibol Dam, Sirikit Dam). This reason, totals 16,782 projects (until year 2015) were developed for irrigation system in Thailand [2] but the water supply still is not adequate. Nowadays, the several limitation factors in construction a big dam such as government budget limited, suitability- area, geography, environment and ecology system. Also, due to lack of maintenance activities of irrigation infrastructure and the participation of the farmer, water resources development projects were inefficient. Then the Royal Irrigation Department (RID), Thailand revised the development strategy plan for water management projects.

For reaching achievement goal in sustainable development for solving the water shortage problem in Thailand, the maintenance and administrative management strategy plans were proposed.

1. Maintenance strategy plan, the objective of this plan is to increase the water storage capacity of the existing irrigation system using maintenance, construction, repair of irrigation infrastructures.

2. Administrative management strategy plan, this is the water management corporative plan by water users in the service area of dam. The main purpose of this plan is to make the plant cultivation plans for water consumption activities in drought area.

From above strategy plan, water users group were set up for encouraging participation in the management of irrigation under an agreement between farmers, water users and government agencies. This group will receive a sense of ownership of Irrigation Infrastructure (II), which will lead to joint management and maintenance of irrigation systems is substantial. This will cause integration in all sectors. A quantity of water for irrigation is sufficiently thoroughly and fairly.

The research study is to develop the simple regression model for evaluate FP's level in the Irrigation System Maintenance (ISM). The Major factor affecting the farmer's participation in ISM activities were

determined. The outcomes of this research are, to identify the participation's problems, to suggest and guide on the IMS of RID, Thailand.

2 LITERATURE REVIEW

ISM means monitoring, inspection, repair, construction of additional irrigation project to ensure the most efficient use of the water, to maintain the workability and powerful of II [3-4]. Maintenance system helps to effective used the II as follow by designed capacity, but also to maintain the life cycle of irrigation building. This system was divided into three categories as following [5],

1. The normal maintenance is the repair and maintenance of II those were a small damaged.

1.1. The rapid maintenance for damage prevention by explores the causes of damage and breakdown in specific case. After that, specify the processes for prevention II from the specific damages.

1.2. Routine maintenance is the repair and maintenance of the II, the main damage of II in every years, to maintain the workability and powerful of II along the designed period.

2. The special repair work is to repair irrigation systems damaged beyond regular maintenance, such as damage caused by natural disasters and the cumulative damage at yield point of II's materials.

3. Improvement, in case of II is could be not repaired or malfunction, then the new design for renovate/construction of II were proposed. (May be, construction an additional small II) [5].

Thailand government policy aims to promote the decentralization management, include local, sub-district and provincial administrative organization. Then the farmer's Participation in Irrigation Management (PIM) is promoted, this means; the management of irrigation system by farmers/water user whose be a part of the decision maker in the term of participant of RID activities. The duties and responsibilities of RID consist of two main missions: Construction and Operation/Maintenance (COM). These missions are separated into a three consecutive forms as COM projects were done by government only, by farmer only and by both sides; these are as shown in Figure 1 [6].

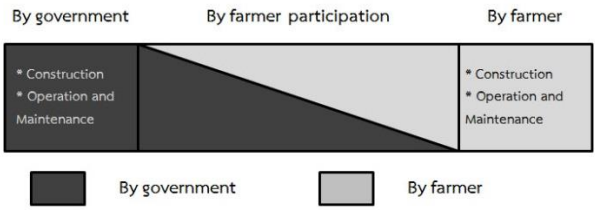

Fig. 1 – Irrigation management form.

Many techniques using FP for the design of sustainable and practical activities [7-9], these techniques does not apply in Irrigation system especially in Thailand. The time of maintenance and rehabilitation versus cost can greatly influence their effectiveness and cost as well as the overall II life (adopted from [10]), thus if were possible to reduce the cost and monitor II more frequently, there would be several benefits by using farmer's participation.

3 METHOD AND DATA

3.1 Study area and sample

The population of this research is the farmers who live in the service area of Khun Dan Prakarnchon, Operation and Maintenance project, Nakhon Nayok province, North Eastern, Thailand. Total 59 water users groups are equal the total 595 members. Appling Taro Yamane formula, total 239 samples were used.

3.2 Questionnaire

The tool used to collect data was questionnaire this divided into the five main sections.

Section 1: Farmer Socio-economics' data.

Section 2: General activities of Irrigation water users' data.

Section 3: Farmer's satisfied level of participation in ISM activities.

Section 4: Problems and Suggestions in ISM activities.

Section 5: Overall efficiency service level of ISM projects.

3.3 Reliability verifying of questionnaire

The pre-survey of 30 samples using questionnaire were verified the reliability and consistency, and also were improved before collect data. These samples were test using coefficient of alpha or Cronbach (α) as 0.901 (α > 0.75) [11] , this was indicated that the data has consistency and reliability adequate for data collection.

3.4 Correlation and Quantitative analysis

Descriptive Analysis is described or depicts the variables or characteristics of the population including frequency, Percentage, Means, Standard deviation; S.D. Quantitative Analysis is hypothesis testing by parametric statistic for interval and scale information including t -test, F - test (one way-ANOVA).

Simple regression models were used to describe the significant FP's factors of each IMS's activities.

4 RESULTS AND DISCUSSION

4.1 Farmer Socio-economics' data

The Farmer Socio-economics' data in study area include gender, age, education level, status of water users group, occupation and house hold monthly income are as shown in table 2.

From Table 2, approximate 50:50 percent of Farmer participation Groups (FPG) as male and female. FPG age during 46-55 years old is the highest number of FPG's member. Total 75 percent of farmers graduated the primary school, thus this is the normal characteristic of farmer in developing country. Mainly member of FP is active role in water users group. Finally, the Agriculture occupation is the main occupation of FPG with the monthly income as rate 5,000-10,000 baht.

4.2 General activities of Irrigation water users' data

The general activities data of FPG include agriculture land holding, crop cultivation types, planting location along alignment of canal/ditch and irrigation plant system these are as shown in table 3. There are 67.78 percentage of farmers rent the farm that plant a rice which located in a middle part of canal/ditch alignment. The flooding system is favorite system that was used in irrigation plant system.

4.3 Farmer's participation level in ISM activities

There are five ISM activities of RID were adopted to measure the level of participation of FPG [12]. The five levels of participation score are separated into the range 1.00-1.80, 1.81 - 2.60, 2.61 - 3.40, 3.41 - 4.20 and 4.21 -5.00 which are classified into excellent, good, moderate, fair and poor level as following.

Table 2 – Basic Socio-economics'data of FPG.

Personal data	Number	%
1.1 Gender		
Male	126	52.72
Female	113	47.28
1.2 Age		
<= 35	10	4.18
36-45	37	15.48
46-55	81	33.89
56-60	47	19.67
>= 61	64	26.78
1.3 Education level		
primary school	179	74.90
Secondary school	42	17.57
High school	12	5.02
High vocational certificate	4	1.67
Bachelor	2	0.84
1.4 Status & role in water users group		
Member	207	86.61
Assistant group leader	9	3.77
Committee	4	1.67
Group leader	19	7.95
1.5 Occupation		
Agriculture	214	89.54
Trade	6	2.51
Private business	2	0.84
Official	3	1.26
Company employees	14	5.86
1.6 Household monthly income (Baht)		
<= 5,000	33	13.81
5,000-10,000	121	50.63
10,001-20,000	57	23.85
20,001-30,000	21	8.79
30,001-40,000	5	2.09
>= 40,001	2	0.84

Table 4 shows the basic statistics of FPG in ISM activities. FPG's members were participated in ISM activities with the average score of 2.67 in moderate level. The farmer's participation level could be rearranged from highest to lowest level as score of 2.85, 2.81, 2.80, 2.53 and 2.34 which are as following, Dredging cannel, Donation for ISM activities, Development operation and maintenance of ISM plan, Compliance with regulations of ISM projects and Inspection and operation of II.

Table 3 – Agriculture activities of FPG

Personal information	Number	%
2.1 Agriculture Land holding		
Own	77	32.22
Rentals	162	67.78
2.2 Crop cultivation types		
Rice	196	82.01
Sweet plum mango	23	9.62
Marian plum	5	2.09
Pomelo	4	1.67
Vegetable	11	4.60
2.3 Planting location along alignment of canal/ditch.		
Upper	73	30.54
Middle	102	42.68
Lower	64	26.78
2.4 Irrigation plant system		
Sprinkler	25	10.46
Flooding	196	82.01
Furrow	18	7.53

Table 4 – Basic statistics of FPG in ISM activities.

Participation Activity	$\bar{X}$,	S.D.	Level	Rank
P1. Dredging cannel.	2.85	0.97	Moderate	1
P2. Inspection and operation II.	2.34	0.91	Fair	5
P3. Donation for ISM activities.	2.81	0.87	Moderate	2
P4. Compliance with regulations of ISM projects.	2.53	0.89	Fair	4
P5. Development operation and maintenance of ISM plan	2.80	0.87	Moderate	3
Average Score	2.67	0.90	Moderate	

Table 5 – Problems and obstacles in the using of irrigation water for the occupation or consume.

Problems and obstacles	Number	%
Non-problem	83	34.73
Problems	156	65.27
PB1.Lack of Water Volume	36	23.08
PB2.Despoil of water cause non-reliability of water discharge	59	37.82
PB3.Weeds in canals	50	32.05
PB4.Leakage of canal	8	5.13
PB5.Malfunction of water Gate	3	1.92

Table 6 – Overall efficiency level of ISM office.

Irrigation project efficiency	Number	%
Excellent	6	2.51
Good	96	40.17
Moderate	99	41.42
Fair	37	15.48
Poor	1	0.42
Total	239	100.00

4.4 Problems and Suggestions in ISM activities

There are five problems participation of RID activities were classified as the lack of water volume (PB1), despoil of water cause non-reliability of water discharge (PB2), Weeds in floating in the canals (PB3), Leakage of canal (PB4) and Malfunction of water Gate (PB5). These problems are as shown in table 5. The result shows that total 37.82 percentages of IPG's members despoiled the water because non-reliability of discharge water. Thus this problem should be solved as soon as possible too.

4.5 Overall efficiency service level of ISM projects.

The overall efficiency service level of ISM projects are as shown in table 6**.** The FPG member offered that the irrigation project efficiency is in moderate level, 99 of the samples or 41.42 % and 96 of the samples or 40.17 % offered that the irrigation project efficiency is in excellent level. This result is to indicate that more efficient in service's level of ISM projects, with the high score with 80 percentage of total complacence (moderate to good level).

4.6 Multiple linear regression analysis

Table 7 shows, the factors related with FPG (independent variables) in the participation's level of ISM activities (dependent variable) were determined using stepwise regression method. This is a semi-automated process of building a model by successively adding or removing variables based solely on the t-statistics of their estimated coefficients.

Table 7 – Description Variables of FPG using in the process of building a level of participation model.

Variables	Description
Socio-Economic factors	
AGE	Age
EDU	Education
SAR	Status and role in FPG
LHD	Land holdings
OCU	Occupation
FPG factors relate with ISM activities	
CCT	Crop Cultivation Type
MOI	Methods of Irrigation
TRN	Irrigation officers training, knowledge promoting in irrigation systems maintenance regularly.
MET	Irrigation officers meeting with water users committee and the member for operation and maintenance planning appropriately.
ASL	Irrigation structure, on farm canal, ditches is completely.
MNT	The irrigation structure inspected and maintenance can use it throughout operated duration.
DVS	The division of activities in irrigation system maintenance for members of irrigation FPG is clearly.
VOT	The voting committee of irrigation water users group transparent and according to the agenda.
FUN	The establishment of a fund for the irrigation system maintenance.
TPR	The committee of irrigation FPG managing in a systematic and possible with accuracy.
RUL	Enforcing rules regarding the irrigation system maintenance will be made up strictly and appropriate sanctions.
IFM	The members of irrigation FPG received and coordinated information clearly and accurate.

4.6.1 Model for dredging cannel with participation's level (PLM_{Dred}).

The farmer's participated in dredging the ISM activities related with 3 factors are as shown in equation 1.

$$PLM_{Dred} = 1.016 + 0.522(LHD) + 0.213(SAR) + 0.162(RUL) \quad (1)$$

Multiple correlation coefficients is 0.768 and 73.50 percent for predicted the farmer's participated in dredging the irrigation system. Standard error of prediction is ± 0.312.

4.6.2 Model for inspection and operation of II with participation's level (PLM_{IO})

The Inspection and operation of ISM activities related with 4 factors are as shown in the equation2.

$$PLM_{IO} = 1.7 + 0.209(MNT) - 0.273(ASL) + 0.111(AGE) + 0.142(TRN) \quad (2)$$

Multiple correlation coefficients is 0.795 and 78.70 percent for predicted the farmer's participated in checking and operating the irrigation system. Standard error of prediction is ± 0.380.

4.6.3 Model for donation for ISM activities with participation's level (PLM_{Donate})

The farmer's participated in donating for ISM activities related with 4 factors are as shown in the equation 3.

$$PIM_{donate} = 2.492 + 0.406(LAN) - 0.288(TPR) + 0.231(DVS) - 0.146(CCT) \quad (3)$$

Multiple correlation coefficients is 0.796 and 75.70 percent for predicted the farmer's participated in donating for irrigation system maintenance activities. Standard error of prediction is ± 0.417.

4.6.4 Model for compliance regulations of ISM activities with participation's level (PLM_{Rule})

The farmer's participated in compliance regulations of ISM activities include 6 factors are as shown in the equation 4.

$$PIM_{rule} = 1.014 - 0.121(CCT) + 0.389(MOI) - 0.183(EDU) + 0.164(SAR) + 0.170(MET) + 0.166(FUN) \quad (4)$$

Multiple correlation coefficients is 0.787 and 77.40 percent for predicted the farmer's participated in compliance with regulations maintenance of irrigation FPG. Standard error of prediction is ± 0.479.

4.6.5 Model for development operation and maintenance of ISM plan with participation's level (PLM_{Devpln}).

The farmer's participated in development operation and maintenance of ISM plan related with 5 factors are as shown in the equation 5.

$$PIM_{Devpln} = 2.535 - 0.255(OCU) + 0.176(SAR) - 0.161(CCT) + 0.249(TPR) - 0.133(VOT) \quad (5)$$

Multiple correlation coefficients is 0.771 and 72.10 percent for predicted the farmer's participated in irrigation operation and maintenance plan. Standard error of prediction is ± 0.479.

4.6.6 Model for overall of participation's level with ISM activities (PLM_{ALL})

The farmer's participated levels in overall ISM activities related with 5 factors are as shown in the equation 6.

$$PIM_{ALL} = 2.004 - 0.123(CCT) + 0.170(SAR) + 0.238(LHD) + 0.091(IFM) - 0.103(EDU) \quad (6)$$

Multiple correlation coefficients is 0.774 and 72.50 percent for predicted the farmer's participated in ISM activities. Standard error of prediction is ± 0.275.

5 CONCLUSION

The topography of Khun Dan Prakarnchon Dam Operation and Maintenance Project is plain. As a result, the people of the area are farmers mainly including rice cultivation and horticulture (fruits). The water for agriculture used from main canal of Khun Dan Prakarnchon Dam Operation and Maintenance Project. The average age of samples in the research is about 50 years old. The samples lived in the area for over 44 years. About 89.54 percent of the samples are the farmer. About 66.78 percent of the samples are rent the agriculture land. And about 74.90 percent of the samples are graduated in primary school.

About 41.42 percent of the samples offered that Khun Dan Prakarnchon, Operation and Maintenance project, RID, Thailand, efficiency is in the moderate level. Most of IPG's members despoiled the water because non-reliability of discharge water. Thus this problem should be solved as soon as possible too.

The FPG member offered that the irrigation project efficiency is in moderate level, 99 of the samples or 41.42 % and 96 of the samples or 40.17 % offered that the irrigation project efficiency is in excellent level. This result is to indicate that more efficient in service's level of ISM projects, with the high score with 80 percentage of total complacence (moderate to good level). This research also shows that there are the three main activities help to promote the FPG activities, those were 1) Dredging cannel, 2) Donation for ISM activities and 3) Development operation and maintenance of ISM plan.

The models could be analysis the relationship between individual socio-economic factors, FPG factors related with ISM activities and participation level. The main factors are education of FPG (EDU), status and role (SAR) in FPG, land holding (LHD), crop cultivation type (CCT), the members of irrigation FPG received and coordinated information clearly and accurate (IFM) those are as shown in the equation 6 above.

6 RECOMMENDATION AND SUGGESTION

Since only one set of FPG in 2015 was used in this study and more intensive investigation must be carried out FPG data in various years. In the further studies, it should be possible to apply this research to other dam project for promotion the water user participation in Thailand. Final the RID, Thailand, will know the water user participation level in irrigation system management policy.

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ECONOMIC EVALUATION OF VENTILATED FAÇADES SOLUTIONS FOR RESIDENTIAL BUILDINGS

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Abstract

The practice of economic methodologies to estimate life costs of building technologies has allowed select alternative solutions with lower maintenance costs and higher probability of reuse and recycling. This work aims to contribute to the identification and selection of constructive solutions and materials for the implementation of ventilated façades in exterior building walls, these solutions being compatible possible the economic objectives in the various stages of life cycle of a building.

In this work, the construction solutions that minimize the economic costs of investment, maintenance and deconstruction also contribute to increase quality of life of the occupants, due to the better performance that these constructive solutions will have at the functional and architectural level, health, wellbeing, comfort and social responsibility.

The constructions scenarios of ventilated façades were also studied taking into account the economic impact throughout the life cycle of a building. The best ventilated façade scenario was also studied taking account the economic performance.

It is expected that this work will contribute the increase of designer's knowledge of the construction solutions potential and that will lead to the selection of more economic ventilated façade systems aiming to provide the adequate comfort conditions to the occupants of the buildings, minimizing the economic costs during the life cycle of the building.

Keywords: Ventilated façade, Economic evaluation, Investment, Maintenance, Deconstruction.

1 INTRODUCTION

Constructive solutions for exterior walls has been researched in order to thinner solutions and therefore lightest; composed of a series of layers with increasingly specific functions. Within this trend emerged the ventilated façade. This type of building technology can be used in the rehabilitation of buildings which present problems – for example, thermal and acoustic insulation, lack of water tightness or cracking - as in the construction of new buildings. This solution contributes to the energy saving and reduction of risk of premature degradation of materials and prevents thermal bridges and condensation, giving to the building a higher quality and comfort. This constructive technology is associated with the resurgence of simple exterior walls solutions that had fallen into disuse since the mid-twentieth century.

The ventilated façade system is basically composed by an anchoring support, with a layer of thermal insulation material, by a ventilated air chamber, by fixing devices (superstructure), by coating material and joints between boards, in addition to other components required for normal operation.

The purpose of an economic assessment façades, in the construction life cycle, is to support the decision on the selection of the construction alternative looking for the optimization of the ratio between technical and economic conditions concerning a more cost-effective conservation, maintenance and deconstruction. The methods of economic assessment applicable to the analysis of façades can be summarized as follows:

- The management level of assessment should be clearly identified;
- The economic analysis provides the basis for taking decisions, but does not include the decision;
- Criteria, rules or guides choices should be formulated separately and before applying the results of the economic assessment unless the criteria are simple and easy to understand;

- An economic analysis must consider several alternatives within the resource constraints of time and cost;
- The alternatives should be compared through the same time period, so that most of the factors involved in the comparison can be defined with the same viability.

2 APPLIED METODOLOGY

2.1 Propose and case of study description

An economic assessment of constructive solutions takes place is proposed through a methodology of analysis on basis for comparison is, for each element, the constructive solution of ventilated façade more applied - the reference solution. The methodology to implement will be based on the MARS-SC (Metodologia de Avaliação Relativa de Sustentabilidade - Soluções Construtivas / Methodology for Relative Assessment of Sustainability - Constructive Solutions). This methodology proposes that the sustainability of constructive solutions are evaluated in relation to the reference solution, that is, the best constructive solution applied to a given location. In this methodology three aspects are considered: environmental, functional and economic [1].

For the case of study the *Edifício Séc. XXI - 8* has been used (the building was under construction during the preparation of this work – Fig. 1). It is located in the Autonomous Region of Madeira (RAM), namely in the Funchal Municipality (Portugal). The building presents a rectangular geometry, being implemented in a noble area of the Funchal City. It consists of six floors (5 floors) and a garage. In the process of study building, attending to the economic evaluation and life cycle of construction will be proposed to apply the construction technology of ventilated façade more appropriate. The building has a cost of sale of 2,500 €/m^2 and is intended for medium/high class.

Fig. 1 – Representation of the *Edifício Séc. XXI 8*, to be analyzed in the study case.

2.2 Methodology for economic assessment

2.2.1 Quantification of economic parameters

At this stage was established the number and the type of parameters to be analysed. The parameters definition to be analyzed depends on the objectives of assessment: the characteristics of construction solutions, the functional requirements, the local and the personal characteristics of the available data [1]. The method for the evaluation of life cycle costs may include the initial investment, the cost of use, replacement, repair and maintenance and the costs of demolition and transport. The residual value, associated with the potential for reuse and recycling is generally not considered. On application of constructive solutions methodology in this study for economic assessment, three economic parameters are considered: the initial investment cost (€/m^2), maintenance cost (€/m^2) and the cost of deconstruction (€/m^2).

2.2.1.1 Initial cost

The initial costs of a building depends on a number of factors, including [2]:

- The type and number of constructive solutions and other sustainable technologies that are incorporated;
- The type of building;
- The location of deployment;
- The climatic characteristics of the site;
- The experience of the project team.

In carrying out this work the economic parameters, relative to the costs of investment, will be obtained directly through budgets that the companies that produce the ventilated façades provide for implementing on study building. In this study the economic parameters, in respect of investment costs - C_I, will be obtained directly through budgets that companies that produce the ventilated façades provided for implementing in the study building, in €/m^2.

2.2.1.2 Maintenance cost

To characterize the maintenance management from an economic point of view, one shall analyse in the context of overall costs (not just initial costs). Thus, the overall cost is an economic concept that integrates the initial investment costs and deferred costs, i.e., it is the only number that integrates the following costs [3]:

- Initial cost (investment cost or cost of construction);
- Maintenance costs/maintenance (lifelong);
- Operating costs;
- Costs of use.

Currently, given the difficulty in quantifying the costs of use, those are not included in the overall costs [9]. The overall cost updated with regard to maintenance, in a simplified way, can be calculated by equation (1).

$$C_{MA} = \sum_{i=1}^{n} C_{MC} \times (1+a)^n + \sum_{i=1}^{n} C_E \times (1+a)^n + \sum_{i=1}^{n} C_R \times (1+a)^n \quad (1)$$

In that: C_{MA} - maintenance cost, in updated value term; C_{MC} - the annual maintenance costs; C_E - annual expenditure of exploitation; C_R - expenditure with substantial repairs or replacements of elements; *i* - refresh rate (does not include the effect of inflation); *n* - the useful life of the element on which it is to consider the overall cost (constructive solution, part of the building or building total).

2.2.1.3 Deconstruction cost

The deconstruction of a building is a process that is characterized by a careful dismantling, in order to allow the recovery of materials and components for construction, promoting re-use and recycling.

In this task the performance in terms of deconstruction parameter for the construction of ventilated façades technology, will be evaluated for life service of the building, taking into consideration:

- The materials costs of construction system that can be reused;
- The materials costs of construction technology with the potential to be recycled;
- The cost of need of deconstruction to some element.

The overall cost updated with regard to deconstruction, in a simplified way, can be calculated by equation (2).

$$C_{DA} = \sum_{i=1}^{n} C_D \times (1+i)^n - \sum_{i=1}^{n} C_{REU} \times (1+i)^n - \sum_{i=1}^{n} C_{RCL} \times (1+i)^n \quad (2)$$

In that: C_{DA} - cost of deconstruction in terms of current value; C_D - expenses deconstruction of elements; C_{REU} - expenses reuse elements; C_{RCL} - costs of recycling elements; *i* - Refresh rate (does not include the effect of inflation); *n* - The useful life of the element on which it is to consider the overall cost (constructive solution, part of the building or building total).

2.2.2 Aggregation parameters

The presentation of the economic performance, D_E, for each solution through the listing of results obtained at the level of the economic parameters considered (investment, maintenance and deconstruction) will be obtained using the equation

$$D_E = C_I + C_{MA} + C_{DA} \quad (3)$$

2.2.3 Standardization parameters

The standardization of parameters aims to avoid the scale effects in aggregating of the parameters of each indicator. In the standardization is used the formula of Diaz-Balteiro [4], equation (4).

$$\overline{D_{E_i}} = \frac{D_{E_i} - D_{E_i^*}}{D_{E_i^*} - D_{E_{i*}}} \forall i \quad (4)$$

Wherein D_{E_i} represents the result of the measurement of parameter i. $D_{E_i^*}$ and $D_{E_{i*}}$ correspond to the best and the worst result of the economic parameter.

The standardization method used, makes the parameters considered in evaluation of life-cycle costs and converts them into a adimensional scale from 0, the worst value, and 1, the best value.

3 SOLUTIONS FOR THE IMPLEMENTATION OF VENTILATED FAÇADES

In this work eight solutions of ventilated façades (Fig. 2) are studied. Two technologies of composite panels coated with aluminium, one in panels of aluminium, two in phenolic panels, one in nature-cement panels, one in natural stone boards and one in ceramic boards.

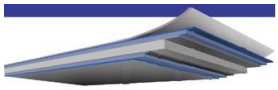
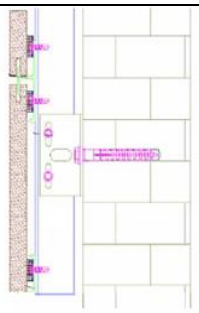
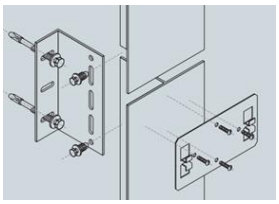
 **Ventilated façade solution 1 (VF1):** Composite panel-Alucobond® [5]	 **Ventilated façade solution 2 (VF2):** Composite Panel-Reynobond® [6]	 **Ventilated façade solution 3 (VF3):** Aluminum panel – Reynolux® [7]	 **Ventilated façade solution 4 (VF4):** Phenolic panel - Trespa® 8 mm with visible fixation [8]
 **Ventilated façade solution 5 (VF5):** Phenolic Pane l-Trespa® 8 mm with visible fixation [8]	 **Ventilated façade solution 6 (VF6):** Nature-cement – Panel Eternit® 8 mm visible fixation [9]	 **Ventilated façade solution 7 (VF7):** Natural stone boards of granite -Levantina® [10]	 **Ventilated façade solution 8 (VF8):** Ceramic boards-Butech® [11]

Fig. 2 – The eight solutions of ventilated façades to study in this work.

4 RESULTS

The cost of a building must always be analyzed in perspective of life-cycle costs, where the various costs and income associated with the building, since the preliminary project phases until the end of its useful life are considered. Table 1 presents the results obtained in the methodology of comparative economic analysis for the eight scenarios and Table 2 displays the ventilated façades solutions ranked in descending order of economic performance standardization.

The standardization of economic parameters under study is a fundamental process in comparative economic assessment methodology of ventilated façades because turns non-dimensional the parameters on a scale between 0, the worst value – more expensive, and 1, best value – less expensive, thus preventing scale effects. The best value corresponds to the solution with the value of 1.00, the VF3 (implementation of a front aluminum panel-Reynolux®). The less favorable solution in this parameter corresponds to the solution that offers the value of 0.00, i.e., the worst solution for ventilated façade is VF8 Solution (solution in ceramic plates-Butech®).

Table 1 – Results obtained for the economic performance for each one of scenarios of ventilated façade construction.

ID Solution	C_I (€/m^2)	C_{MA} (€/m^2)	C_{DA} (€/m^2)	D_E (€/m^2)	$\overline{D_E}$ (€/m^2)
VF1	100,00	95,76	25,05	220,81	0,87
VF2	95,00	95,76	25,05	215,81	0,90
VF3	48,00	120,38	25,05	193,43	1,00
VF4	90,00	119,96	25,05	235,01	0,81
VF5	140,00	130,22	25,05	295,27	0,53
VF6	122,50	85,65	25,05	233,20	0,82
VF7	173,45	82,13	25,79	281,37	0,59
VF8	202,59	181,20	24,57	408,36	0,00

Table 2 – Ventilated façade solutions prioritized by descending order of economic performance.

ID Solution	$\overline{D_E}$
VF1	1,00
VF2	0,90
VF3	0,87
VF4	0,82
VF5	0,81
VF6	0,59
VF7	0,53
VF8	0,00

The ventilated façade has a weight of 4% on the total cost of the building. Knowing the costs of investment of solutions and analysis the typical solution of façade construction technology in RAM - plastered and painted façade with a cost of about 30€/m^2, it is presented in Table 3 the values that represent the total cost of the implementation of these solutions in the building.

Table 3 – Total cost of the solutions for the exterior envelope of the study building.

ID da Solution	C_I (€/m^2)	Total cost of the building facade (€)
Plastered and painted façade	30,00	36 000,00
VF1	100,00	120 000,00
VF2	95,00	114 000,00
VF3	48,00	57 600,00

5 FINNAL REMARKS

For the case study of this work was considered that the construction of ventilated façades with aluminium panels (VF3) would be the ideal solution to implement in the study building. However, the construction company has determined that the solution to implement in the construction of ventilated façades in the Edifício Séc. XXI - 8 would be the solution in composite panel with aluminum cladding - Reynobond® (VF2).

The selection of the VF2 solution, on the part of the company rests by the experience in the work of the installation of the ventilated façade, Decorplak (subcontracting company). According to the same, the VF2 solution offers greater resistance and flatness more evident when handled for the purposes intended geometry. The VF1solution and VF3 solution presents a more malleable workability, occurring sometimes irregularities, marks or creases on the surface of the panels.

The VF1 solution (solution of ventilated façade reference) represents a 1.1 times higher cost of implementation the VF2 solution. It turns out that there is a gain of 6 000 €, when implementing this solution in relation to the previously technology solution used by the construction company.

The VF3 solution, the ideal solution according to the methodology of comparative economic assessment for scenarios of ventilated façades, represents a cost of 2.0 times lower than the VF2 solution. Despite this difference of values be of 56 400 €, knowing that the workability of the aluminum panels may compromise the aesthetic end of the façade, makes the cost of implementation of soluçãoVF2 in final sale of the building pays off, because this will in aesthetic value terms and safeguards the brand image of the company, ensuring low maintenance and high durability.

With regard to conventional façades execution solution in RAM, plastered and painted façade, this represents a cost of 3.2 times lower than the application in study building of VF2 solution. As in the previous case, despite a lower cost solution have 78 000 €, regarding VF2 solution, makes the

building mark difference by aesthetic value compared to conventional buildings. In addition to safeguarding the brand image of the construction company, the implementation of the VF2 solution will provide a functional improvement to their users, due to the inherent qualities of the system. Other determining factors in the selection of VF2 solution are to provide greater durability to building, protecting the internal structure of the building, reduce the problems related to moisture infiltration and provide better thermal comfort to their future users.

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APPLICATION OF NOVEL OPTIMIZATION TECHNIQUES IN WATER RESOURCES MANAGEMENT

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Abstract

The quest for more robust but at the same time user-friendly optimization techniques is nowadays more intense than ever. This need to develop and apply new optimization techniques in order to achieve more efficient and effective solutions in complex management and design problems, has led to the introduction of a series of interesting new methods. Amongst the various new methods introduced during the past few years, metaheuristic algorithms stand out. Metaheuristic algorithms, as a rule, are inspired by natural or artificial procedures. In that sense they imitate natural or artificial phenomena that continuously advance to better states in order to carry out internal search processes in the quest for optimal solutions.

Harmony Search Algorithm (HSA) is a music-based meta-heuristic algorithm and its applications cover a wide range of scientific fields. In this paper, the main features of this method are presented along with a specific groundwater resources management application. This application is analyzed, simulated and optimized using a specially-designed computer software programmed in MATLAB environment. The created software includes a user-friendly GUI (Graphical User Interface) that allows the user to easily interact with the optimization tool.

Keywords: Optimization, metaheuristics, decision making, water resources management, harmony search algorithm

1. INTRODUCTION

The determination of the optimal values of the numerous parameters involved in the design of complex engineering problems has always been a challenge for those involved. From early times people have realized that managing a situation that included many alternatives, is actually a quest for the determination of the solution with the more positive and less negative impacts. The procedure to determine the “best” solution is called optimization.

The use of optimization approaches and techniques has gradually replaced the practice of empirical determination of crucial design parameters. A simple optimization technique is an exhaustive algorithm. Such an algorithm through a series of “trial and error” runs, determines the best solution after evaluating all possible alternatives. This technique is used even in our times since it is the easiest to understand, regardless the fact that it is the most time-consuming.

The foundation and establishment of the science of management and optimization was set through time, along with the development of mathematics and the new tools they provided in handling alternative solutions. Optimization methods can be distinguished according to the procedure used for problem solution to the following general categories (Katsifarakis, 2012).

1.1 Linear Programming

This category includes techniques for the solution of linear models. These are problems that are described with a linear objective function and linear constraints. Most common linear programming techniques are the simplex method, integer or mixed programming and the transport problem.

1.2 Network Theory programming

These techniques include problems where every possible alternative solution can be graphically represented. This representation is usually visualized with nodes and lines. Typical problems are the

shortest path problem, the highest flow and the problem of identification and control of technical structures.

1.3 Non-linear programming

These techniques, unlike the linear programming ones, include problems where either the objective function either / or the constraints are of non-linear form. Most common solution techniques are the dynamic programming, the neutral point technique and a large number of techniques based on differential equations.

1.4 Multi-objective programming

These techniques can handle problems that simultaneously need to optimize not just one objective function, but several. These techniques include multi-targeting optimization, Pareto analysis, fuzzy optimization.

1.5 Stochastic programming

Stochastic optimization techniques represent a wide range of methods. The criterion that distinguishes them from the deterministic ones is their stochastic character. In this way, while in the deterministic methods where the introduction of input data leads always to the same output results, this is not the case with the stochastic ones. Thus stochastic optimization does not always ensure that the total optimum will be reached. But due to their stochastic character, repetitive application of a stochastic simulation, especially in complex problems, is more likely to finally reach the total optimum than a single application of a deterministic one. Most common stochastic techniques are the decision making theory, the game theory, the Markovian theory and many others.

1.6 Heuristic and Metaheuristic methods

These methods define a completely new approach on optimization and they will be analyzed extensively in the following. Their characteristic is that they scan the area of potential solutions searching for the overall optimal one, testing and evaluating solutions along the way. The simplest form of such a procedure is to test and evaluate all possible combinations. Since this option is neither efficient nor effective, they usually use a strategy for accelerating the whole procedure. This strategy is often inspired by a natural phenomenon. In this way there are methods that simulate the theory of Darwin for the evolution of species, the harmony in music, the behavior of flocks of animals, the social structure of ants or bees etc. It is of course hard to distinguish where the simulation of the natural phenomenon ends and where the pure mathematical analysis begins (Chiong, 2009).

These methods define the most modern tool of research as far as optimization is concerned. They actually can provide “good solutions” where other more conventional methods, fail. Table 1 provides a summary of some of the most important methods:

Table 1 – Metaheuristic optimization methods (Katsifarakis, 2012).

Method	Creator	Year	Natural phenomenon
Genetic algorithms	J. Holland	1975	Darwin’s theory of evolution
Simulated annealing	S. Kirkpatrick(et.al)	1983	Metallurgy
Tabu search	Fred W. Glover	1989	Avoiding sacred things
Ant colony	M. Dorigo	1992	Social structure of ants
Particle swarm	J. Kennedy	1995	Animal behavior
Harmony search	Z.W. Geem	2001	Music
Bees algorithm	S. Nakrani	2004	Social structure of bees

2. HARMONY SEARCH ALGORITHM

One of these metaheuristic methods, the “Harmony Search Algorithm” (HSA) will be briefly described in the following and will be applied in the solution of a groundwater management optimization problem.

2.1 Relationship between music and mathematics

Very early in time, people realized the strong relationship between music and mathematics. Since the ancient times, mathematicians tried to interpret the governing rules of mathematics using the art of music. Amongst them the work of Pythagoras, the Greek philosopher and mathematician, stands out. Pythagoras tried to investigate the laws that define sounds and thus he, informally, founded the science of acoustics.

In the following centuries this relationship was retained. Very often musicians tried to use mathematics in order to deeply understand music. On the other hand, mathematicians, like Fibonacci, through their work, assisted artists and composers to seek harmony. During recent times, since the Baroque period, this bond has been strengthened. Sometimes as a conscious effort by musicians-composers and sometimes as part of a rumored and almost mystical relationship, mathematics and music came closer. Iannis Xenakis represents a very special example from the 20th century. Xenakis combined very skillfully his identities as a mathematician and a composer. His work, through which he was recognized as one the most important composers of the century, is based on the use of mathematical functions to produce music and sounds (Theodossiou and Kougias, 2012, Theodossiou et al, 2014).

This relationship inspired Zong Woo Geem in the development of a new optimization algorithm, a meta-heuristic algorithm, based on music. Being a Civil Engineer and a musician himself, he presented in 2000 the Harmony Search Algorithm through an application in the design of water supply networks (Geem, 2000, Geem et al 2001).

2.2 Method analysis

The new algorithm was inspired by the improvisation process that a skilled musician follows when he is playing in a music band. During his performance the musician has one of the following choices:

- To play the famous tune, the melody that characterizes the music piece. This specific melody is called “theme” in music. Obviously, every member of the band knows the theme and can play it by heart. In other words all musicians have this melody in their minds, stored in their memory.
- A common choice a musician has is to play something similar to the theme. Very often, musicians try to enrich a music piece slightly changing or adjusting pitches of the memorized theme. In this way, musicians are free to explore the theme and listeners hear its new versions. Tasteless iterations of the same tune are avoided.
- Finally, another choice is to start an improvisation. This choice, which is so common in Jazz music, gives the freedom to the musician to play random tunes, sometimes notes with very small (or no) relation to the performed piece. The performer uses his talent and imagination; he explores new music worlds and refreshes the music material with new themes.

The Harmony Search Algorithm is a stochastic meta-heuristic method based on the sequential production of possible solutions. It belongs to the category of “neighborhood meta-heuristics” that produce one possible solution per iteration. This procedure is completely different from that of the population methods that produce a number of possible solutions during every iteration (e.g. genetic algorithms).

Every possible solution consists of a set of values of the decision variables of the function that needs to be optimized. Each one of these sets of values is called a “Harmony”. During the optimization process, a number of “harmonies” equal to the “Harmony Memory Size” are stored in the “Harmony Memory” (HM), a database that includes the produced set of solutions. Every component of the new harmony chosen from HM, is likely to be pitch-adjusted, thus providing neighboring values for some of the harmonies chosen from HM. The third choice is to select a totally random value from the possible value range. Randomization occurs with a very small probability and increases the diversity of the solutions.

The algorithm ends when the predefined total number of iterations (IN) has been achieved. (Kougias and Theodossiou, 2011, Kougias, 2013, Karakatsanis, 2013).

The parameters that define the way the Harmony Search Algorithm is applied over an optimization problem, are:

- HMS: Harmony Memory Size
- HMCR: Harmony Memory Consideration Rate
- PAR: Pitch Adjusting Rate
- IN: Iteration Number

Even though the HSA was originally designed for the optimization of the design of water supply networks (Geem, 2000), its applications soon expanded in a wide range of scientific fields. Applications in structural, geotechnical and mechanical engineering, in transports, in medicine even in the design of space stations were developed. Thus, while during the first years almost 50% of the applications were targeting water resources management and other hydraulic works, the wide spreading of the method has led to a reduction of this percentage to less than 15% in 2010 (Kougias and Theodossiou, 2011, Tiwari and Harding, 2011, Thangaraj et al, 2013, Theodossiou et al. 2015). However, research regarding hydraulic works is still expanding to other fields as groundwater modeling and management.

3. PROBLEM DESCRIPTION

In order to demonstrate the usefulness of optimization and the potential of Harmony Search Algorithm, a water resources management problem is presented. In the aquifer of figure 1, eight wells pump a certain amount of water in order to satisfy the demand. Supposing that all wells pump the same amount of water, a sustainability issue is raised based on the fact that the interrelation of wells, depending on their relative position, results in different groundwater-level drops, different pumping cost and different impacts to the aquifer system.

Instead of applying the same pumping rate to all eight wells, the introduction of an optimization approach could result in a more sustainable pattern, ensuring the abstraction of demanded amount of water and the in a more rational, from an economic and ecologic aspect, way.

3.1 The mathematical equations

One of the main problems in applying optimization techniques is the transition between the actual problem and its mathematical model. No natural phenomenon or applied situation can be fully described by mathematical equations. This is because each model incorporates a number of constraints and assumptions that are not applicable in natural systems. Thus the simulation of natural systems with mathematical models must be applied with extreme caution.

Mathematical models that simulated the flow in groundwater aquifers are essential tools for their rational management, since they can be used for the estimation of the consequences from the application of different management scenarios. For the investigation of possible alternative management plans, the simulation models should be combined with optimization and system analysis methods. Amongst others, the objectives of water resources management problems could be the preservation of the quantity and quality of groundwater resources, the restoration of the environment and the improvement of the benefits from the exploitation of water resources and the investment in water related projects.

The aquifer management models that combine flow simulation and optimization models can be separated into two categories, characterized by the method used to link the simulation model to the optimization one. The first method is called “Embedding method” and the second one is called “Response Matrix method”.

In the current paper, the Embedding Method is used, according to which the mathematical equations describing the groundwater flow are used to describe the objective function and the constrains of the management model.

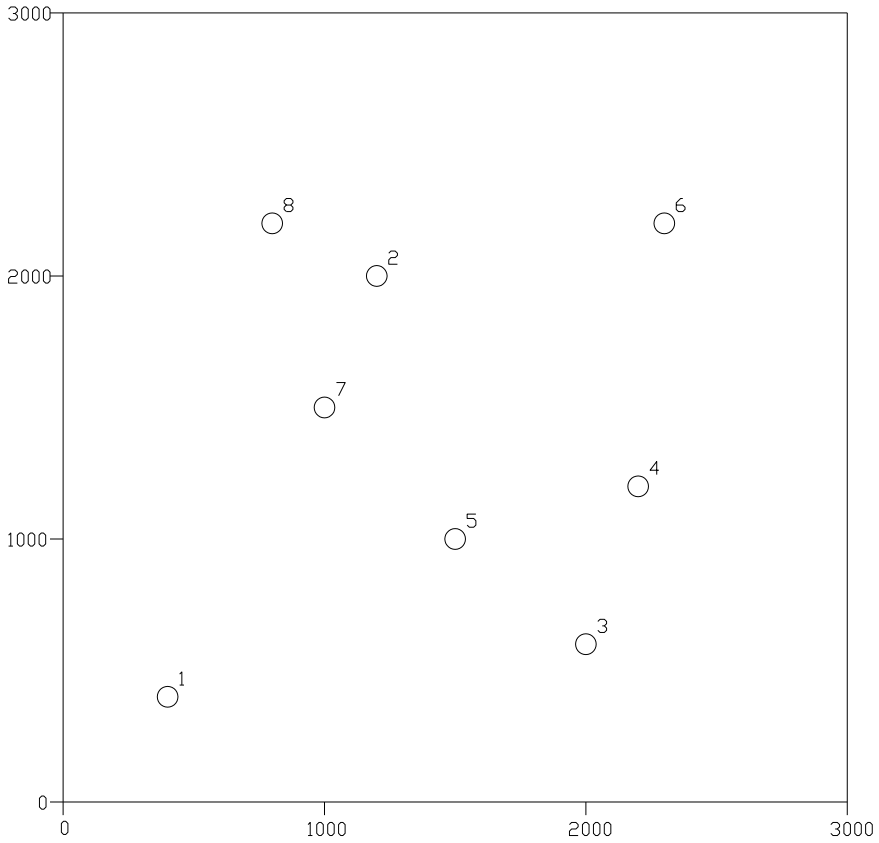

Fig. 1 – The under study aquifer and the position of the eight pumping wells.

The aquifer is considered to be unconfined and homogeneous so the groundwater flow under the pressure of a system of wells is described by the following non-linear equation (Bear, 1979):

$$h_i^2 = H^2 + \frac{1}{\pi K}\sum_{i=1}^{n}\left[Q_i \ln \frac{\sqrt{(x - x_i)^2 + (y - y_i)^2}}{R} \right] \quad (1)$$

where, h_i the hydraulic head at an observation point

H the initial hydraulic head before the introduction of the system of wells

K the hydraulic conductivity coefficient

R the radius of influence

n the number of active wells

Q_i the pumping (positive) or the injection (negative) rate of the i-th well

x, y the coordinates of the observation point

x_i, y_i the coordinates of the i-th well

For the formulation of the optimization model, the definition of the objective function and the constrains, is needed.

3.2 The objective function

The objective function of the problem is the minimization of the pumping cost and of the impacts of the pumping wells to the aquifer system. The mathematical formulation of this approach is presented in many forms by various researchers. The most common ones (Latinopoulos et al., 1985), is the simple linear equation, demanding the minimization of the total abstracted water:

$$\text{minimise} \sum_{i=1}^{n} Q_i \tag{2}$$

where Q_i is the pumping rate of the i–th well

as well as the non-linear function combining the pumping rate and the groundwater-level drop. The non-linearity of this function arises from the fact that the water-level drop is a function of the pumping rate.

$$\text{minimise} \sum_{i=1}^{n} \left[Q_i \, \Delta h_i \right] \tag{3}$$

where Δh_i is the water-level drop at the boundaries of the i-th well estimated from the subtraction of the resulting hydraulic head (h) from the initial hydraulic head (H) of equation 1.

Replacing Δh from equation 1, the objective function presented in equation 3, is formulated as:

$$\text{minimise} \sum_{i=1}^{n} Q_i \left[H - \sqrt{H^2 + \frac{1}{\pi K} \sum_{j=1}^{n} \left[Q_i \ln \frac{\sqrt{(x - x_j)^2 + (y - y_j)^2}}{R} \right]} \right] \tag{4}$$

3.3 The constrains

Two kinds of constrains are introduced:

(a) Abstraction of the demanded amount of water.

The target of the problem is to re-arrange the pumping rates from the eight wells in a more sustainable way, ensuring though, the abstraction of the same total amount of water. This is expressed by:

$$\sum_{i=1}^{n} Q_i \geq TAW \tag{5}$$

where TAW represents the Total Abstracted Water

(b) Control of the water-level drop at the wells

In order to ensure the good function of the wells, a constrain is imposed so that the resulted water-level drop will not exceed the half of the initial hydraulic head. The mathematical form of these constrains is:

$$h_i^2 \geq \left(\frac{H}{2} \right)^2 \tag{6}$$

The variables hi are evaluated through equation 1 based on the values of the pumping rates which are the decision variables of the problem. It must be noted that in equations 6 the control is based on h_i^2 and H^2. This is because, without affecting the concept of the equations, these constrains become linear and much easier to solve through the optimization model (under the condition that both h and H have either positive or negative values).

4. RESULTS AND CONCLUSIONS

The application of the Harmony Search Algorithm for the solution of the optimization problem described by the objective function of equation 4, under the constrains of equations 5 and 6, let to the optimal results presented in Table 2. The problem was solved assuming that the hydraulic conductivity

K of the aquifer as equal to 0.1 m/d, the radius of influence R, 2280 m, the initial hydraulic head H, 150 m and the total abstracted water, 160 m^3/h.

For the solution of the problem, a specially-designed computer software programmed in MATLAB environment was used (Karakatsanis, 2013). The created software includes a user-friendly GUI (Graphical User Interface) that allows the user to easily interact with the optimization tool and the introduction of the objective function, the constrains and the Harmony Search Algorithm's parameters, as described in paragraph 2.2.

The software was created by members of the Sisyphus Optimization research group (http://www.sisyphus-optimization.web.auth.gr/). This research group comprises scientists who deal with the development of novel optimization techniques, the formulation of optimization software and the solution of complex engineering problems.

Table 2 – Comparison of the initial function scheme and the optimized one.

	Initial function		Optimized function	
Well	Pumping rate Q_i (m^3/h)	Pumping cost $Q_i \Delta h_i$	Pumping rate Q_i (m^3/h)	Pumping cost $Q_i \Delta h_i$
1	20	1446.73	25.793	2568.94
2	20	2630.81	17.024	1695.50
3	20	1976.52	20.721	2063.79
4	20	2181.86	19.045	1896.87
5	20	2845.43	16.409	1634.33
6	20	1665.82	23.560	2346.49
7	20	2871.82	16.577	1651.07
8	20	1997.32	20.870	2078.65
$\Sigma Q_i \Delta h_i$		17616.31		15935.65

It can easily be concluded that for the specific dataset, there is a reduction of the pumping cost of 9.5%, achieved just by re-arranging the function of the wells. It is also obvious that the pumping rate from relatively remote wells (such as wells 1, 3, 6 and 8) increased, compared to the initial pumping rate. This was anticipated and can be explained by the fact that remote wells don't interrelate significantly with the rest of the wells, thus resulting to minimum water-level drops.

Ii must be noted that despite the fact that the problem is highly non-linear, since both the objective function (eq.4) and the constrains of equation 6 are non-linear functions of the decision variables (pumping rate), the Harmony Search Algorithm had no problem at all to solve the optimization problem and determine the optimal distribution of the pumping rates amongst the active wells.

This observation leads to the conclusion that the method is robust, flexible and adjustable, user-friendly and easily applicable to a variety of problems that are described by a series of alternatives, for the determination of the optimal set of values of the decision variables of the function that needs to be optimized.

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EDUCATION OF DOCTORAL STUDENTS FOR SUSTAINABLE FUTURE

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Abstract

Civil engineers have the knowledge, attitudes and skills to change the thinking of the society which will be in balance with nature. Energy efficiency and sustainability are key drivers of the expression of the sustainable development and it is defined as approach that meets the needs of present and future generations. To achieve sustainability in civil engineering we need to educate our young generation to follow this trend. This issue requires a multidisciplinary approach and establishment of criteria in accredited study programmes to meet future urban visions. If the supervisor of PhD. students will lead them to include in their study plan this mission they will support by their outputs the transition to the sustainable society.

The main aim of the article is to present the themes and study plans of doctoral student's research at Faculty of Civil Engineering in Slovakia. Our education of doctoral students is meeting future challenges of achieving sustainability in their proposals and designs by implementing green, smart and effective technologies and visions.

Keywords: doctoral students, technology, research projects, education, sustainability

1 INTRODUCTION

Inspired by contemporary environmental and sustainability issues we think that interdisciplinary investigating to the science and engineering from many research domains and excellent research facilities should be supported in the first line. Some missions of the Technical University of Košice (TUKE) consist of developing scientific knowledge based on its own original findings and providing excellent education on all three levels of tertiary education, as well as lifelong education. The university has a long history and was founded in 1952, but its roots must be sought much deeper in the past. As early as 1657 the Universitas Cassoviensis was established in Košice, but technical education in Slovakia was only elevated to higher - education level in 1762, when the Austro-Hungarian monarch Maria Theresa established the Mining Academy in Banská Štiavnica. This provided education and promoted research activity in a group of scientific disciplines ranging from ore mining through to production and processing of metal materials. The number of students currently attending nine TUKE faculties is 10 643. Out of this number there are 8 728 full-time students (5 293 Bachelor students, 3 435 Master students and 672 Postgraduate students)[1]. Faculty of Civil Engineering (FCE) is the fifth faculty of the Technical University of Kosice.

1.1 Faculty of Civil Engineering

The Faculty of Civil Engineering, as a part of the Technical University of Kosice in Slovakia was established in 1976 (February 20, 1977). During 38 years of continuous operation about 6 500 successful graduates have passed through the gates of the faculty to take on positions such as foremen, successful designers, managers, CEOs, as well as scientific researchers. Within the further development of educational and research process it has the stable position as the internationally recognized university workplace. The main goal of the faculty is to contribute to development of R&D and educational process in Slovakia, as well as in Europe. The main interest of the faculty is to contribute to development of new effective design theory and methods concerning engineering

structures. Nowadays more than 960 full time students study at the Civil Engineering Faculty. The crucial research-educational units of the faculty are:

- Institute of Structural Engineering
- Institute of Architectural Engineering
- Institute of Construction Technology and Management
- Institute of Environmental Engineering.

The high level of education and R&D is provided by 8 professors, 17 associate professors, 38 assistant professors (with PhD.), 2 lecturers and 5 researchers. In 2014 faculty participated in complex accreditation process and renewed study programmes. Implementation of European funds at FCE has significantly improved the quality of its educational and scientific research infrastructure.

2 DOCTORAL STUDY PROGRAMMES

The main aim is to prepare students for their future work or scientific career. Successful applicants can fulfill their ideas in 4 study programmes:

- **Theory of Architectural and Indoor Engineering**
  Duration of study: 4 years
- **Theory and Design of Engineering Structures**
  Duration of study: 4 years.
- **Environmental Engineering**
  Duration of study: 4 years
- **Theory of Technology and Management in Civil Engineering**
  Duration of study: 4 years

Excellent laboratories [2] are prepared for them to create new experiments with the support of their supervisors. We strongly encourage them to spend the year abroad at the foreign university to get new ideas and inspiration. Presentation and articles at foreign conferences and symposium are also important part of their study plan. We would like to present 2 works for each study programme with the focus on their innovativeness and sustainability impact.

2.1.1 Study programme Theory of Architectural and Indoor Engineering

This study programme is oriented towards students who need to develop more knowledge about buildings. Dissertations in Architectural Engineering are focused mainly on theoretical and experimental analysis of the building construction, perimeter, roofs and floors on the ground, light external walls, facades, transparent parts, but also the creation of indoor environment. Part “Building Services” focuses on environmental engineering, water supply buildings, heating, ventilation, air conditioning and so on. Research is also directed to energy efficiency in buildings, reducing the need for energy, the use of unconventional energy resources in supplying energy buildings, sustainable buildings, development of new materials and technologies, fire safety of buildings. Successfully defended work from August 2015 was focused on **Monitoring physical characteristics of envelope structures in non-stationary conditions.**

1. Short description: The target of the analysis of transient numerical calculation and results of experimental on-site temperature measurement is the detail design of the place where window and window sill brick wall are connected. This connection (window sill lining) is due to its material and geometric heterogeneity significant in terms of impact on surface temperature, but also the heat flux. Objective structure is a panel fragment of an experimental cell for measuring the physical properties in real conditions.

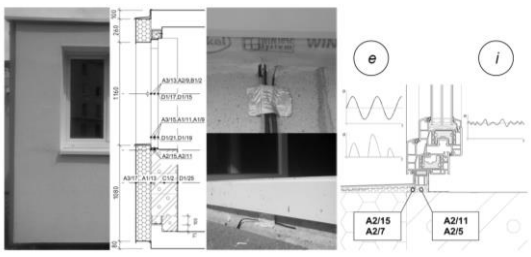

Fig.1. and 2 – Solved places in window sill of brick wall construction of the experimental chamber.

Aim of this study was to compare the temperature rates in the connection of window and wall at point of window sill, obtained from the measurement and transient numerical calculation. Simulation and experimental measurement in different types of devices represent efficient scientific tool of prediction of behavior especially building envelope (Fig.1, 2).The second work is aimed at sustainable roof construction represented by green infrastructures. It gives us closer look at the interconnection of 4 main infrastructures and shows the important nexus between water and green roof in the urban water cycle.

2. Short description: We want to believe, that humans are not the main cause of current global warming and climate changing. It is the sun getting brighter, planet receiving more and more energy and warming up.

Fig.3 – Experimental constructions at university campus .

Question is if human´s dominion over nature caused this and what can be done about it. Is this temporary, is this real, is this caused by lack of nature, lack of water, or is this really caused by human´s activities. The Earth and nature has always found its own way to solve issues imposing troubles. Weather, climate, water, earth, population, food. Question is how the Earth is going to solve these problems now and what is it going to mean for humans. We are struggling with many issues. This thesis is about green roofs, their partial position as nature in the city and their position in every day human´s life. This thesis is about water and humans. Green roofs representing green in terms of benign integration of natural an artificial and green in terms of tool solving water retention issues (Fig.3). The thesis presents intended proceeding in order to fulfil the MEANDER vision objectives of the dissertation work.

2.1.2 Study programme Theory and Design of Engineering Structures

The third level of this study programme is offered to civil engineers who wish to prepare for their future scientific research career. The theoretical basis of the study lies in the natural sciences, especially the physical and mathematical disciplines amplified in the field of mechanics, including Dynamics. A graduate of this programme has the ability to clearly formulate a scientific research problem, object and goal of research and progress in the applied theoretical subject as structural engineering, dimensioning concrete, steel, prestressed and timber structures.

The first thesis is aimed at **Analysis of the resistance of deck bridges with encased steel beams.**

1. Short description: Thesis is focused on the issues of the bridges with encased steel beams. Part of the work discuss information about designing process of plate bridges in the past and also about present form of design and realization of these type of constructions in Slovakia as well. Theoretical part also contains new knowledge about composite bridges in abroad. Experimental part of the thesis comes with new experience obtained by research of constructions with encased steel beams. Research was provided at 50 experimental beams with rigid steel reinforcements, with five different types of composite contact. Those discusses in this thesis were performed with closed steel beams with holes in the walls and upper flange. Results provided from experimental part are created from static, dynamic and long term tests. Obtained results are compared with numerical simulation and analytical calculation. Work is also provided with information about getting material properties of concrete and steel. Push - Out tests examine contact between concrete and steel. Conclusion of the work is created based on the comparing the results and numerical calculations.

Fig. 4 – Analysis of the resistance of deck bridges with encased steel beams.

Second work was target at the residual resistance of ceiling panels.

2. Short description: The subject of the thesis is to determine the residual resistance of ceiling panels in harsh environments based on assessment of the state of the ceiling of prefabricated panels in selected agricultural buildings in terms of their static functions affected by aggressive media (Fig. 5).

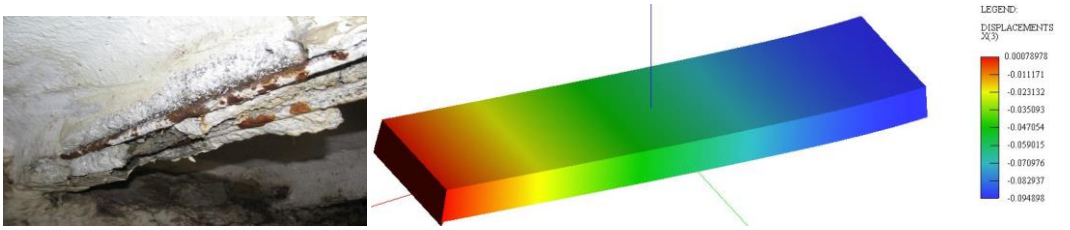

Fig. 5 – Degradation of panels.

The overall evaluation of the results of these examinations and analyses:

- studied ceiling panels (and thus the entire roof structure of an object to -174) are not in such a critical state that it was necessary to remove the structure
- the important conclusion is that the reduction of its resistance does not occur to a great extent the influence of the load, but due to aggression livestock environment
- real ceiling panel showed good agreement with the modeled beam under identical parameters

The original strength of concrete and sufficient concrete cover, the only parameter which changes could help to increase the resilience of the diameter of the rods and it seems appropriate diameter of 10 mm.

- the use of the model - based on the measured deflection of the real panel using
- curve model simulated the same parameters can be determined in a reserve load
- subtlety panels helps to early onset of the degradation process, it is appropriate
- to recommend increase of the thickness and structure to the rib plate.

2.1.3 Study programme Environmental Engineering

A graduate of this programme has the ability to clearly formulate a scientific research problem, object and goal of research and progress in the branch of environmental engineering, and to solve the formulated problem with appreciation of social, ethic, legal, and economic relations of research work.

Topics of PhD. thesis at Institute of Environmental Engineering

- environmental assessment of building materials and buildings;
- indoor pollutants occurrence prediction for guarantee of environmental safety, acceptable quality and indoor hygienic in buildings;
- concrete composites durability and (bio)corrosion of building materials;
- waste utilization in building materials preparing;
- hemp hurds use in lightweight composite;
- sustainable rainwater management;
- logistic model development for flood crisis management;
- erosion-transport processes and their impact on the siltation of small water reservoirs;
- environmental risks identification and assessment in the selected watershed of East Slovakia;
- application possibilities of remediation methods in the elimination of environmental risk of old mine loads.

One of the most innovative themes is the analysis of organic compounds occurrence in indoor environment of buildings.

1. Short description: The aim of thesis is monitoring of organic compounds occurrence in indoor environment of selected buildings. Investigation of individual volatile organic compounds (VOCs) occurrence in indoor air and influence on building users are the main contribution of the research work. An electronic nose based on gas chromatography is used for analysis of individual VOCs.

Method of research
Measurement of TVOC concentrations is performed using gas chromatograph (GC) with surface acoustic wave detector (SAW). Organic compounds are separated in a short capillary column, usually with 1 m length and exit the column at characteristic times. A library of retention times of known chemicals indexed to the n-alkane response (Kovats indices) allows for machine independent measurement and compound identification. GC/SAW (zNoseTM) analyser (Fig. 6) with the precision of 5% RSD, 10% accuracy and sensitivity at low ppb level for most compounds is used for measurement in indoor environment. Identified VOCs in a renovated apartment are illustrated in Tab. 1.

Proposed second theme is aimed at study of resistance of the cement composites against the aggressive environment.

1. Short description: The research is aimed at the study of performance of cement composites of various compositions in sulphate aggressive environment in order to increase the building materials´ durability and resistance. In accordance with sustainability in civil engineering, the cement composites based on addition of the supplementary cementations materials with special regards to waste materials (silica fume, fly ash, slag) are studied.

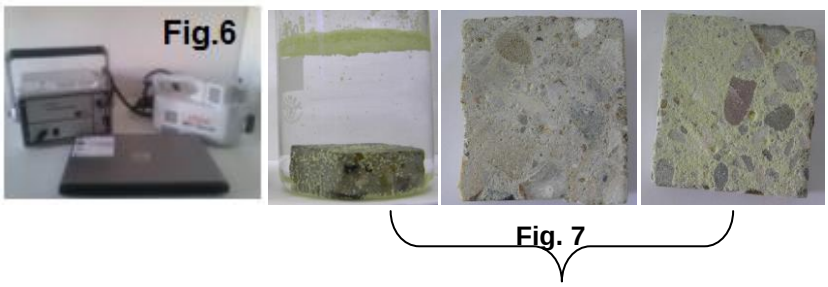

Fig. 6 – zNoseTM analyser and Fig. 7 – Cement composite sample in microbial environment and visible surface changes due to sulphate attack.

The investigation is focused on analysing the mechanical, physical and chemical properties of cement samples such as compressive strength, porosity, weight changes, leaching out of basic elements, pH changes etc. Aggressive sulphate environments are simulated by chemical sulphate solutions as well as by microbial sulphuric acid produced by microorganisms Acidithiobacillus. An example of surface changes after microbial sulphate attack is illustrated in Fig. 7. Leaching out concentrations of calcium during the experiments are given in Fig. 8.

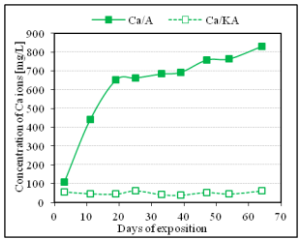

Fig. 8 – Leaching out of Ca ions for samples A (microbial sulphate environment) and KA (a-biotic sample) during 63 days of the experiment.

2.1.4 Study programme Theory of Technology and Management in Civil Engineering

A research of doctoral students at Institute of construction technology and management moves towards the issue of increasing the efficiency of design and management of construction projects. The integrated design and management of construction projects based on ICT (Building Information Modelling, Integrated design and Delivery Solution, Integrated Project Delivery, etc.) presents the relatively new approaches of solving of these projects. The research in this field is focused on the investigation of opportunities and limitation through the base of knowledge about constructive, material, technological and cost parameters of construction.

The present outputs of doctoral students work are aimed on the:

- using of BIM technology for management of construction project,
- analysis of design parameters for the building site facilities in 3D environment,
- analysis of safety risks through visualization of construction processes,
- automated budgeting in relation to 3D BIM models.

Fig. 9 – Interactive interior design through virtual reality [3].

The ambition of doctoral students' research is the creation of new intelligent tools for collaboration of engineering and constructive solution in virtual environment. The collaboration allows the identification and reduction of constructive, material, technological and economic risks already in the design phase of buildings.

1. Short description: Development of interactive tool for construction project delivery through dynamic real-time visualization presents results of current doctoral students' work at institute. The simulation and variants solutions in virtual reality allow satisfy the individual requirements of customers. The customers get accurate and clear vision about future investment, including the optimizing of incurred costs.

The important results of this activity is the establishing of startup company VIZUALIZACKY.SK (www.vizualizacky.sk)[3]. The startup enterprise, through its leader (doctoral student of institution), received important awards (absolute winner of Student Entrepreneur Award 2014, winner of National Innovation Competition 2014, nominee of Slovakia at contest Global Student Entrepreneur Award 2015 in Washington D.C., the selection of renowned magazine FORBES – the most talented young people under 30 years).

3 CONCLUSION

FCE as a part of TUKE is providing its environment with scientific and technological knowledge basis, innovation and workforce, in order to form beneficial and sustainable future and high quality of student's life. This is achieved at FCE by innovative research and excellent education in all scientific branches [1]. Within the continuously rising performance of the faculty focused on research and educational system our doctoral students have a lot of possibilities to obtained financial support for their projects, to attend the lesson, to use the laboratories of excellence to present their ideas at seminars and conferences. The quality high level education is confirmed by positive professional acceptation. A lot of our graduates are known leading personalities of Civil Engineering. The young generation ideas help us to create the sustainable future and lead to resilient society in the context of sustainable constructions.

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BIM EXPERIENCE AND FUTURE CHALLENGES IN BRIDGE DESIGN AND CONSTRUCTION

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Finland

Abstract

Product modelling (or Building Information Modelling, BIM) is the most recent and developed method for structural design. Nowadays, it is almost a standard method for building design, but not yet commonly applied for bridges and other infrastructures. It has proven its power in tailored applications in special design fields, but in multidisciplinary design tasks there is no common or open enough interface to use shared information in the design work. Visualization of the design in 3D, part and material libraries, geometry and quantity information are all included in the same model. In addition, applications for part prefabrication are found to be great tools for construction market as well.

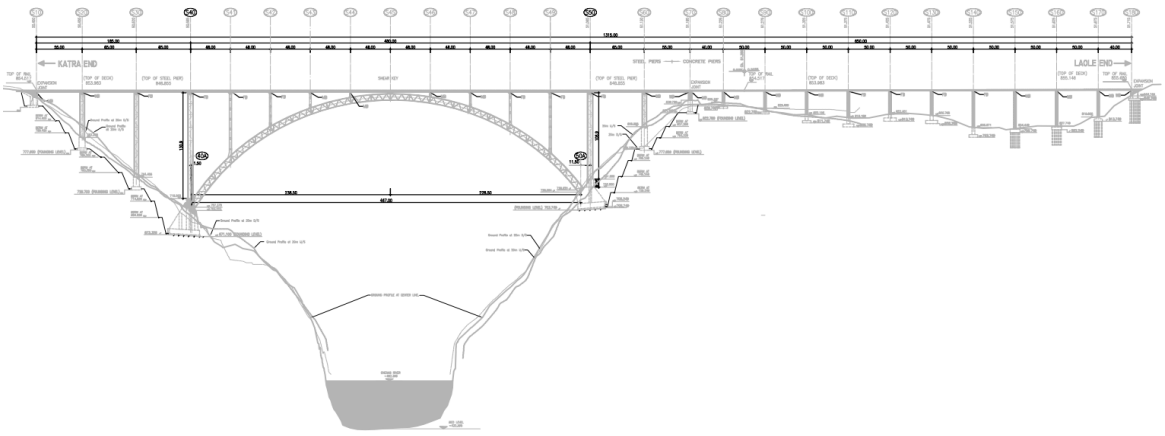
To take advantage of BIM, certain accuracy and exact modelling is requested. In infrastructure design, particularly during conceptual and general design stages, quite complex tools for draft design are required, when structural principles, main dimensions and average quantities shall be estimated. Here a BIM-based design method offers remarkable advantages and makes it easy to adjust the design, when the work is advanced to the construction stage.

Keywords: BIM, Bridge modelling, product modelling, steels structures, multidisciplinary projects, infrastructures.

1 CHENAB BRIDGE

1.1 Steel structure modelling

The modelling in bridge design has started from modelling of the steel structures to produce part and assembly drawings for fabrication. Steel structures are now modelled for fabrication over two decades. With generally available commercial software packages, even most complex steel structures can be modelled so that finally all single part fabrication information can be exported directly from the model without any drawings. Chenab Bridge is a steel railway arch with a 467m main span, whose design is a great example of successful use of BIM [1].



Chenab Bridge elevation

The detailed design model of the bridge included all the fabrication information from material data to the part geometry including all the bolt holes and edge cuts for welding and the cutting, which is executed with CNC (Computerized Numerical Control). Even the Bridge is located in mountainous Cashmir area in India, far from industry, the modern technology is available and used.

1.2 Possibilities provided by the model of the steel structure

When all the steel in structure is included into the model, the modern softwares provide possibilities to control the procurement and the material flow. Purchased steel can be connected to the parts to be fabricated and later on traced, as it has been used. All the material records for the quality control can be enclosed in digital format into the model.

Scheduling tool is available to be connected to the material and component flow so that the progress can be controlled and planned. The model provides visual presentation easily to see the current state of progress with erection history and the next planned stages.

2 INFORMATION MODEL IN CONTRACTS

2.1 Rao II Bridge

Rao II Bridge is a medium size cable-stayed Bridge in Haiphong city in Vietnam. The two main spans of the bridge are 70 m and 120 m, and the approach span is 40 m. Pylon height is 47 m. The substructures (bored piles, foundations, piers, abutments) and pylon are made of reinforced concrete and the cable-supported superstructure is a steel-concrete composite structure. The design of the bridge was completed in 2006 and the bridge was inaugurated in 2010.

Rao II Bridge at the erection stage.

The design task for consultant included the engineering design and the preparation of the plans for construction (construction and workshop drawings with erection calculations) was included into the contractor's scope. The contract documents for the steel structures included layout drawings with selected details. Traditional dimensional and reinforcement drawings were prepared for the concrete structures.

Due to the accuracy requirement for the complex geometry, the Engineering design drawings for steel structures were prepared by modelling. Every detail was not needed to be modelled, but the tools that had shown the effectiveness in detailed design, were used to define exact geometry for the structure. Member collisions and complex details could then be seen beforehand and solved out more easily. The Rao II Bridge contract was based on unit prizes. Consequently, the quantity estimate was of great importance as usual in countries with high bureaucracy. With the model, the requested amount of structural steel was estimated with great precision. The geometry of the concrete structures was included into the model for design quality assurance.

For the construction design (drawings and plans), the model was handed over to the contractor. The contractor used the model with great success for the steel structure drawing preparation (single part and assembly drawings). The contractor also modelled temporary structures thus ensuring the compatibility. The derric crane used for segment lifting had pre-defined positions for the whole erection with pre-fabricated connection points. The geometry during the back and approach span launching with cambered steel girders was also controlled easily with the model. The provided model included

the geometry of the final structure. The geometry control during the erection was easily done based on the calculated geometry deviation to the final at each step. The model provided much relief to the geometry control when any surveyed point was possible to be compared to the final geometry and estimated deviation during the erection.

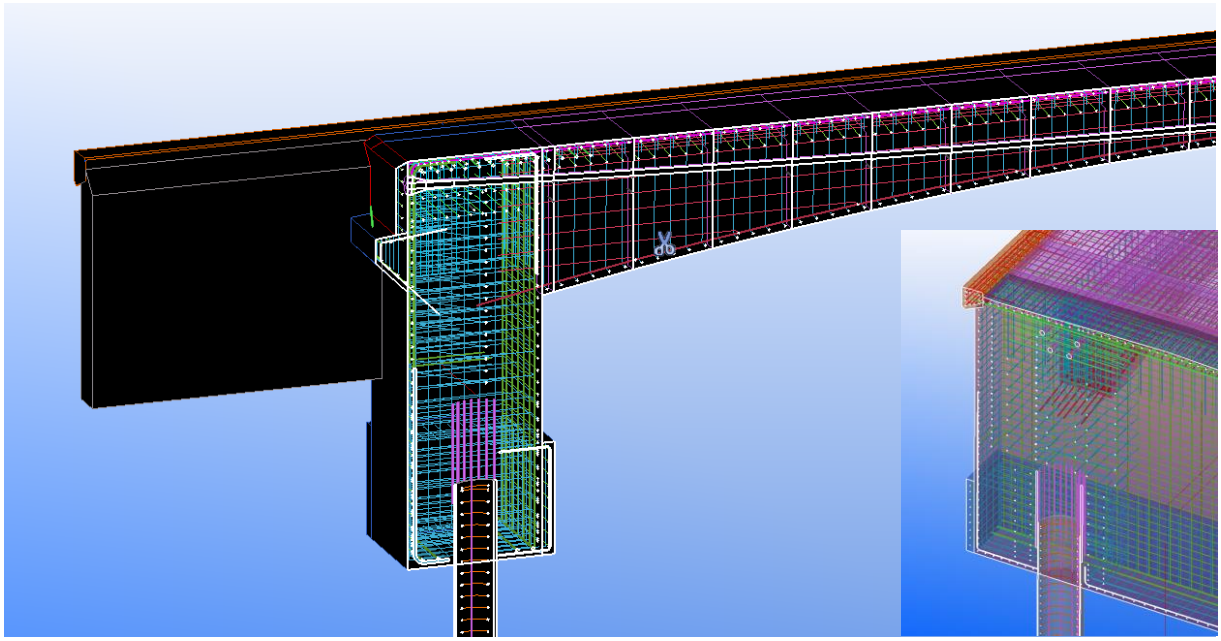
If the structure is modelled in details, it includes all the information for construction. The model can be prepared by various ways, with all the details or more generally, but it's status can easily be defined for the contract in all cases. There is no obstruction (except common practise) to use product model as the only definite contract document. There are examples of projects, where the model is the definite design for contract. Some of the cases include model-based drawings, but it can also be obligated for the contractor to prepare documents he needs for construction [2,3].

3 NAHKURI BRIDGE

Because of the success of structural modelling, not only in steel structures or buildings, but in road and geotechnical design as well, it has been applied more and more for infrastructures by various successful pilot projects. The Finnish Transport Agency has announced that they request modelling for all bridge designs after April 2014. Anyhow, applicable standards and modelling practices are not created yet. Nahkuri Bridge is an example of the current practice for Bridge design according to which the design shall include

- product model,
- construction drawings,
- particular specification,
- bill of quantities,
- cost estimate,
- bar bending lists, and
- plan for prestressing works.

Nahkuri Bridge is a small prestressed concrete frame bridge with a span of 24,0 m and effective deck width 7,5 m, founded on drilled steel tube concrete composite piles. The design is completely done by modelling. The model includes the structural components such as concrete, steel, reinforcement and prestrssing steel. Also the bridge accessories such as waterproofing and asphalt layers were included.



Reinforcement details of the Nahkuri Bridge.

Construction drawings were produced from the model so that if any changes are made in the structure (in the model), the drawings will indicate the changes automatically. Material lists (as basis for bill of quantities) were extracted out from the model and included steel, concrete, pre-stressing steels and reinforcement. Also the bar bending lists for reinforcement were automatically extracted for pre-fabrication. Traditional particular specification and the plan for prestressing works, were enclosed in the model.

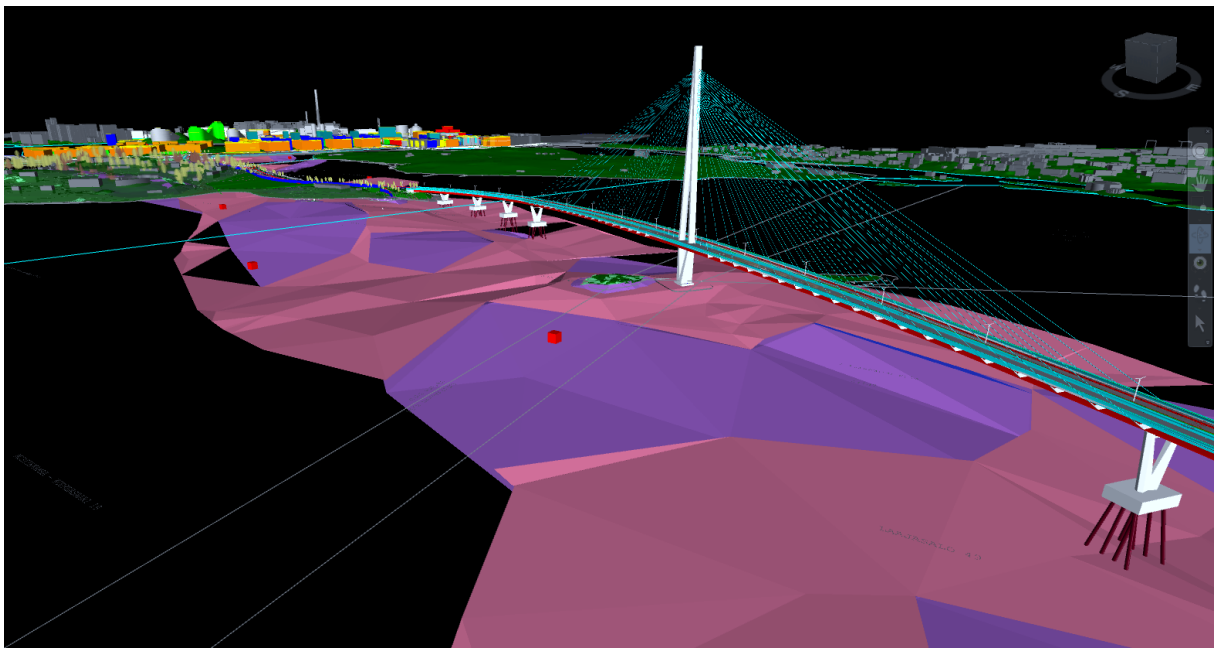
In the Nahkuri Bridge construction the new bridge replaced the existing one (which was not modelled). There was no need for road construction or soil enhancements works at site. The bridge was the only thing that was modelled for the project. For the procurement, the drawings were the contract documents and the model acted as supporting material. At the site the work was done by the contractor without any interest or capability to use or get advantage of the model, so finally it was only a little more expensive way to produce the drawings.

4 CURRENT MULTIDISCIPLINARY PROJECTS BY MODELLING

Nowadays modelling has been applied in different ways for different applications in the field of infrastructural design. In addition to structural design for instance the surveys and geotechnical investigations are stored into the database, from which the sections and elevations, as well as the quantity lists and visualisations, may be produced. The value merging the separate models, even partially referred so that part of the design work can be done in same database in real time, is nowadays seen most valuable and actively piloted in several major projects in Finland.

4.1 Kruunusillat (Crown Bridges)

Kruunusillat will connect the Kruunuvuorenranta district in the eastern coast of Helsinki, under development from 2013, to the Helsinki city center. Kruunusillat is approximately 2,3 km long link via the Korkeasaari zoo-island containing two bridges. The longer of the bridges spans app. 1,2 km, making it the longest bridge in Finland. Both bridges will serve trams, bicycles and pedestrians only.



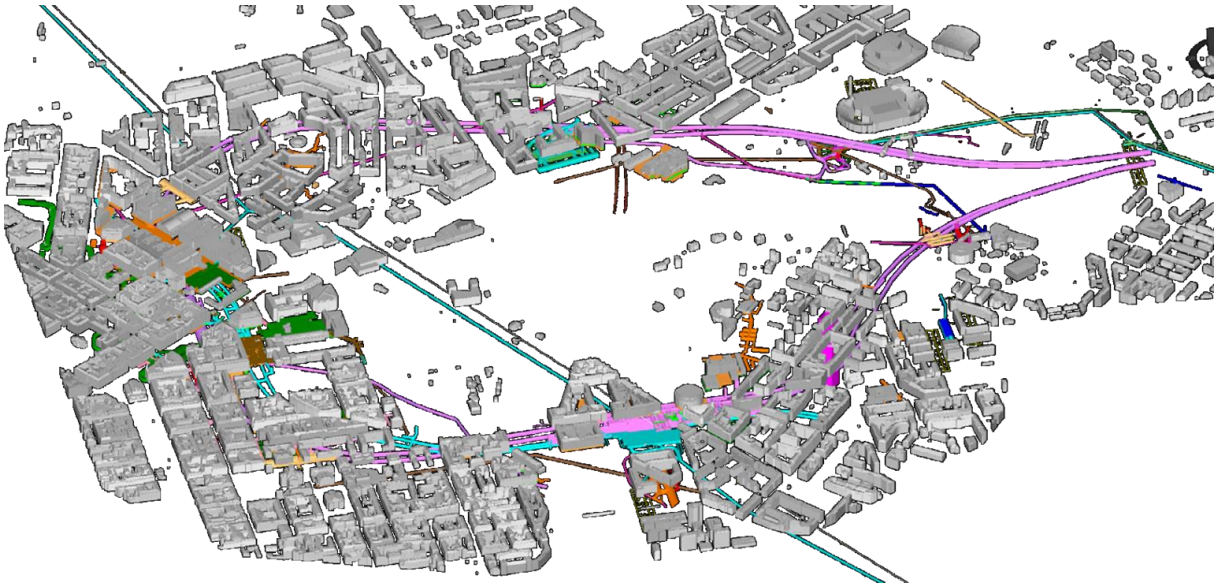
Model of the Crown Bridge

For the project the modelling has been chosen to be the primary design method and is expected to produce illustrative designs and improve compatibility between different design areas (for the general design). The client has set high expectations for modelling and during the project, new applications based on the modelling has been applied. Mobile model viewer with map and camera application has been found useful for visualization. 3D game engine enabling real-time walking on the Bridge deck with natural and designed lightning, has also been used as a tool in lightning design. These completely new applications were only possible because of the modelling.

The general design of the route was completed in 2015 and the city plan was approved consequently. The next stages in the future design will include street plans and preliminary engineering design. Final engineering designs will follow later. The more detailed design will take place in the becoming stages, and the challenge for modelling increases accordingly. At the same time, the tools for modelling give new possibilities. In this project the strategy for modelling is a living document updated regularly.

4.2 City Rail Loop in Helsinki

The City Rail Loop is a planned urban railway line for commuter trains under the Helsinki city centre. The 8 km long (6 km in tunnel) loop-shaped railway starts in Pasila and runs in a tunnel via Töölö, Helsinki city centre and Hakaniemi back to Pasila. The City plan for the Rail Loop has been approved (June 2015) and the detailed design is ongoing for the procurement and construction. Latest cost estimate for the project is 956 M€ (cost at level 2020). The project is the largest design project based on information / product modelling in Finland. The complex project located in built, urban and historical environment with multidisciplinary integration of all fields of expertise is done by modelling.



City Rail Loop product model.

In the City Rail Loop design process the modelling is expected to [4]

- improve communication with authorities and decision makers,
- give support for city planning,
- help finding possibilities and best practises,
- improve quality and cost control in design, and
- improve productivity in construction.

All this is obtained by means of model-based

- information and communication,
- quality control,
- procurement and contracts,
- production planning and management, and
- information management over the whole lifecycle.

5 FUTURE OBJECTIVES

Modelling in recent projects has primarily been applied for specific tasks with tailored applications. That has brought productivity to the work and quality into the designs. Visualisation of the designs has also improved communication. It is easy to see, that merging separate models of different design fields would do the same for the whole multidisciplinary projects.

Current multidisciplinary projects have shown that amount of information becomes easily too big for the normal office computers and desktops. Most of the tools are created for specific application including particular information only for certain task. Information that other parties may need is often secondary for the specific task and thus not stored. Site measurements (eg. laser scanning) produce easily a huge amount of information. To get it practically usable, a lot of filtering, interpretation and

post processing is required. Sometimes information is only available with limited accuracy and it might be even misleading, if the status of the information is not clear. The amount and quality of information require separate data managing and usage, especially in multidisciplinary projects.

In addition to the amount and quality of the data, there are several general challenges. There is no common interface between applications. There are compatibility issues, even with different versions of the same software. There is no generally accepted approval and filing procedures for the designs. Time as a variable and detailing/accuracy level in modelling often increase the required work unreasonably.

Modelling provides a lot of new possibilities. If the existing information and new designs are collected once into a model, all the information can be used similarly in various simulations and analyses (traffic, lightning, noise, fire). In case of design changes, the initial information will be updated respectively. Also the information collected once can be maintained as a maintenance log so that any updates, repairs and measurements can be stored into the data. Measurements can also be automatically collected by a health-monitoring system.

To enclose BIM to sustainable design and property management requires pre-defined goals and means - what is expected and how it will be achieved. As the investment is often the biggest environmental load in infrastructural projects [5], the BIM should be used to minimize the use of material and work. How, it is should to be defined project based. There is also no limitation to create any kind of tools on the BIM produced data to evaluate sustainability in design (eg. CO_2 calculation application). How to use BIM in lifecycle management can be based on existing technology, if the goals and means can be defined. In all cases, modelling should be a tool for means, not an end as itself.

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ENERGY EFFICIENCY: PCM SOLUTIONS FOR SCHOOL BUILDINGS

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Abstract

The high energy storage capacity per unit volume at a nearly constant temperature characterizes and distinguishes Phase Change Materials (PCM) from conventional building materials. In a given day, when the ambient temperature rises enough to reach the solid–liquid transition temperature, the PCM, incorporated in a construction element, changes from solid to liquid with endothermic behavior (latent heat) thus limiting the heat flow towards the interior of the building. On the other hand, upon an environmental temperature decrease, the PCM, that is now in the liquid state, may reach the liquid–solid transition temperature (melting temperature) again and shift to solid state, with energy liberation (exothermal process), thus delaying the cooling tendency inside the building. The permanence at a known melting temperature range will stabilize interior ambient temperatures thus influencing the thermal comfort sensation. This work consists on the study of the thermal behavior and energy consumption of a building when influenced by the incorporation of PCM. The case study is composed by the computer rooms located at the Faculty of Engineering of University of Porto – FEUP, with the reason of the need of an intervention in those spaces, whose temperature reaches high uncomfortable values during the summer. To accomplish this goal, the building will be numerically simulated through a calculation engine complemented with a user friendly graphical interface. The numerical simulation allows the recreation of various scenarios in the computer rooms with the purpose of understanding the reaction of PCM subjected to different environments.

Keywords: Phase Change Materials (PCM), Energy efficiency, New materials, Sustainability.

1 INTRODUCTION

Phase change materials (PCM), studied and tested for four decades, are one of the renewable energy solutions that arouses more interest in the scientific and industrial circles as an alternative to systems that consume fossil energy, as they have a cross-application to several areas, such as food industry, textile industry, aerospace industry and especially in construction. These are materials with a high heat storage capacity due to an exponentially increase of its enthalpy at a certain defined temperature, which in the case of incorporation in buildings corresponds to the melting temperature of the material. Its application in buildings causes a reduction of peak temperatures and, consequently, a decreasing of daily temperature variation and power consumption.

However, its application to buildings turns out still rather limited and costly. Facing safety reasons required by the regulations, only a small percentage of PCM can be used [1]. In addition several tests concluded that the main limitations of the PCM, including high initial cost, loss of capacity for absorbing heat, corrosiveness, flammability and leakage of PCM in the liquid state, are slowing, to a certain extent, the expansion of these materials on the market [2].

Still, good prospects arise on the horizon. On one hand, there has been a growing interest in fatty acid and hydrated inorganic salts, since they have more benefits than disadvantages. Due to its high latent heat per unit volume and non-flammability, the hydrated salts can not only replace the widespread use of paraffin as to show a better performance than other competitive technical solutions, as in the case of thermal insulation. For this purpose some challenges must be addressed, namely the effect of super cooling and difficulties in microencapsulating hydrated salts, due to their water content. On the other hand, the market for incorporation of PCM in building materials is vast with a large growth potential. Once the manufacturing industry bases its prices on future market expectations, prices will trend down in the near future [2].

2 PHASE CHANGE MATERIALS

2.1 Properties, groups and categories

Thermal comfort of interior building spaces can be achieved using sensible heat form– related with conventional building materials; or via latent heat form – associated with PCMs. PCMs used for latent heat storage in buildings are characterized by an endothermic behaviour (with energy accumulation) during the transition from solid to liquid and exothermal process (with energy liberation) during liquid-solid phase shift. The solid-liquid PCM group comprises three categories: organic PCMs (paraffins and fatty acids); inorganic PCMs (salt hydrates and metallics); and eutectic mixtures (organic-organic, organic-inorganic, inorganic-inorganic) [3].

Thermal properties, like melting temperature and phase change enthalpy, are crucial to the process of selecting a suitable PCM for thermal energy storage. The scheme shown in Fig. 1 makes a distribution of the existing PCMs trough those two essential thermal properties.

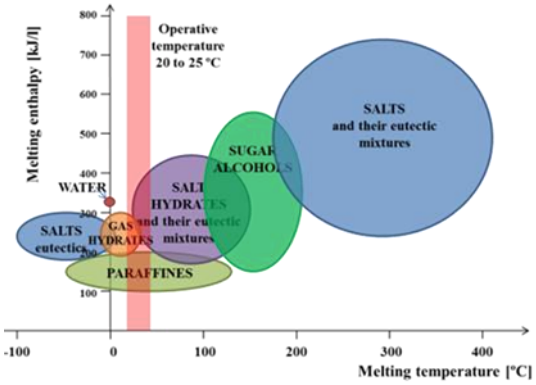


Fig. 1 – Melting temperatures and phase change enthalpy for existing PCMs (adapted from [4]).

Salt hydrates and eutectic mixtures present the highest phase change enthalpy for the operative temperatures required inside building spaces. However, the set of characteristics presented by paraffins makes of these the most desirable materials to be used in latent heat storage systems. Organic materials, such as parrafins, are chemical stable, offer no super-cooling and are available in a large temperature range with low cost.

2.2 PCM in building materials: incorporation methods

Phase change materials can be incorporated into conventional construction materials mainly by three different technics: direct incorporation, immersion and encapsulation [5]. Direct incorporation is the simplest method in which liquid or powdered PCMs are directly added to building materials such as gypsum, concrete or plaster during production. Immersion technic of PCM is used in porous construction materials such as: concrete or bricks. Those materials are dipped into melted PCM that is absorbed by capillarity. With direct incorporation or immersion methods construction materials are imposed to be in contact with PCM. No extra equipment is needed in both methods but leakage and incompatible with construction materials may be the biggest problems [6].

To avoid incompatibility problems, due to the direct contact between conventional construction materials and PCMs, encapsulation method arises. Encapsulation eases the process of handling and incorporating of PCM into building materials, the leakage problem can be avoided and the function of the construction structure can be less affected.

Macro-encapsulation for PCM can present many different shapes: tubes, spheres or panels and can be obtained from several materials like aluminium or polymers. Macro-encapsulated PCMs can be easily placed in ceilings [7] or under-floor systems [8]. It has the disadvantages of poor thermal conductivity and tendency of solidification at the edges (crystallization) [9]. Micro-encapsulation can be described as the technology in which PCM particles are enclosed in a thin, sealed and high molecular weight polymeric film. Micro-capsules, with diameters that can vary from 1 to 1000 μm, prevent PCM from leakage during the phase change process. Micro-encapsulated PCMs are easy to incorporate and don't request for a modification in known construction manufacturing processes. Plasterboard with

micro-encapsulated PCMs is one of the most widespread solutions of PCM incorporation into building materials [10-13].

2.2.1 Sub-subsection: Guidelines for References

The list of the references should be given at the end of the paper. References are numbered in brackets by order of appearance in the document (e.g. [1], [2], [3]). The same reference can be cited more than once in the text with the same reference number.

3 NUMERICAL APPROACH

3.1 Heat transfer in PCM

During the process of melting and solidification of the PCM, the potential heat transfer mechanisms are conduction and convection. The method of enthalpy [14] is a known mathematical solution that accounts only for the conduction process. It was formulated to deal with the nonlinearity of the liquid-solid interface of the PCM and the unknown nature of this boundary that separates the two states location. The consideration of this method simplifies the thermal problem, since the equations that govern the numerical resolution are the same for both states. The interface conditions are set automatically by means of a fixed scale and a mushy zone (mole) is created, thereby avoiding significant discontinuities that may create some numerical instability.

3.2 Calculation engine

EnergyPlus [15] is described as a simulator of building's energy performance that combines the best features of BLAST and DOE-2 programs along with new capabilities. Based on the description of the building defined by the user, EnergyPlus calculates the heating and cooling loads necessary to maintain a value of setpoint temperature, the operating conditions of a secondary HVAC system and the energy consumption of primary equipment installed. It is currently one of the most used programs in energy simulation of buildings, already validated by the BESTEST method.

In this case, the program uses the implicit finite difference method - CondFD. The iterative nature of the implicit solution allows taking into account in a precise way the enthalpy change of the phase considered when simulating the PCM. The temperature-enthalpy function is calculated by updating the effective specific heat of the material at each iteration. For the numerical simulation of the case study it was chosen the full implicit scheme. The full implicit scheme is based on the approximate solution of Adams Moulton. It is considered first order in time.

3.3 Numerical simulation

The simulation takes place from 1st to 28th July (4 weeks), during which is predicted higher values for outdoor temperature. It was defined a sub-hourly simulation interval of 2 minutes (time step 30), meaning that calculations are performed 30 times per hour (every 2 minutes). Though it is time consuming and leads to large amounts of information, this simulation to the minute characterizes with detail the thermal behaviour of the spaces. In the case of common building materials, a timestep of 10 minutes is sufficient for a detailed and consistent simulation; however, DesignBuilder advises a simulation interval of at least 20 time step (every 3 minutes) when introducing the phase change material in the building.

The goal of the simulation is to numerically compare the thermal performance and energy consumption of a space with and without incorporation of phase change material (PCM). It will be important to test the performance of these materials with and without operation of HVAC systems (mechanical ventilation). The following graphic (see Fig. 2) shows the operation schedule of the rooms as well as the cooling systems.

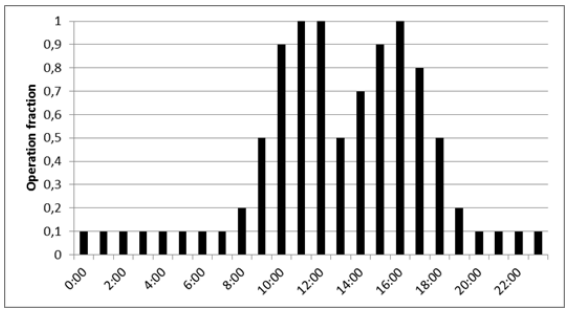


Fig. 2 – Template of operation schedule for computer rooms.

3.4 Weather conditions

Fig. 3 shows the variation of outside dry-bulb temperature during the week of simulation, ranging between 13 °C and 28 °C with an average value of 20 °C. The global solar radiation is also presented in Fig. 3.

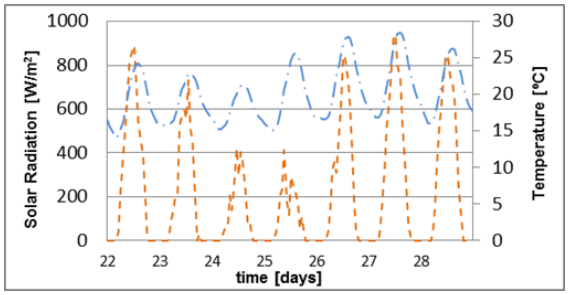


Fig. 3 – Sub-hourly values of outside dry-bulb temperature and solar radiation in Porto, from 22- 28th of July.

4 CASE STUDY

4.1 Context

Due to the high temperatures experienced in the computer rooms of the Faculty of Engineering of University of Porto (FEUP) during the summer months, it emerged the idea of simulating the thermal behaviour of those spaces with incorporation of PCM. The computer rooms are presented as an object of interesting analysis since the temperature of this type of space is strongly influenced by thermal loads generated in particular by the high density of computing equipment.

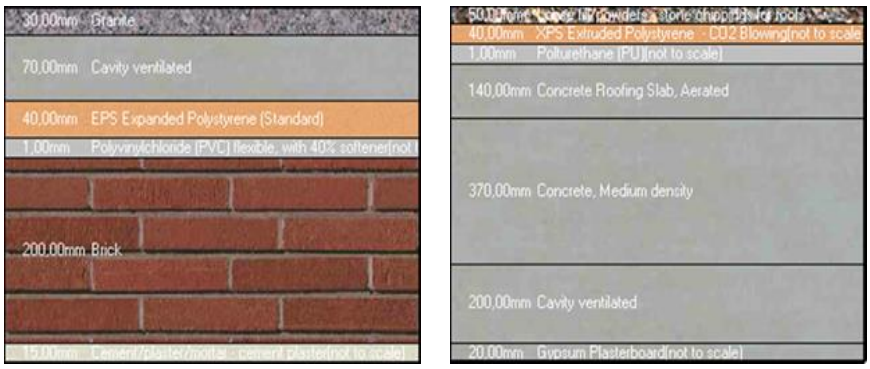
The new facilities of FEUP were inaugurated in 2000 and are located in the Asprela campus, in the city of Oporto. During the summer, the average outside temperature recorded in Oporto varies between 15 °C and 25 °C, exceeding 35 °C in particular hot days of July and August.

4.2 Building details

The computer rooms are located in the block (ii), constituent of building B of the university campus. The block (ii) consists of four floors, with the computer rooms on the third and fourth floors. The floor areas go from 50 m2 to 175 m2 (Fig. 4).

Fig. 4 – Computer rooms of FEUP: block (ii) of building B.

The building presents the typical details of the local regional construction (see Fig. 5). The outer wall is formed by a layer of cement mortar, a layer of brick with thermal insulation and an air-box from the outside, finishing with granite slabs 30 mm thick.



a) b)

Fig. 5 – Composition of wall façade (a) and ceiling (b) of computer rooms.

Note that when simulating the PCM, the cement mortar and the gypsum plasterboard (the inner layers) are replaced by a layer of PCM.

Regarding the cooling of spaces during the hot season, there is a mechanical ventilation system, consisting of outside air extractor louvers located on the wall of the facade and exhaust fans located in the false ceiling.

4.3 Identification of the critical zones

A first simulation was performed with the following settings: rooms naturally ventilated and occupied from 7h00 to 20h00; simulation from Monday to Friday during all the month of July; period of simulation of 10 minutes (time-step of 6). For a faster analysis the period of study was restricted to the week of 22-28 of July, being considered a time interval long enough to detect and understand the effects of PCM.

A close analysis relating sub-hourly operative temperature and daily temperature amplitudes allowed identifying the rooms 208, 213 and 313 as the most unfavourable zones in terms of thermal loading. This article presents only the thermal behaviour of room 313, which denotes a more visible effect of PCM.

4.4 Used PCM

The choice of PCM for each scenario was based on the equality between the melting temperature of the material and the average value of operative temperature for the entire week of 22-28 of July, including the periods of non-occupation. The average values of temperature equals 27.91 °C and 26.89 °C for scenarios 1 and 2, respectively. Table 1 shows the general characteristics of the materials simulated in each scenario.

Table 1. Main characteristics of simulated PCM for each scenario.

	Density [kg/m^3]	**U** [W/m^2]	**Melting temperature** [ºC]	**Specific Heat** [J/kg.K]	**ΔH** x10^3 [J/kg]
PCM M51/Q27	235	9.62	27	1970	135
PCM M51/Q29	235	9.62	29	1970	261
PCM M182	235	2.70	29	1970	261
PCM SP29	1.6kg/l	30.0	29	2000	115

5 RESULTS

5.1 Hourly variation of operative temperature

As a first criterion for evaluating the thermal behaviour of the room 313, was elected the hourly variation of the operative temperature in the week of 22-28 of July for each scenario. The analysis is confined to only two days in order to avoid overpopulating the information and thus allowing an easier interpretation of the graphics.

For scenario 1 (see Fig. 6), the maximum temperature is around 32.59 °C for the room without incorporation of PCM (as expected), recorded at 16h00 of the 23rd. The solution of PCM SP29 (in light blue) is the most effective in reducing the temperature peaks. The maximum temperature recorded for this solution is 31.04 °C, with a maximum difference of 1.55 ° C relative to the solution without PCM, at 16h00 of day 23. The melting temperature and the heat transfer coefficient may help explain the effectiveness of this PCM compared to the other studied solutions.

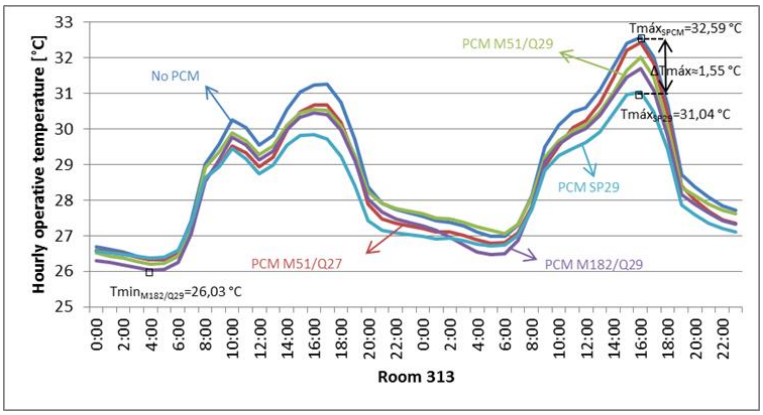


Fig. 6 – Hourly variation of operative temperature on the 22th and 23th for room 313 for the scenario1.

5.2 Maximum daily thermal amplitudes

For scenario 1 (see Fig. 7) stands out the PCM SP29 as the most effective in controlling the daily thermal amplitudes, as it could be expected from the analysis of the graphic of **Error! Reference source not found.**. This PCM has, comparing with the traditional solution of mortar, a difference in daily thermal amplitude of 1.55 °C on the 22nd. To mention the less effective thermal behaviour of the solution of PCM M182/Q29 in controlling the daily temperature range, particularly on days 23, 26 and 27. The probable cause of this lower efficiency is the significant thickness of material that retains longer the heat accumulated during the melting of PCM.

Note also that the values of daily thermal amplitude without PCM are larger in nearly every day, which is due to its far higher values of maximum temperature in face of PCM solutions and not due to its lower values of minimum temperature (see Fig. 7).

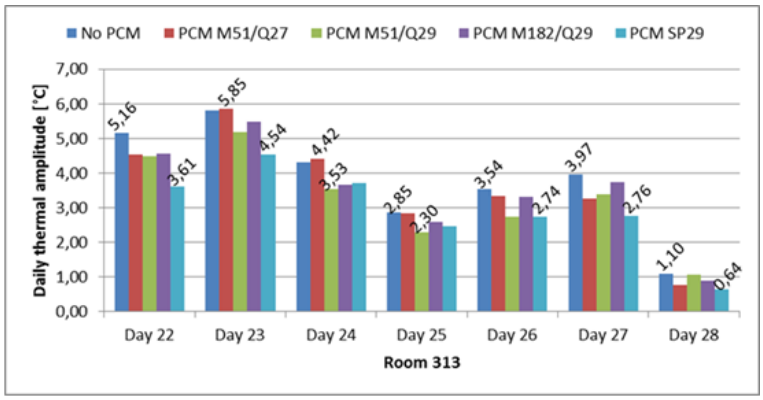


Fig. 7 – Comparison of maximum thermal amplitudes for room 313 with different wall and ceiling coverings, from 22nd to 28th of July for scenario 1.

6 CONCLUSIONS

The numerical simulation of the computer rooms of FEUP allowed concluding that the application of PCM has advantages in increasing the thermal comfort of the occupants.

Were formulated two scenarios, considering the isolated and simultaneous existence of natural and mechanical ventilation. It was found that the effects of PCM are more visible when the space is only natural ventilated, without existence of any mechanical assist system, once the reduction in the maximum temperatures is higher for the set of conditions of scenario 1.

As expected it was verified that the mechanical ventilation of spaces visibly reduces the peak temperature. There is an economy, albeit slight, of the energy consumed by mechanical ventilation with the introduction of PCM in the rooms, ranging between 6% and 10%. It is believed that the high thermal mass of the building made of walls and roofs with thicker layers of material, decreases the potential effects of PCM both in reducing peak temperatures and daily temperature variations, as well as the time lag between extreme temperatures, which turns out to be of great importance in environments conditioned by HVAC systems.

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RECYCLED ASPHALT MIXTURES WITH FOAMED BITUMEN: AN ALTERNATIVE TO BUILD ECOFRIENDLY ROAD PAVEMENTS

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Abstract

Nowadays, recycling has become a very important objective for the society in the scope of a closed loop product life cycle. In recent years, new recycling techniques have been developed in the area of road pavements that allow the incorporation of high percentages of reclaimed asphalt (RA) materials in recycled asphalt mixtures. The use of foamed bitumen for production of recycled asphalt mixtures is one of those techniques, which also allows the reduction of the mixing temperatures (warm mix technology). However, it is important to evaluate if this solution can maintain or improve the performance of the resulting mixtures. Thus, the main aim of the present study is to assess the performance of warm recycled asphalt mixtures incorporating foamed bitumen as the new binder and 50% RA, in comparison with a control mixture using conventional bitumen. Four mixtures have been produced with 50% RA, one of them at typical high mixing temperatures with a conventional bitumen (control mixture) and the other three with foamed bitumen at different production temperatures. These four mixtures were tested to evaluate their compactability and water sensitivity. The laboratory test results showed that the production of recycled mixtures with foamed bitumen can be reduced by 40ºC without changing the performance of the resulting mixtures.

Keywords: Foamed bitumen, recycling, warm mix asphalt, pavements, environment

1 INTRODUCTION

In order to address the current concerns of the society, namely the prospect of a sustainable future, recycling appears as a priority solution increasingly used in the road paving industry. Thus, the incorporation of reclaimed asphalt (RA) material have been studied by a significant number of authors with the main objective of increasing the percentage of RA used in new mixtures ([1], [2], [3], [4]).

The incorporation of higher percentages of RA can have many advantages, both in an economically and environmentally point of view ([5], [6]). In fact, the conservation of resources and the reduction of energy consumption are clear environmental advantages of using RA in recycled asphalt mixtures, as well as the reduction of greenhouse gas emissions. According to Kerkhof [7], the decrease of energy consumption to produce a recycled mixture with 50% of RA material in comparison with a conventional mixture is 14%, and the corresponding reduction in CO2 emissions is 11%.

However, there are some limitations in the incorporation of RA materials to produce hot mix recycled asphalt in plant. Firstly, the fact that the material is heterogeneous, requiring a more careful treatment previous to production. Moreover, the aged bitumen present in the RA material implies some attention such as the use of lower production temperatures (or selective heating of RA and new aggregates) and the use of a new bitumen with a higher penetration grade or the use of rejuvenating additives to improve the flexibility of the resulting mixture. Another problem is the severe overheating of the virgin aggregates when high percentages of unheated RA material are introduced. In order to solve this problem, recent studies divided the RA material in two fractions (coarse and fines) and the coarse fraction is heated together with the virgin aggregates while the fine fraction is kept at ambient temperature up to the moment it is introduced in the mixer ([4], [8], [9]). Another reason for this procedure is the fact that the fine fraction contains a significantly higher percentage of bitumen, which thus can be preserved from unwanted additional ageing or burning.

Some of the problems associated with the use of RA in recycled asphalt mixtures can be solved by using lower mixing temperatures. In order to reduce the production temperature the road paving industry is increasingly turning to Warm Mix Asphalt (WMA) as an environmentally friendly production process. This technology refers to innovative technologies that involve the use of organic additives, chemical additives and water-based or water foaming technologies. With this technology, asphalt mixtures can be manufactured and spread at temperatures 20 to 55 ºC lower than conventional hot

mix asphalt (HMA) ([10]). The use of foamed bitumen was the WMA technology selected to carry out this particular study with recycled mixtures, namely because it is able to avoid the use of additives.

Foamed bitumen is obtained by adding a small amount of cold pulverized water into preheated bitumen. The water vaporizes and the liberated steam is encapsulated within bitumen, resulting in a temporary expansion of its volume together with a reduction of its viscosity ([11]). This process can present many advantages such as improved strength and durability of the mixture, energy savings during production, improved workability, among others ([12]).

The most important characteristics in the production process of foamed bitumen are the expansion ratio (ER) and the half-life (HL) ([11]). The ER is a relation between the volume of the bitumen after expansion and the initial volume of bitumen. Normally the foamed bitumen is characterized by the maximum expansion ratio (ERmax) that represents the maximum volume obtained. The half-life (HL) is the elapsed time between the moment that the foam was at its maximum volume and the time when this volume reduces to a half of that value. Higher ER values mean a higher reduction of bitumen viscosity and consequently better workability of the mixture. At the same time, HL values must be high enough to maintain the bitumen foam stable during the time needed to produce the asphalt mixture.

The present study assessed the possibility to produce recycled mixtures with 50% RA at lower temperatures by using foamed bitumen in comparison with a control mixture produced with a conventional bitumen. The expansion characteristics of the bitumen with and without foaming additive and its basic characteristics have been evaluated and the effect of the production temperature has been assessed by testing different asphalt specimens for compactability and water sensitivity.

2 MATERIALS AND METHODS

2.1 Materials

The new bitumen used in this study was a virgin bitumen with a penetration of 47dmm, both for the control and the foamed bitumen mixtures. The new aggregates are granite igneous rocks and the filler is limestone. The use of those aggregates are justified by the proximity of their sources. The RA material used in this study is the result of milling off the surface layer of a pavement of a highway and it was divided in fine and coarse fractions by using a classifier with a mesh of 8 mm.

2.2 Methods

2.2.1 Foamed bitumen production process

A Wirtgen WLB 10 S lab scale plant was used to produce the foamed bitumen, which injects water and air into hot bitumen in an expansion chamber, promoting the formation of the bitumen foam. This equipment has been developed at a laboratory scale with the objective of making the analysis of the foamed bitumen characteristics in small scale possible (mix design), but it is similar to the equipment used in a normal or in plant scale.

In order to increase the stability (measured by the half-life) of the foamed bitumen, a small amount (between 0.2 and 0.6%) of a specific additive called Iterfoam B® was used. The air pressure used in the foaming equipment was 5.5 bar (default value), while the temperature of bitumen was 160 °C according to previous studies (the same temperature was used in all the components of the machine). The percentage of water used was evaluated in this work, for typical values between 2 and 4%.

2.2.2 Selection of mixing temperatures

The production temperature of bituminous mixtures is a very important factor, especially when dealing with warm mix asphalt technologies. In order to better understand the effect of the foamed bitumen technology used in this study, and its ability to lower the mixing temperature, some workability and performance tests were carried out in the studied mixtures, especially compactability and water sensitivity tests. Thus, three mixtures with 50% RA and foamed bitumen were produced at different temperatures (FB230, FB 210 and FB 190 mixtures in Table 1). For comparison reasons, a similar hot mix asphalt (HMA) mixture (control mixture in Table 1) was also produced with the same 50% RA material but without foaming the 47 pen grade bitumen.

The bitumen of the RA material was totally reused in the new recycled mixture. Taking into account the reuse of the bitumen present in the RA material, and the need to protect it from heating, only the

coarse fraction (20%) was heated together with the new aggregates, while the fine fraction (30%) was introduced at ambient temperature (Table 1). To mitigate the ageing effect of heating the coarse RA fraction, the time during which it was submitted to high temperatures was limited two hours.

Table 1 – Reference and real temperatures of the recycled mixtures produced.

Mixture	Ref. Temp. (ºC)	Real Temperatures (ºC)				
		New aggregates	Course Fraction	Fine Fraction	Production	Compaction
FB230	230	231.2	233.8	26.6	160.4	144.3
FB210	210	213.0	213.5	23.6	138.2	125.1
FB190	190	192.8	193.9	25.6	134.4	114.7
Control	230	229.0	229.0	24.4	160.1	143.9

In order to maintain the homogeneity of the specimens produced at each studied temperature, all specimens produced at that temperature were manufactured from the same batch (3 specimens for compactability tests and 6 specimens for water sensitivity tests).

The compactability tests (EN 12697-10) were carried out using a Marshall Impact compactor (EN 12697-30) with a measuring device for automatically recording the thickness of the specimen after each compacting blow. According to the standard, the compaction of the specimens comprised the application of a total of 200 blows only in one side of the specimen.

The evaluation of water sensitivity was made using a mechanical test (indirect tensile test) conducted on two groups of three specimens kept in different conditioning environments (wet or dry). The assessment of the water sensitivity is obtained by measuring the mean indirect tensile strength (ITS) of specimens kept dry at 20+/-5ºC, according to EN 12697-23, and specimens kept in water (ITS_w) at 40+/-1ºC over a period of 68 to 72h, according to EN 12697-12. After 68 to 72 hours under the conditions of preparation described, the two groups of specimens are placed at a temperature between 5ºC and 25ºC before the test (15ºC in this specific work). Following the determination of the ITS of each specimen, it is possible to calculate the average value of each group and the indirect tensile strength ratio (ITSR), which corresponds to the ratio between the ITS of the wet group (ITS_w) and of the dry group (ITS_d) of specimens. The air voids content of the specimens was also assessed because it has a significant influence on the water sensitivity performance of the asphalt mixtures.

3 RESULTS AND DISCUSSION

3.1 Foamed bitumen characteristics

As abovementioned, a foam promotion additive was used in this study to improve the half-life results. In order to select the parameters for the process of foamed bitumen expansion, tests were performed with different percentages of the additive Iterfoam B® and different percentages of water. The virgin bitumen without additive was also foamed to evaluate its expansion characteristics. The results of the foaming process are showed in Fig. 1. The additive improved the expansion ratio and the half-time, and the best combination both in terms of higher expansion as higher half-time was 0.4% additive and 3% water.

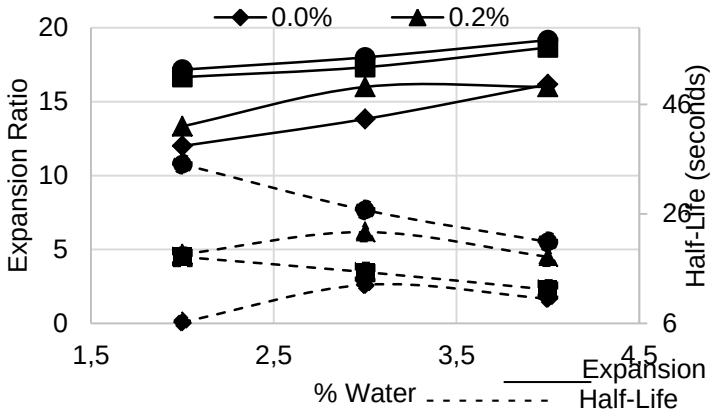

Fig. 1 – Foamed bitumen expansion ratio and half-life results.

The foamed bitumens with different percentages of additive were also evaluated for their basic characteristics, and the corresponding penetration (EN 1426) and softening point (EN 1427) results are presented in Table 2.

Table 2 – Foamed Bitumen basic characteristics

	Penetration (dmm)	Softening Point (ºC)
Virgin Bitumen (VB)	47.3	50.1
VB + 0.2% Iterfoam B®	40.9	50.6
VB + 0.4% Iterfoam B®	44.0	49.7
VB + 0.6% Iterfoam B®	45.2	49.7

The results of the several combinations are similar, which shows that the additive does not significantly affect the properties of the virgin bitumen.

3.2 Compactibility test results

After selecting the best combination to foam the bitumen, four mixtures were produced both with foamed bitumen at three different temperatures and with virgin bitumen without any foaming process, as previously presented in Table 1. Those mixtures were first tested for compactability, in order to assess the evolution of the air void content of the specimens during the compaction process for each production temperature. In this study, this procedure was repeated for several test temperatures to understand the influence of temperature in the workability of the mixture and, consequently, in the air voids content of the mixture. Based on the results obtained in Fig. *2* it is possible to verify that there are no significant differences for the foamed mixtures produced at 210 and 230ºC, in terms of air voids content, and the results obtained for the control mixture also are very similar to these two mixtures (it is only slightly higher, showing that the foaming process improved the workability of the mixture). An additional, but small increase in the air void content was obtained for the mixture with foam bitumen produced at 190ºC, as a result of a reduced workability after reducing 40 ºC the production temperature. This may mean that the maximum reduction of temperature is being achieved in this situation.

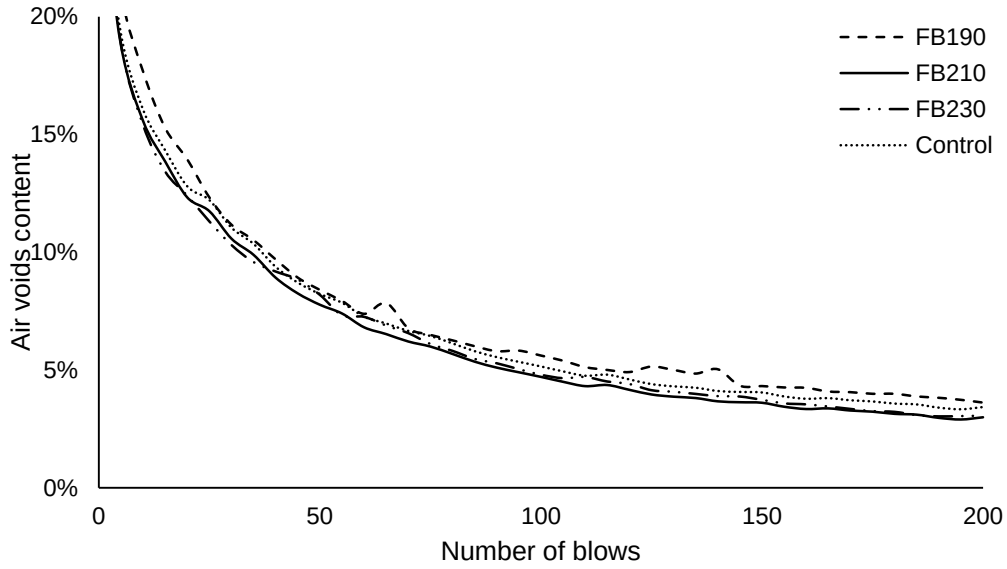

Fig. 2 – Compactability test results of the studied mixtures.

In order to compare the compactability results to those of the specimens prepared for the water sensitivity tests, the air void content should be measured after 150 blows, which is equivalent to the compaction energy used in the Marshall compaction by applying 75 blows in each face of the specimen. Those values are presented in Table 3, and they are clearly within the typical air voids content values expected for this type of asphalt mixtures for surface layers.

Table 3 – Air voids content of the specimens after 150 compacting blows

	Control	FB190	FB210	FB230
Air Voids content (%)	4.0	4.3	3.6	3.7

3.3 Water sensitivity test results

The water sensitivity tests are used to assess the durability behaviour of asphalt mixtures after long term contact with water. The way the asphalt mixture is affected by the contact with water might cause some problems, including the breaking of the bond between the bitumen and the aggregates (loss of adhesion) and the reduction of the stiffness and resistance of the asphalt mixture (loss of cohesion).

The value of air voids content is closely related to the water sensitivity of asphalt mixtures. Thus, all specimens used for this test were also characterized to assess the air voids content (Table 4). As it can be seen, the results are not significantly different from those of the specimens evaluated in the compactability tests. The main difference was observed for the mixture produced at lower temperature (FB190), which showed the highest increase in the air voids content.

Table 4 – Air voids content of the specimens used in the water sensitivity tests.

	Control	FB190	FB210	FB230
Air Voids content (%)	4.3	4.8	3.5	4.1

The water sensitivity test results are shown in Fig. 3, where it is possible to observe that the mixtures with foamed bitumen have a higher value of ITSR compared to the control mix. Comparing the control mixture produced at 230 °C with the mixture with foamed bitumen produced at the same temperature, it is possible to verify that the ITSR value improves considerably when using the expanded bitumen (probably due to its improved workability). Moreover, the results obtained for the mixture produced at lower temperatures (190°C) showed very interesting ITSR values (above 85%), similar to those of the control mixture.

Although for the mixture produced with foamed bitumen at 230°C presents a lower ITSdry value, the difference to the other ITSdry values is not significant. The relatively high ITSR values obtained for all mixtures may be caused by the use of 50% RA material, which is very stiff and is not affected by water. Summing up, it can be concluded that it is possible to produce recycled asphalt mixtures with 50% RA with foamed bitumen, reducing the production temperature by 40ºC without significantly affecting the volumetric properties of the mixtures and their water susceptibility.

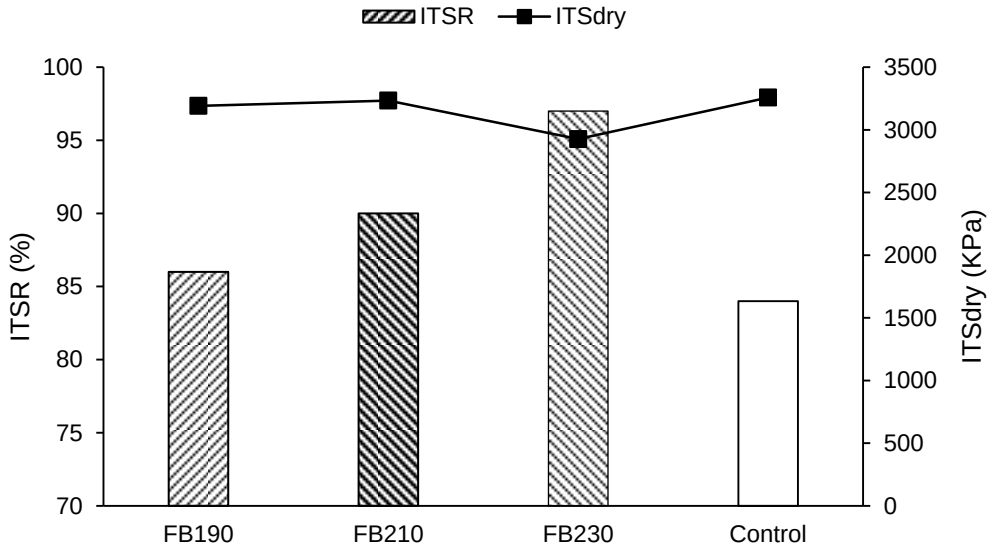

Fig. 3 – Water sensitivity test results.

4 CONCLUSIONS

The use of foamed bitumen in the production of asphalt mixtures incorporating 50% RA material have been tested and the results show that this technique could be a good option to reduce the production temperatures of this type of mixtures.

Assessing the water sensitivity and compactability results obtained in this study, it was observed that is possible to reduce the mixing temperature by 40 ºC, at least in the production process used in laboratory.

Taking into account these results, this solution should now be applied "*in situ*" in the near future, after additional validation with rutting and fatigue performance tests.

5 ACKNOWLEDGMENT

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MACROECONOMIC SUSTAINABILITY OF THE CONSTRUCTION INDUSTRY IN SUB-SAHARAN AFRICA

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Abstract

The contribution of construction to the national economy and its role in socio-economic development has been dealt with by various writers and international organizations, and many of them have focused on developing countries. In a macroeconomic perspective, a particular feature is that construction is the only sector of the economy that appears twice in the national accounts of any country: a major component of fixed capital formation; and as a sector that contributes to the gross national product. Another main aspect derived from a seminal work in the field is that there is a changing development pattern of the construction industry based on the stage of development of a country´s economy. The role of construction infrastructure in the process of development has gained a new stimulus following the United Nations Declaration at the Millennium Summit in New York, 2000, where 8 millennium development goals (MDGs), measured through 21 targets, were devised. Some of the MDGs and the soon-to-be adopted sustainable development goals (SDGs), also at the United Nations Conference, September, 2015, have to do with construction infrastructure and/or the services rendered by these infrastructures. As each country is the main responsible for its own economic and social progress and in the face of macroeconomic constraints in many parties of the developing world, an important question that arises is how a well-functioning construction industry could contribute to the attainment of those targets. Using most recent data drawn from United Nations and The World Bank publications, and making use of an analysis developed in previous works, this study presents some insights of the development of the construction industry in two groups of countries in Sub-Saharan Africa, according to their level of economic development. Some preliminary recommendations aimed at public policy development are also drawn.

Keywords: Construction industry, economic development; sustainable development indicators; Sub-Saharan Africa.

1 INTRODUCTION

The relationship between a country's stage of development and the level of activity in the construction sector is one, which has received great attention at the macroeconomic level for a number of years. Some writers have attempted to model the relationship and found a positive correlation between several measures of construction output and the level of income per capita [1], [2], [3]. These findings have been the subject of much argument due to problems related with the reliability of data, limitations of the coverage and methods of analysis employed. Existing paradigms on the structural change in the construction industry, as a national economy develops over time tend to be based on cross-sectional data across countries rather than longitudinal studies based on one country's time-series statistics. However, a seminal work in this field made use of a longitudinal analysis to present a development pattern for the industry, at a global scale, also based in the stage of economic development of a country's economy [4]. An important aspect of the proposition was that, in the early stages of development, the share of construction increases but ultimately declines, in relative terms, in industrially advanced countries - and even at some stage, the decline is not only relative but also in absolute terms. The positive association between construction investment (indeed physical infrastructure) and economic growth has been subject of debate for the part of the proponents of endogenous growth theory and international organisations such as the World Bank in the *Structural Adjustment Programme* for Africa [5]. Indeed, in the aftermath of the 1979-980 oil-shock and the international financial crisis that followed in 1981, most of Sub- Saharan African countries experienced until the mid-1990s a decreasing growth in per capita income (see Table 1) despite heavy investment in construction and other physical capital over the period 1970-1980. It could be argued according to this reasoning that rather than the quantity of infrastructure, the main concern in the developing countries of Africa should be the quality of the infrastructure, and by prioritising investments that modernise production and enhance international competitiveness. In the early 2000s, international

organisations and development agencies started to become aware of the important role infrastructure would play for attaining all the MDGs (and now their substitute, SDGs) in Sub-Saharan Africa.

An important question which should be the concern of the construction economics research community and national and international development agencies is how a well-functioning construction industry could contribute to a sustainable economic growth and development [6].

The structure of this paper is as follows: the next section presents a quantitative analysis of the relationship between the measures of construction output and those of the national aggregate in two groups of countries in Sub-Saharan Africa, according to their stage of economic development: Low Income Countries (LICs) and Middle Income Countries (MICs). The statistical sources and data are presented and commented on, and the analysis and discussions of the results are elaborated upon. The third section explores the link between construction investment and economic and social targets related to the SDGs. A concluding remark finalizes the analysis presented in this paper.

2 QUANTIFYING THE RELATIONSHIP BRTWEEN CONSTRUCTION AND GROSS DOMESTIC PRODUCT

2.1 Data and methodological issues

The main statistical sources used in this analysis are the 2015 edition of the *Yearbook of National Account Statistics: Main Aggregates and Detailed Tables* from the United Nations [7] and *Africa Development Indicators 2012-2013* from the World Bank [8]. The internet site of the UN statistical office presents data on gross domestic product (GDP) and its components both in the expenditure, production and income approaches. This publication presents various sets of economic series detailing the evolution of GDP and its components in different statistical formats over the long period 1970-2013, at the world, world regions and country levels. The *Africa Development Indicators 2012-2013* presents a series of national and fiscal accounts for all African countries for the period 1980-2010. In order to place the two country groups in the economic development arena, gross national income (GNI) per capita for the bench mark year 2010 was taken. This report also presents the following definitions of the income groups of countries according to the 2010 GNI per capita: low income countries (LICs), US$ 1,005 or less; lower- middle- income (LMICs), US$ 1,006-3,975; upper-middle-income (UMICs), US$ 3,976 -12,275; and high income countries (HICs), US$ 12,906 or more.
Cross-matching sources, data are available for 38 countries and these can be split into two groups according to the level of GNI per capita in 2010. Group I – LICs comprises the following countries: Benin, Burkina Faso, Burundi Central African Republic, Chad, Comoros, Democratic Republic of Congo, Gambia, Guinea, Kenia Liberia Madagascar, Malawi, Mali, Mozambique, Niger, Rwanda, Rwanda, Togo, Uganda and Zimbabwe. Group II – MICs comprises the following countries: Angola, Botswana, Cameron, Cape Verde, Republic of Congo, Cote d'Ivoire, Equatorial Guinea, Gabon, Ghana, Lesotho, Mauritius, Namibia, Nigeria, Senegal, Seychelles, South Africa and Swaziland.Thus, Group II comprises both LMICs and UMICs, and only Equatorial Guinea could, in theory, be considered a HIC, owing to its high GNI per capita (US$ 13,720).
Table I presents the evolution of GDP per capita, both of Sub-Saharan Africa as a whole, as well as excluding two important economic players of that region, South Africa and Nigeria, for the period 1980-2010.

Table 1 – GDD per capita in Sub-Saharan Africa in 1980-2010, real.

	Constant prices (2000 US$)				Average annual growth (%)		
	1980	1990	2000	2010	1980-90	1990-2000	2000-10
SSA	594	539	508	653	-0,9	-0.6	2.6
SSA excluding S. Africa	372	344	332	458	-0.8	-0.2	3.2
SSA excluding S. Africa and Nigeria	354	340	323	437	-0.3	-0.2	3.0

Source: [8]

The evolution of the indicator of construction industry activity –share of the construction value added in GDP – is presented in Fig.1 and Fig.2 as the mean average for the two groups of countries for the period 1980-2010.

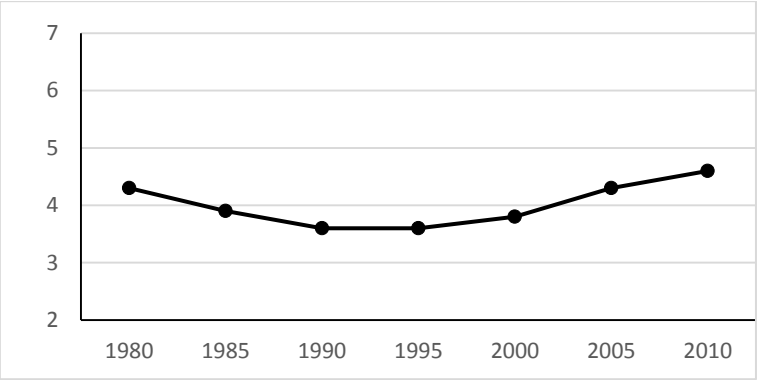

Fig.1 – Share of Construction in GDP (%) in Group I, 1980-2010.

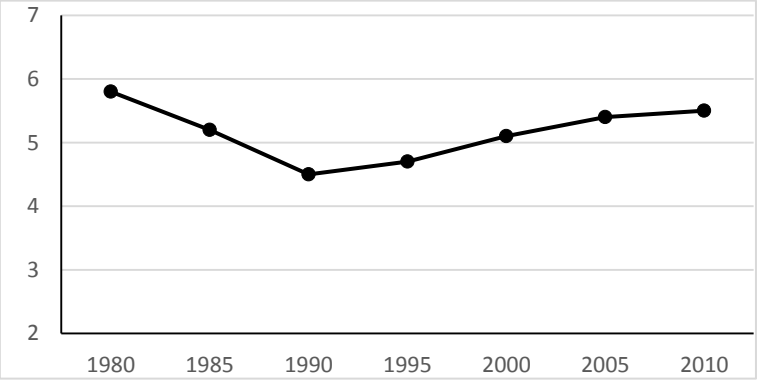

Fig.2 – Share of Construction in GDP (%) in Group 2, 1980-2010.

2.2 Analysis and Discussions

Table 1 shows the evolution of GDP per capita in Sub-Saharan Africa as well as that of Sub-Saharan Africa excluding South Africa, and then Sub-Saharan Africa excluding South Africa and Nigeria. The division shown in Table 1 is a reflection of the clout those two countries represent in the Sub-Saharan African economy. South Africa's and Nigeria's GDP in nominal prices comprised over fifty percent (50.4 percent) of Sub-Saharan Africa's GDP in 2010. The reasons for this dominance are not the same for the two countries. Nigeria plays a big role because it is, by far, the most populous country in the region, whereas South Africa is important owing to its unmatched industrial structure and technological development that makes it the economic pole of Sub-Saharan Africa.

Table 1 shows that both the region and its subdivisions, in terms of GDP per capita, experienced decreasing growth in the period 1980-2000 and a reasonable upturn in the period from 2000 onwards. According to data constructed from the World Bank [8], the LCIs, as a group, experienced a dramatic decreasing growth in GDP per capita in the period 1980-2000, and an average annual rate of growth of about 2.5% in the period 2000-2010. Again, data constructed from World Bank show that the countries comprising Group II (MICs), in terms of GDP per capita, grew slightly in the period 1980-2000, with an average annual growth rate of about 1%, and notched up a spectacular rate of growth of an annual average rate of more than 4% in the period 2000-2010.

Now, looking at the relationship between the construction sector and the national economy, Figs 1 and 2 show that the evolution pattern of the share of CVA in GDP in the developing countries of Sub-Saharan Africa is markedly different according to the country's stage of economic development as determined by GNI per capita. The share of CVA in GDP in Group I (mean average of the group), despite differences across countries as well as taking into account annual fluctuations, varied from 3.6 % to 4.6 % of GDP, as is illustrated in Fig.1. In terms of the evolution in the period, the share of that indicator was in line with the development pattern of GNI per capita: it decreased in the period 1980-

1990 (from 4.3% to 3.6 %), measured as an average for the group), remained practically stagnant in the period 1990-2000, and grew at a reasonable rate in the period 2000-2010 (from 3.8 % to 4.6 %, again measured as an average for the group). It is worth noting that in the latter years of the period, the share of CVA in GDP was higher than that in the earlier years of the same period. That is, in the first stages of economic development, and in an increasing growth pattern, the construction industry tends to grow faster than national output. Conversely, in an economic downturn, the industry tends to decrease not only absolutely but also relatively [9].

Regarding the middle-income countries (Group II), Fig.2 shows that the share of CVA in GDP (mean average of the group) varied, in general, from 4.5 % to 5.8% in the period 1980-2010, also disregarding differences across countries as well as annual fluctuations. Fig.2 also shows that the share of CVA in GDP decreased from 5.7% in 1980 to 5.1 % in 2000 (measured as an average for the group) despite a growth in GDP per capita, as already pointed out, at an average annual growth rate of about 1% in the period 1980-2000. From 2000 onwards, the share of construction in GDP increased gradually and then remained practically stagnant at around 5.5% of GDP. The pattern experienced by the MICs is worthy of note: despite a significant increase in national income per capita, particularly in 2000-2010, the share of CVA in GDP in the late years of the period did not reach the value attained in the beginning of the period. It could reasonably be said that the construction industry activity in the MICs reached a peak, in relative terms, in the early 1980s. These results presented here seem to corroborate those of a previous work concerning the developing countries of Africa [9] that found that in the developing countries of Africa that have middle-income status or are in a sustained process of reaching it, and have achieved a certain level of the construction industry activity (say 5 to 6 percent of GDP, depends upon the year taken as basis), the proportion of construction in GDP tends to remain stagnant, i. e. the rate of growth of construction volume follows that of the national economy.

3 CONSTRUCTION IINFRASTRUCTURES AND THE POST-2015 DEVELOPMENT AGENDA

The construction industry has historically been linked with the process of industrialisation and development. Railway systems and canals played an important role in the connection of different regions of Europe, North America and in some parts of Latin America. Transport infrastructure facilitated trade and co-operation between countries and also the diffusion of technical innovations from the most advanced to the less advanced areas of the globe [10]. The construction industry played a key role in the reconstruction of war-ravaged Europe: the heavy programme of construction improvement of housing and social infrastructure, besides its contribution to the national output, was also a reflex of a better re-distributive economic policy in Europe after World War II. Following the UN Millennium Declaration in 2000, the Heads of State and Government of Sub-Saharan Africa have emphasized the role transport infrastructure can play in enhancing inter-regional cooperation and foster economic and social development [11].

In the early 2000s, the physical infrastructure in Sub-Saharan Africa was in a very poor state. External capital flows (particularly from donor countries pertaining to the Development Assistance Committee of the OECD) for African infrastructure had reached a historic low [12]. The Group of Eight Summit at Gleneagles in 2005 called for action by the major economies and multilateral donors in the financing of Sub-Saharan African infrastructure. This led to the formation of the *Infrastructure Consortium for Africa.* This consortium would constitute a forum where major donors could work with continental and regional institutions to spearhead economic integration [12]. One of the practical results of this political arrangement was the publication of the flagship report "*Africa's Infrastructure: A time for Transformation*". This publication diagnosed the infrastructure needs of Sub-Saharan Africa, addressing the twin challenges of financing and sustainability, particularly the attainment of the millennium development goals (MDGs).

As stated before, the sustainable development goals are part of the post-2015 development agenda. The United nations General Assembly, in its sixty-ninth session, of 12 August 2015, decided "to transmit the outcome document entitled *Transforming our World: the 2030 Agenda for Sustainable Development* to the General Assembly at its seventieth session for action during the United Nations Summit for the adoption of the tpost-2015 development agenda, to be held from 25 to 27 September 2015" [13]

In this new agenda, there are 17 SDGs associated with 169 targets that will stimulate action in the following critical areas: people, planet, prosperity and peace [13]. Some of these goals and targets have to do particularly with construction investment and the construction sector in the developing

world. These are: Goal 6- Ensure availability and sustainable management of water and sanitation for all; Goal 9- build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; Goal 11- make cities and human settlements inclusive, safe, resilient and sustainable. Of particular relevance for construction infrastructure in Sub-Sharan Africa is target 9.1- develop quality, reliable and sustainable and resilient infrastructure, including regional and transborder infrastructure to support economic development and human weld- being.

Table 2 indicates that the estimate for the overall cost to build, maintain and operate Africa´s infrastructure is US$93 billion annually over the period 2006-2015, approximately 15% of Sub-Saharan Africa's GDP in 2006. Of this total, about two thirds are for investment and about one third for operation and maintenance. In sectoral terms, about 40% is allocated to the power sector. The second-largest component is water supply and sanitation (WSS) – a key sector for meeting the SDGs – with about 23% of the total and the third largest share of the cost is associated with transport, which is approximately 20% of the overall spending needs.

Table 2 – Overall Infrastructure Spending Needs for Africa, 2006-2005 *(US$ billions annually).*

Sector	Capital expenditure	Operation and maintenance	Total needs	Funding Gap
ICT	7.0	2.0	9.0	1.3
Irrigation	2.7	0.6	3.3	2.4
Power	26.7	14.1	40.8	23.2
Transport	8.8	9.4	18.2	(1.9)
WSS	14.9	7.0	21.9	11.4
Total	60.4	33.0	93.3	30.6

Source:

In terms of regional groups, the burden of the price tag relative to the countries' GDP is markedly different across groups. For middle-income countries and resource-rich countries, the amount is in the range of 10% to13% of their respective GDPs. For low-income countries, as much as 25% of GDP would be needed [12]. If one takes into account that the middle-income countries already spend a reasonable share of their wealth in investing in infrastructure and the spending needs are almost equally divided across groups, one can envisage the implausibility for the poorer countries in Africa to finance the funding gap of their estimated spending needs. As Table 2 shows, the funding gap for the infrastructure in Sub-Saharan Africa is US$ 30.6 billion or about 2.5 % of GDP in 2010, taking into account efficiency improvements. About US$ 23 billion a year, or over 70% of the funding gap, is for the power sector. The other significant component of the gap, representing a shortfall of US$ 11.4 billion is associated with WSS. The funding gap in the latter sector in the low-income countries looks like an unattainable target in the foreseeable future in the light of the present economic situation and prospects of the countries themselves, and the challenges posed to the development partners by the 2008 global financial crisis.

The WSS sector, besides its direct effect on the provision of water and sanitation services, has a pervasive impact on other social targets, namely in the prevention of disease, improvement in education and promotion of gender equality so that women save time when they begin using an improved water source [6]. Transport fosters trade by reducing the cost for transporting goods and passengers, reduces child/maternal mortality and improves access to education services. Electricity enhances productivity, eradicates poverty by fostering economic growth and reduces child/maternal mortality.

An efficient construction industry can contribute to the efforts to tackle these problems. For example, it can address the vulnerabilities of slum dwellers by devising labour-intensive and cost-effective technologies, and by implementing practical sustainable measures in the framework of the *Agenda 21 for Sustainable Construction in Developing Countries* [14].

4 CONCLUSIONS

The picture that emerges from the analysis of the evolutionary process of the construction industry and its role in national socio-economic development suggests that the share of construction in gross domestic product tends to increase with the level of per capita income in the first stages of economic

development. When countries reach a certain level of economic development, the construction output will grow slower than national output in the later stages of their development. That is, it decreases relatively but not absolutely. Thus, it is reasonable to assume that when a certain level is achieved (say the share of CVA in GDP at around 5% to 6%) and countries enter into a path of sustained economic growth and development, the construction output tends to grow, in general, with the same rate of growth as that of the general economy.

The results of the study also underlie the twin challenge of finance and sustainability in Sub-Saharan Africa in the effort towards attaining the MDGs, and the situation is particularly acute in the low-income countries in the light of the countries' own economic circumstances and prospects, and the current global financial crisis. The results of the study may have some implications for public policies. Given the experience of the growth process in Sub-Saharan Africa, what should be the focus of growth-enhancing policy in the two groups of countries? How can the construction industry contribute to this end, and help a country in Group 1 to move to Group 2? For example, further investment in construction infrastructure might be recommended for countries in Group 1 but might not necessarily be a growth priority for countries in Group 2 [10]. For the low – income countries, taking into account the dire financial stress facing these countries, the analyses suggest that most of the effort should be directed at construction investment projects in order to achieve a level of the construction industry activity of, say, 5 to 6% of GDP which is required for a reasonable functioning of the economy. The priority should be given to construction investment projects that have high multiplier effects in the economy, particularly transport and multi-purpose (power and water) infrastructures. A concerted effort to implement sub-regional infrastructure projects seems also to be the way forward.

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CUTTING CARBON CUTS USE OF RESOURCES AND COSTS: HOW LOW WHOLE LIFE CARBON REDUCTION CREATES EFFICIENCIES AND UNLEASHES INNOVATION IN CIVIL ENGINEERING.

THE CASE OF THE INFRASTRUCTURE SECTOR IN THE UNITED KINGDOM

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Abstract

Carbon reduction is traditionally associated to the assessment of carbon emissions savings which are linked to the operations of infrastructure assets. This is due to the close relationship between energy use, operational carbon emissions and operational cost. Nevertheless, recent research and best practice on the assessment and minimisation of embodied carbon (or capital carbon) and whole life carbon showed an equally strong link with the reduction of capital and whole life costs respectively.

This paper presents the fundamentals of whole life carbon assessment based on embodied and operational carbon evaluation, as well as links between low whole life carbon design, low cost delivery and operation of infrastructure. Such analysis is performed in association to:

- implications of setting low carbon asset management as a strategic organisational objective;
- impacts on asset delivery by introducing a bespoke carbon assessment tool used to calculate embodied and operational carbon content of project options against set carbon targets;
- effects on the engineering standards and outcomes based design finalised to build “as little as possible and as much as needed, smartly and efficiently”.

Cases from different infrastructure sectors (water, power distribution and transmission, transport) will be presented to consolidate the message that low whole life carbon solutions create efficiencies and save resources; unleash innovation; drive capital and operational costs down. Savings of up to 39% in embodied carbon and 34% in operational carbon produced average reduction in capital costs of 22%.

Finally, transferable key enablers of change for any kind of infrastructure asset owner and their supply chain will be described: an empowering leadership, a culture of innovation and effective commercial solutions.

ASSESSING CLIMATE CHANGE IMPACT IN HOSPITALITY SECTOR. SIMPLIFIED APPROACH USING BUILDING RESOURCES CONSUMPTION SIGNATURE

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Abstract

Climate impact assessments and the development of adaptation strategies requires the study of vulnerabilities and risk to climate variables. The energy and water consumption demand in hotel usually change with occupancy rate and climate. In this article a simplified methodology is presented and applied to identify the climate change impact in hospitality sector using the building energy and water signature. This methodology is applied to sixteen hotels (nine in Lisbon and seven in Algarve) with four and five stars rating. The results show that is expect an increase in water and electricity consumption (manly due to the increase in cooling) and a decrease in gas consumption (for heating). The hotels in Algarve are more vulnerable than Lisbon hotels.

Keywords: climate change, energy, water, hotel, tourism.

1 INTRODUCTION

Hotels are one of building types that consumes more energy and water per person and are vulnerable to climate change because in the occurrence of extreme events (heat waves, water stress) same failures could compromise the hotel services (comfort) and increase energy cost or compromise the landscape and amenities due to water use restriction (UNEP)

Climate impact assessments and the development of adaptation strategies require the study of vulnerabilities and the knowledge about critical climatic variables, namely the availability of high-resolution climate change scenarios. As part of the global CORDEX framework, the EURO-CORDEX provides regional climate projections for Europe at 50 km (EUR-44) and 12.5 km (EUR-11) resolution [5].

To study the risk and vulnerability of hotels to climate change regarding resources consumption (energy and water), in previous studies building energy modelling simulation (BEMS) technique were used to study the increase in energy and water consumption ([12], outros). In general the climate change impact in building is performed studying the transformation of energy and water demand of the building for future climate scenarios [12]. But, hotels are complex buildings and quite different from each other and simplified BEMS usually neglect some important hotel features and projected estimates didn't match hotel sector understanding and expectations.

Taking account all uncertainties, the use of building signature could be helpful to assess in a more clear way the impact of CC in the hospitality sector and using a broad sample. Statistical analysis of the global energy consumption obtained from bills shows that the energy consumption may be predicted within 90% confidence interval only with the outdoor temperature [9], [13] and [8]. The use of regression method was also used by designers to target building design parameters in early design that drive energy performance [10].

2 METHODOLOGY

The proposed methodology to assess the climate change impact in the hospitality sector, regarding comfort and rational use of resources, is proposed to be supported by the estimate of the change in the energy and water demand of the buildings for climate projection. In this simplified approach, it's proposed to use the energy and water signature of the building, using the last three years' monthly data for energy and water consumption, observed weather data and services provided (guest per night and covers).

This methodology is in line with building energy consumption calculations with quasi steady state linear models such as defined in standard ISO 13790:2008 [7]. The building energy and water signature is derived using a multiple linear regression (eq 1 and 2). This type of model assumes that the energy and water consumption is linear related with number of guest, covers and outside weather. In the first two cases this could be true (Pinto, 2015), but usually the building energy demand is not linearly related with outside weather, due to dynamic heat flux phenomena, building thermal inertia, changes in the air flow rate, etc. Despite this limitation for short period analysis, regression analysis is helpful when using longer periods, when some of this phenomena are averaged. For instance, using monthly data, the influence of any phenomenon having dynamics faster than 1 month is neglected, but better correlation are obtained than using short time intervals (10 minutes, 1 hour), due to the influence of random, non-measured disturbances like occupancy, ventilation rates and solar gains that do not follow a normal (Gaussian) distribution (Ghiaus, 2006). In figures 1 to 3 are presented the relation between electricity consumption (EkWh) and independent variables such as outdoor temperatures, occupancy (PAX) cover, etc. The same is done in figures 2 and 3, for gas consumption and water consumption. Those figures, and the study of data from other hotels with Akaike Information Criterion (AIC) show that:

- Occupancy and meal are correlated and in this study it will be used de occupancy do assess the influence of occupancy.
- The influence of climate on building resource consumption is related with average outdoor temperature and we could disregard Heating Degree (GDaq) days and Cooling degrees day (GDarr) that are related with average outdoor temperature.
- Water consumption is strongly related with occupancy and in other hotels with precipitation.
- It's noted that occupancy is also related with outdoor average temperature.

With the previous information, to find the hotels energy and water signatures it was used the linear models presented in eq 3, 4 and 5. This type of energy and water signatures are fit if they present R^2 not smaller than 0.75 and if the independent variable has p-value not greater than 5%.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p + \varepsilon \quad (1)$$

$$\hat{Y} = \beta_0 + \beta_1 \hat{X}_1 + \beta_2 \hat{X}_2 + \ldots + \beta_p \hat{X}_p \quad (2)$$

$$E(kWh) = a_e + b_e.T + c_e.G \quad (3)$$

$$G(kWh) = a_g + b_g.T + c_g.G \quad (4)$$

$$W(m^3) = a_w + b_w.T + c_w.G + d_w.P \quad (5)$$

where: G, guest/day; T, average monthly outdoor temperature, P, average monthly precipitation a_i, b_i and c_i are the regression coefficients.

3 METEOROLOGICAL DATA AND CLIMATE CHANGE

Precipitation and temperature observations used in the present work were obtained from the IPMA (Portuguese Institute for the Sea and Atmosphere) observation network. The consist in daily accumulated precipitation and mean, maximum and minimum daily temperatures, measured in five locations, three in the Lisbon area and two in the Algarve, during three years from January 2012 to December 2014.

Data used to evaluate the impacts of climate change was obtained from the EURO-CORDEX initiative (http://www.euro-cordex.net/). EURO-CORDEX is an international climate downscaling initiative that aims to provide high-resolution climate scenarios for Europe (Kotlarski, et al., 2014). The regional simulations were downscaled from the new CMIP5 global climate projections [3] and the new representative concentration pathways (RCPs) [2], [4]. Only one ensemble member was used, the one produced by the ICHEC, forced with global climate simulation produced within the EC-EARTH consortium. Daily precipitation and mean daily temperature were extracted from the EUR-11 (12.5 km) resolution domain, for two locations, one in the Lisbon area and another in the Algarve (Vilamoura). Climate projection corresponding to two emission scenarios, RCP4.5 and RCP8.5 were used.

Three sets of climate data, of twenty years each, were obtained for each scenario. The first represents the beginning of the 21st century (2011-2030), the second the mid 21st century (2031-2050) and the third, the end of this century (2081-2100), figure 1 and table. Heating degree days and cooling degree days were computed on base 20ºC and 22ºC.

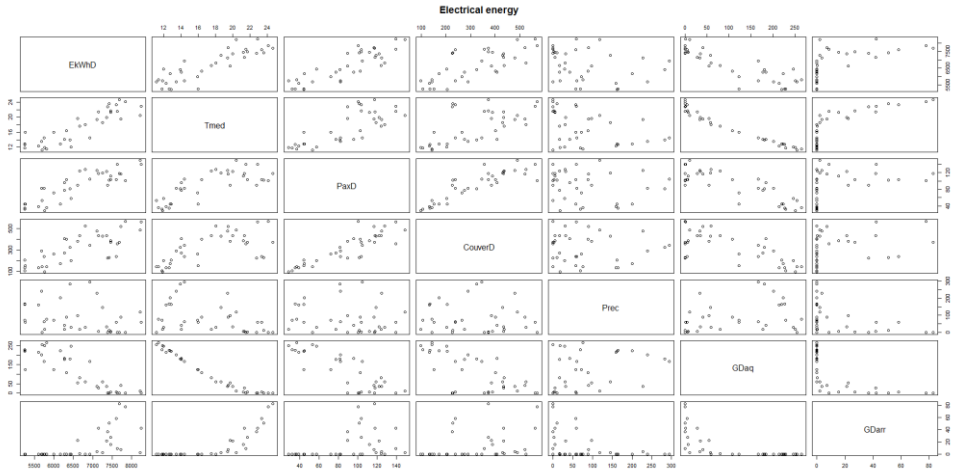

Fig. 1 – Electrical energy consumption and independent variables for one hotel.

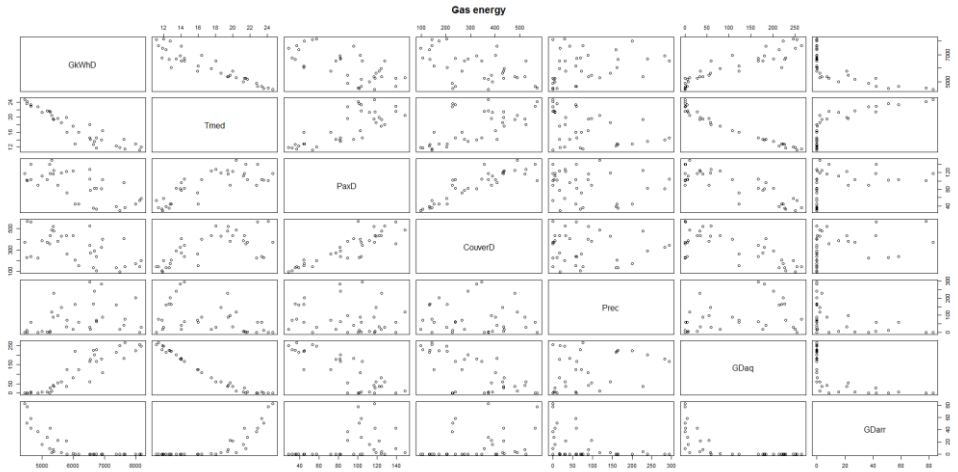

Fig. 2 – Gas consumption and independent variables for one hotel.

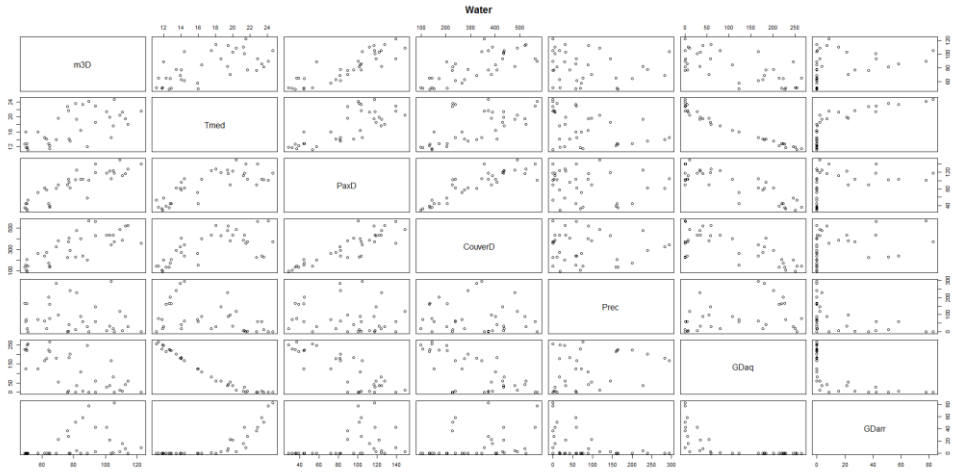

Fig. 3 – Water consumption and independent variables for one hotel.

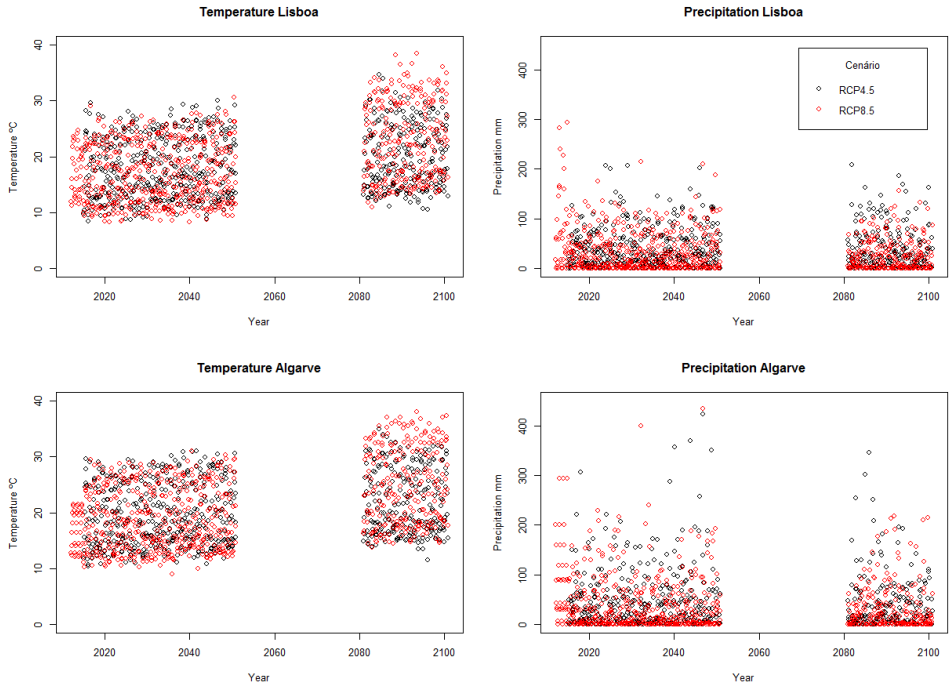

Fig. 4 – Meteorological data and climate change.

Table 1 – Meteorological data and climate change.

Label	Temperature				Precipitation			
	Lisboa	Algarve	Lisboa	Algarve	Lisboa	Algarve	Lisboa	Algarve
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Min	8.4	8.2	10.4	9.0	0	0	0	0
1st Quartile	13.8	13.8	15.5	15.2	2	1	1	0
Median	17.8	18.2	19.4	19.7	20	17	16	14
Mean	18.7	19.1	20.4	20.7	36	43	32	37
3rd Quartile	23.3	23.6	25.3	25.6	57	57	48	53
Max	34.6	38.5	35.0	38.0	294	424	294	435

4 CASE STUDIES

To assess the climate change in hospitality sector the previous methodology was applied to sixteen hotel, nine hotel in Lisbon and seven in Algarve. The main characteristics of studied hotels and main results are shown in Table 2. All the hotel belong to four or five star category. For both Lisbon and Algarve hotels a 25 kWh/gn (σ=13) electrical energy consumption is estimated. Larger water consumption are detected in Algarve (average 700 l/gn vs 440 l/gn) hotels and more gas consumption in Lisbon hotels (average 23 vs 17 kWh/gn). The majority of this hotels has satisfactory energy efficiency levels. Regarding the presented results, all the hotel are sensitive to climate change. For the period 2030 to 2050, the foreseen climate change impact on building is relatively small compared with prediction for the period 2080 to 2010, were the obtained results with scenario RCP 8.5 are also different from scenarios RCP 4.5.

In the period 2020 to 2030, the most sensitivity aspect is the increase in water and electricity consumption of Algarve hotels. In the period 2080-2100, the expected increase in electricity and water continues to be important in Algarve (28% for energy and 50% for water) but also in Lisbon (14% for energy and 9% for water). With this scenario a decline in gas consumption mainly for heating is also predicted.

Table 2 – Climate change impact in hotels.

Hotel n.º	Place	Nº beds:	N.º rooms	Average ocupancy annual	E eletricity (kWh/PAX)	E gas (kWh/PAX)	Water (l/pax)	Scenario RCP 8.5						Scenario RCP 4.5					
								E CC (2030 a 2050)	E CC (2080 a 2100)	G CC (2030 a 2050)	G CC (2080 a 2100)	W CC (2030 a 2050)	W CC (2080 a 2100)	E CC (2030 a 2050)	E CC (2080 a 2100)	G CC (2030 a 2050)	G CC (2080 a 2100)	W CC (2030 a 2050)	W CC (2080 a 2100)
1	Lisboa	380	180	<50%	49	46	609	0%	10%	-1%	-26%	1%	0%	2%	5%	-5%	-13%	0%	0%
2	Lisboa	252	126	<50%	29	13	511	0%	6%	0%	-29%	3%	14%	1%	3%	-5%	-15%	9%	21%
3	Lisboa	249	198	<50%	15	10	348	0%	16%	-1%	-32%	2%	14%	3%	8%	-6%	-16%	7%	16%
4	Lisboa	48	26	<50%	27	25	396	0%	10%	-1%	-26%	2%	1%	2%	5%	-5%	-13%	1%	0%
5	Lisboa	274	137	<50%	30	17	283	1%	16%	0%	-19%	2%	0%	3%	7%	-3%	-9%	1%	0%
6	Lisboa	56	28	<50%	36	65	1,079	0%	17%	-2%	-65%	1%	0%	3%	8%	-12%	-33%	1%	0%
7	Lisboa	140	70	50% a 70%	12	7	133	0%	17%	0%	0%	0%	0%	3%	8%	0%	0%	0%	0%
8	Lisboa	528	301	50% a 70%	22	1	421	0%	12%	0%	-3%	0%	0%	2%	6%	-1%	-2%	0%	0%
9	Lisboa	518	259	50% a 70%	8	19	162	1%	24%	-1%	-29%	0%	0%	4%	12%	-5%	-14%	0%	0%
10	Algarve	514	257	<50%	13	13	424	4%	26%	-15%	-97%	14%	68%	8%	16%	-30%	-57%	24%	47%
11	Algarve	624	312	<50%	27	21	715	6%	40%	8%	54%	15%	50%	12%	22%	16%	30%	22%	40%
12	Algarve	462	231	<50%	30	22	1,188	2%	10%	-22%	-150%	3%	12%	3%	5%	-47%	-92%	4%	7%
13	Algarve	128	55	<50%	17	19	618	2%	15%	-2%	-14%	6%	25%	4%	8%	-4%	-8%	8%	15%
14	Algarve	378	231	<50%	49	20	878	3%	22%	-3%	-23%	20%	113%	6%	12%	-7%	-13%	33%	84%
15	Algarve	508	182	<50%	23	20	497	9%	57%	-10%	-70%	12%	61%	16%	31%	-21%	-41%	18%	34%
16	Algarve	382	114	<50%	15	5	609	3%	23%	-11%	-74%	10%	51%	7%	13%	-23%	-43%	16%	31%

5 CONCLUSIONS

In this article is presented a simplified approach to draw building signatures for energy and water consumption. For sixteen studied hotels, it was found that relevant independent variable are outdoor temperature, occupancy and precipitation.

With scenarios RPC 4.5 and RCP 8.5 and with the building resources consumption signatures it was forecasted the impact of climate change in the electricity, gas and water resources consumption. For electricity it's forecast an increase in consumption in the order of 10% to 28% (2030-2100), mainly due to the increase in the demand of air condition systems and refrigeration systems. From this model, it's also expect an increase in water consumption of this buildings, maybe for gardens and pools. Besides those increase, it's also expected a decrease in the energy consumption in heating systems, specifically in the gas consumption. The changes are essentially observed in the period 2080-2010, but in the period 2030-2050, some change are also expected, mainly in Algarve hotels, the most vulnerable zone of the two places studied.

This results are in line with other international studies, that predicts an increase in energy consumption of this order of magnitude [11], and show the importance of the development of adaptation plans in the hospitality sector to decrease cooling load demands, water use and also dependency from fossil fuels to cut costs and the impact of energy prices volatility.

This simplified methodology, supported by average monthly data is suitable to assess the impact of climate change at a time lapse of one month. To study the impact of climate variability a smaller time scale is needed, for instance one day and even an hour is required and this aspects will be studied in the framework of AdaPT project.

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ISO 12006-2:2015 FRAMEWORK FOR CONSTRUCTION INFORMATION

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Abstract

The ISO 12006-2:2015 is the latest output from the work developed by the Technical Committee ISO/TC 59 - Building Construction, Subcommittee SC 13 - Organization of information about construction works. This standard sets the main principles for the development of built environment classification systems. The second version results from the lessons learned with the development of CICS - construction information classification systems and integrates innovative trends, as information technologies and new forms of procurement. The definition of classification systems is essential for an improved and more effective information exchange across the construction process. Moreover, with the growing use of computer based technologies to support the construction project development, higher requirements are demanded in this field, as it constitutes also a branch towards construction sustainability. The authors have been involved on the development of construction classification systems for the Portuguese reality and are following several international initiatives. This paper has the objective of highlight the importance of classification systems for the construction sustainability, major changes of the new version and discuss the ongoing developments on UK as well as future trends for a national system.

Keywords: Information Organization, Construction Works, Standards, Classification Systems.

1 INTRODUCTION

Classification Systems are methodologies based on common relations or affinities that are used as a guidance or roadmap on many different subjects. Moreover, the definition of a classification fosters the organization and standardization as it enables the stabilization of terms, methods and concepts. By using pre-established terms, a classification is a spatial, temporal, or spatio-temporal segmentation of the reality. A classification system is a set of boxes (metaphorical or literal) into which things can be placed to perform some kind of work - bureaucratic or knowledge production. In an abstract and ideal sense, a classification system exhibits the following properties:

- Consistency - unique classification principles in operation;
- Mutual exclusivity of categories;
- System that tends to be complete [1].

Complex issues may lead to the creation of relations based on a distribution of classes. Usually, classification systems define codes, numerical, alphabetical or alphanumerical, for the different classification classes, levels and, in broadly form, for objects. One of the most familiar examples of the definition of different classifications is the human body; parts, systems, organs, among others. As the human body, the built environment is made of complex entities that are composed by parts that can be similar to those previously mentioned. Notwithstanding, the build environment results from construction processes. These involve several stages and a group of agents from very different technical disciplines [2]. Since the beginning of the 20th century, in order to enhance the information exchange and to promote mutual understanding on these issues, many organizations related with the construction industry began to develop classification systems, specially addressed for specific construction issues [3]. The main objective was to solve recurrent problems, most of them related with the design stage. From construction products to work results or rules of measurement, several efforts were made in different countries. The construction industry can be rather different in some topics from country to country, due to cultural, technological or legal aspects. This hampered a wide adoption of some of these systems [4]. This theme led to the establishment of a task group in order to define a common framework that could promote principles in order to set a level of harmonization for the CICS

- Construction Information Classification Systems development. More than 20 years after, ISO 12006-2:2015 defines new guidelines for the CICS evolution.

The present paper follows the efforts made to publish the second version of this standard. A comprehensive explanation of the major changes is performed in order to enhance the key facts that led to this evolution and also to frame the main principles by comparison with the existent classification systems. International and national insight is performed regarding the already developed systems. The discussion and conclusions are centered on analysis and current situation at national level, as well as the ongoing developments in the UK. These scenarios are considered firstly the most important from the point of view of dynamic and direct influence on the sector. In addition, reflect the author's knowledge regarding the follow up they are performing on this theme and in these two realities. Through this knowledge it will be possible to systematize the classification systems to be used and outline their developments in order to follow the rules defined by this new document and streamline their correlation with other international systems.

2 ISO 12006-2 EVOLUTION

The ISO 12006-2:2015 is the latest result from the work developed by the ISO/TC 59 SC 13 committee. This group has been working on the organization and classification of information in construction theme since the early 90's. The first output produced was the ISO/TR 14177:1994. Later, the evolution of this document led to the publication of a new family of ISO standards. These where the:

- ISO 12006-2 – Framework for classification of information;
- ISO 12006-3 – Framework for object-oriented information exchange;

both published in 2001. The Part 3 was revised in 2007. Regarding the Part 2, the scope of the 2001 version was setting the framework for the development of built environment classification systems. At that time there were few CICS, many of them dated from the late 70's. They had narrow visions of the construction and were developed with the objective of solving specific problems. As an example, the North American Uniformat, a single table system, was specifically developed for building construction (mainly residential) and with the intention of providing references for the description, economic analysis and building management of these types of constructions [2]. It is centered on a construction Elements vision. The British version of the Swedish system, the SfB - Samarbetskommitten for Byggnadsfragor, was developed by RIBA - Royal Institute of British Architects, and it was composed of five tables [5, 6]. It was geared for construction products and building elements. It was meant to provide a satisfactory mean for structuring sets of detailed design drawings, working drawings and specifications. The system that can be considered the wider CICS developed until that moment, is the Uniclass. Published in 1997, it followed the results of the ISO/TR 14177 report. It can be assumed as the first approach to a global CICS and integrates contents of other narrower that were being already used n UK. It has fifteen tables, geared for specific topics and with relations with each other. The main scope in terms of types of constructions is buildings, but it integrated also some contents for civil engineering works. After the publication of the first version of ISO 12006-2, the development of the North American Omniclass, among many others, followed its guidelines [7]. This system can be considered in terms of topics and structure quite similar to Uniclass yet, broader as integrates lessons learned. With the development of other standards, with the increasing requirements of construction life cycle thinking as well as with the adoption of new technologies by the construction industry, ISO 12006-2:2001 was lacking in terms of scope and accommodation to new trends, such as BIM - building information modelling methodologies. Its revision process was lengthy and led to big discussions as other standards, guidelines and classification systems were being developed at the same time. The ISO 12006-2 standard does not provide a complete operational classification system, nor does it provide the content for the tables. Nevertheless, the simple definition of the tables itself and the establishment of some guiding examples was found essential for these ongoing developments. This fact is pretty much relevant as many countries are foreseeing the needs in terms of harmonization between these systems. One aspect that is mentioned on the standard introduction part is that the mapping between national and international classifications should be fairly straightforward, as they are likely to differ in their detail due to differences in terms of construction culture and legislation [8]. This fact is evidenced on the next points. During the revision process a survey was conducted in order to understand the number of CICS developed across the world, as well as their main topics.

The 2015 ISO 12006-2 version takes in consideration developments in information technology and construction procurement. It has been extended and definitions were refined in order to better serve all construction sectors, namely buildings, civil engineering and even process engineering. It is very focused on the information exchange needs across the construction process. Therefore, it aims a complete and consistent approach to construction object classification to facilitate the information exchanges within project stages and between projects [8] On point 3.3 the major changes will be described in detail.

3 DEVELOPMENT

This topic integrates a brief literature review in order to frame the different systems that will be referenced. Notwithstanding, it is mainly geared to the presentation of studies that were developed with objectives similar to the survey that was conducted during the standard revision process. Therefore, identification and overview on classification systems and their scope is presented, followed by the detailed description and applicability of a group, mainly non-construction exclusive. A reflection on national classification systems is also performed. The last part presents the major changes of the standard new version.

3.1 ISO 12006-2 and existent classification systems

The construction industry, as mentioned, involves many stakeholders and different processes, resulting a large, fragmented and complex productive chain. Given these characteristics, the industry cut crosses with other economic activities and all the agents (work owners, designers, contractors, surveyors, manufacturers, others) need to answer to other requirements that are not directly construction related. This has impacts in terms of the classification systems, as the agents need not only to use the CICS on their processes, but also other classification systems that are not construction exclusive. On the author master thesis a review was made in order to identify all the systems that could be used by the stakeholders on the construction related processes. The study was made before the publication of the new version of the ISO standard and therefore, the table designations are the ones set on the 2001 version. The following image identifies the systems, specifies their main topics and application within the industry.

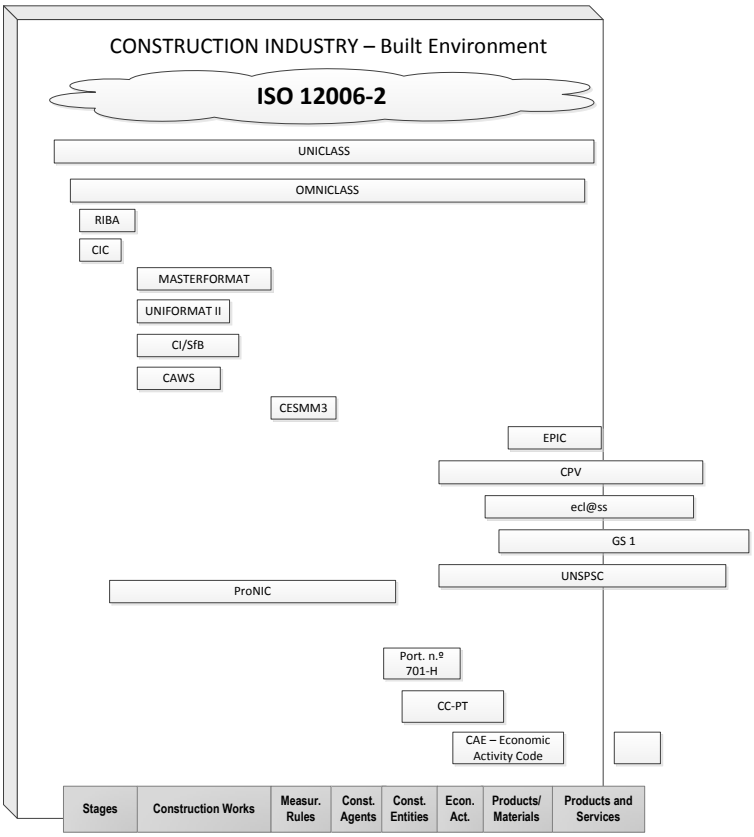

Fig.1 – Schematic overview of the classification systems related with construction [2].

Some of these systems, namely the Uniclass, Omniclass, Uniformat or CI/SfB have been already mentioned. On this part will concentrate on international systems that are non-construction exclusive, as well as international systems that have mandatory application on Europe and therefore in Portugal. In order to have an improved understanding of other systems that come on the image but that won't be mentioned, the following references are recommended; RIBA Plan of Work [9], Masterformat [10], CAWS and CESMM3 [11], EPIC [2] and ecl@ss [12].

One of the specific topics that influenced the revision of the ISO 12006-2 standard, as mentioned, is the procurement process. The most recent EU Directives set the adoption of electronic procurement for all public contracts. There is a classification system that has mandatory use for this process. It is construction non-exclusive but it needs to be set on public contracts for construction services and construction works. This system is the CPV – Common Procurement Vocabulary. Their main objectives within the procurement context are the following:

"The use of standard codes makes it easier to implement the advertising rules and facilitates access to information, thereby:

- boosting transparency in public procurement;
- making it easier to identify business opportunities published in the supplement to the Official Journal of the European Union;
- making it possible to set up an information system for public procurement and reduce the risk of error in translating notices, since the CPV is translated into 22 official languages of the European Community;
- simplifying the task of drafting notices, and in particular describing the subject matter of contracts, for contracting authorities and contracting entities;" [13]

More information about this system can be found on [2]. Regarding this system and aligned with the scope of this work it becomes clear that, although not being construction exclusive, all the public contracts and namely those involving construction products and construction works need to be classified in accordance with CPV.

One system that is quite similar to the previously mentioned in terms of scope is the UNSPSC - United Nations Standard Products and Services Code. This is not mandatory but its application is global. At present time it is managed by GS1 and its being updated on a semester base. Many ERP – Enterprise Resource Planning software manufacturers are adopting this classification system as default on their tools. For this reason its implementation is growing significantly [2]. This group of systems in which ecl@ss and EPIC can be also included are not directly compatible with each other. With the major concern of fostering a future mapping process between them ISO developed a large study to look deep into each one of these classifications [12].

Other classification system that is very important from the European point of view is the EUROSTAT CC – Classification of Types of Constructions. It has its roots on the provisional version of the United Nations Central Product Classification that was published in 1991. CC is designed to serve different purposes such as statistics on construction activities, construction reports, building and housing censuses and price statistics on construction work and national accounts. In addition, CC is to be used on the definition of constructions which will be needed for the provision of information for specific variables (e.g. building permits, production), concerning short term indicators. Also, CC is designed to be used for the whole construction life cycle, namely changes in use, transactions, renovations, demolition. One aspect that is important to highlight is a statement that comes on the CC presentation document: "CC could be used as classification standard for the procurement and tenders on public works contracts initiated by the Commission." [14]

This role is being played by the CPV across all the economic fields of activity. The CC-PT that comes on Figure 1 is the CC adaptation for Portugal. It follows the main classification adding one more level of detail [15].

3.2 Construction classification systems with application in Portugal

Beyond the already mentioned classification systems there is many information not organized on the construction legal framework. Themes as construction agents, roles, disciplines, processes, among others are defined on several diplomas. The Portaria n.º 701-H/2008 is one of the most important documents. Some diplomas of this framework are being reviewed, namely the Public Procurement Code. It is foreseen that on middle 2016 a new version will be published. Besides the legal framework there are some guidelines that can be used, but that do not constitute itself classification systems. The

traditional practice of construction processes in Portugal foresees the development of a detailed technical design, usually performed by a design team that is a service provider to the work owner and then, a contract with the construction company to build the construction entity. The most important document that links to all the other documents and that fully specifies the work to be performed is the bill of quantities. It is specified by the design team and should follow guidelines in terms of organization, prescription and measurement rules. Notwithstanding, the work descriptions can vary considerably on the verge of not being possible to establish comparisons between identical construction works. In order to help solving this problem for the public works, the ProNIC – Protocol for Construction Information Standardization project was developed. As mentioned, its major objective was the establishment of a single and standardized language for construction works that could be used for the production of standardized bill of quantities. ProNIC was commonly classified as a CICS. Yet, it essence is broader in which regards the level of detail of the information, and narrower in what concerns the facets that includes, as it is mainly a single work results table, fitted for some types of constructions, namely building construction and refurbishment operations as well as road construction. Yet, in terms of support it is a database with very different properties and characteristics that allows working that information and present it differently. Therefore, the mentioned characterization does not fit to frame all the possibilities of this tool. One of the aspects that interests the most is the work description, has it details the construction work. This description is parameterized and on the context of a design process it needs to be fulfilled with information that is introduced by a specific user (agent from a design discipline with a specific role on a project). The information to be introduced can be structured in five main groups that can vary according with the specific work. The following figure presents these groups.

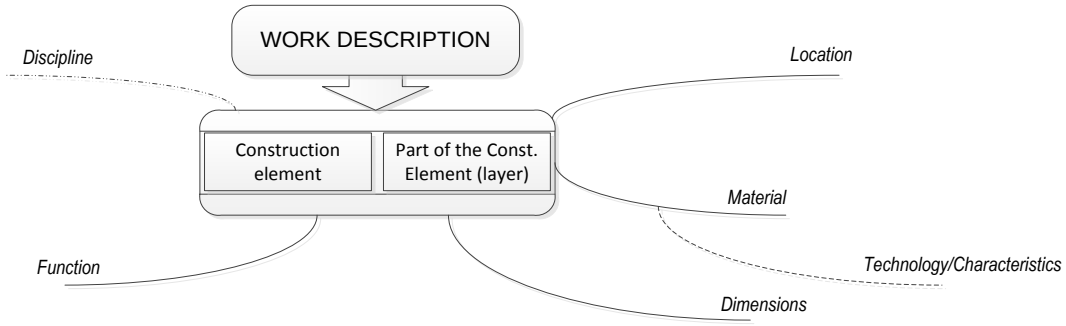

Fig. 2 – ProNIC work descriptions main information group [2].

The development of ProNIC followed the guidelines of ISO 12006-2. As referred, the main concern was the systematization and development of the work results table. Notwithstanding, and in articulation with the legal framework, in can be considered that other tables are also more or less set, yet without the same level of achievement. In accordance with the original version of the standard, and as presented on Figure 1, the other main tables that is possible to find in ProNIC are: Elements, Construction entity lifecycle stages, Project stages and Construction agents. From the information set on the Work results it is possible to gather information for Properties, Construction products, Construction aids and Spaces by fuction or user activity tables. Yet, this requires a specific organization and systematization effort.

3.3 ISO 12006-2:2015 major changes

Since the publication of the 2001 version and as previously mentioned, many CICS where developed across the world following its main principles. Lessons learned from these implementations have been gathered and discussed in order to be integrated on the new version. The scope is therefore mainly the same with few changes that address to a wider application in term of construction life cycle and types of constructions.

An important statement of this standard is that local classification systems should exist in order to suit the specificities of the construction sectors around the world. Notwithstanding, this specificities should be reflected, when possible, on the most detailed levels of the tables. This effort will lead to harmonization and to a streamlined mapping process.

In what regards the CICS format and support, they were commonly arranged in tables and published on paper format. The 2001 version was mainly geared towards this type of support. Developments on

information technology, namely those addressed for new forms of construction procurement and construction management using BIM are now foreseen and framed. The knowledge gathered from the past fifteen years was also important to understand what tables are used the most across the world, taking in consideration the construction cultural, technological and legal differences. From the conducted survey the results point a widely use of two tables:

- Work results (mainly for specifications);
- Construction elements (mainly for cost analysis);

ISO 12006-2:2001			ISO 12006-2:2015		
Title	**Class. Principle**	**Table**	**Title**	**Class. Principle**	**Table**
Classes Related to Contruction Resource					
Construction information	*by type of medium*	A.16	Construction information	*by content*	A.2
Construction agents	*by discipline*	A.15	Construction agent	*by discipline or role or their combination*	A.4
Construction aids	*by function*	A.14	Construction aid	*by function or form or material or their combination*	A.5
Construction products	*by function*	A.13	Construction product	*by function or form or material or their combination*	A.3
Classes Related to construction Process					
Management processes	*by type of process*	A.10	Management	*by management activity*	A.6
Construction entity lifecycle stages	*by overall character of processes during the stage*	A.11	Construction Process	*by construction activity or construction process lifecycle stage or their combination*	A.7
Project stages	*by overall character of processes during the stage*	A.12			
Classes Related to construction Result					
Construction complexes	*by function or user activity*	A.3	Construction complex	*by form or function or user activity or their combination*	A.8
Construction entities	*by form*	A.1	Construction entity	*by form or function or user activity or their combination*	A.9
Construction entities	*by function or user activity*	A.2			
Spaces	*by degree of enclosure*	A.4			
Spaces	*by function or user activity*	A.5	Built space	*by form or function or user activity or their combination*	A.10
Facilities	*by construction complexes, construction entities and spaces by function or user activity*	A.6			
Elements	*by characteristic predominating function of the construction entity*	A.7	Construction element	*by form or function or position or their combination*	A.11
Designed elements	*by Element by type of work*	A.8			
Work results	*by type of work*	A.9	Work result	*by work activity and resources used*	A.12
Classes Related to Property/Characteristic					
Properties and characteristics	*by type*	A.17	Construction Property	*by property type*	A.13

Fig. 3 – Tables titles and classification principles between the two versions. [16, 8].

There are other classifications (or classification tables), potentially just as important, but that are less used. Construction products and construction properties are the major examples of this situation [8]. The terms and definitions part was extended and they were arranged in order to have comprehensive application. This is an ongoing work as a new task force was set to perform a reflection on terms and definitions from a wide set of construction related standards [17]. For an improved understanding of used terms, some definitions are transcribed:

- Object – any part of the perceivable or conceivable world;
- Construction object – object of interest in the context of a construction process;
- Construction process – process which uses construction resources to achieve construction results;
- Construction result – construction object which is formed or changed in state as the result of one or more construction processes using one or more construction resources;
- Construction entity – independent unit of the built environment with a characteristic, form and spatial structure, intended to serve at least one function or user activity;
- Construction complex – aggregate of one or more construction entities intended to serve at least on function or user activity;
- Construction element – constituent of a construction entity with a characteristic function, form or position;
- Construction system – interacting construction objects organized to achieve one or more purposes;
- Work result – view of construction result by type of work activity and resources used;

The new version improves on the explanation of the basic principles of classification and on the guidelines to set the hierarchical levels. It highlights the classes/tables and the general relationship between them. One of the reference standards that was introduced is the ISO 22274:2013 - Systems to manage terminology, knowledge and content - Concept-related aspects for developing and internationalizing classification systems. In accordance with this document classification tables can be enumerative, faceted or a combination of faceted and enumerative with an entry class. This aspect, detailed on ISO 12006-2:2015 Annex B is essential as previously CICS were taught to be faceted.

The major change is expressed in terms of the classification tables. As the previous version, this does not intends to provide a complete and operational system, nor the organization and contents of the tables. Notwithstanding, and in order to set some guidelines, the Annex A provides the recommended table titles and for each one, non-exhaustive examples of information to be defined. Figure 3 presents the evolution in what regards table topics between the two versions.

As presented, the new version sets less tables. Yet, it expands the classification principles resulting the aggregation of two tables in one.

4 DISCUSSION

4.1 Overview

This part will focus on the actions that are being followed by the authors, namely present developments related with classification systems, as well as analysis of the present situation at national level. From what was referred it is important to highlight that:

- Some tables have more application than others;
- It is important to attend local needs, but always foreseeing a common structure and mapping possibilities;
- Adaptation to new processes and innovation must be performed.

4.2 Ongoing international developments – Uniclass 2015

It is important to note that a significant part of Uniclass 2015 development occurred in parallel with ISO revision. Therefore, some differences can be pointed at this moment, even though there is a big concern on producing an ISO compliant CICS. The Uniclass 2015, that it will supersede the original Uniclass, is the unified classification for the UK industry, covering all construction sectors. It is part of the UK BIM strategy [18], playing a key role on the process. The objectives of Uniclass are similar to those presented on the standard. Yet, the BIM strategy and the deadline of 2016 to implement Level 2 BIM in UK lead to an approach geared for the resolution of practical situations within the set of the specific goals. Thus, it is very important to follow up and gather knowledge. The initial classification work has focussed on the 7 core tables that describe an asset required to support the Digital Plan of Work. On a second moment, NBS – National Building Specification will continue consulting stakeholders for the development of the other tables covering Form of Information, Project Management, Construction aids and Properties and Characteristics [19]. Given the discussion, the work results table was removed from comments for the moment. According with NBS, the work results table is found to be a method for linking between tables, particularly between elements and products. Therefore, it will return to discussion after these two are stabilized. Given this, there are some differences between what is set on the ISO 12006-2:2015 and the latest Uniclass 2015 developments. Just few tables are available so the following comparison was made taking in consideration the tables descriptions and the follow up information regarding each one. Figure 4 presents a comparison between the ISO tables and the Uniclass 2015 tables.

From the referred, it is possible to state that substantial differences can be observed. The Uniclass 2015 development is being set by the Level 2 UK BIM deadline and by the experience on using information modelling methodologies. There are some tables that don't have match because they are set on other tools, namely the Construction process and Construction agent tables on the Digital Plan of Work [9]. Notwithstanding, they should be included on the classification system on a future opportunity. In what regards the first group of tables (in blue), it worth's mentioning the division of the Construction elements table on the Ss – Systems and Ee – Elements tables. This situation, although not following the standard, allows these to be grouped, as according with the examples. The Uniclass 2015 systems table can be defined as a class that comes by function and the elements table as another class that comes by combination of position and form. Together, fit on the ISO Construction

element table. The situation that might be more difficult to solve is the one related with the Activities table, that according with its description fits on the Complexes, Entities and Built Space tables. This situation is to be followed as the available information does not allow to go further on the identification of potential problems. In what relates the second group of Uniclass 2015 tables to be developed (in yellow), apart from the CAD table that is not defined on the standard, it is not foreseeable to have matching problems. As it was possible to know there is no Construction Property table on Uniclass 2015 and as mentioned the Work results table is not in discussion for the moment. One aspect that is important to highlight is that on UK electronic procurement is not yet mandatory.

ISO 12006-2:2015		UNICLASS 2015		Current situtation
Title	Table	Title	Table	
Construction information	A.2	Form of information	FI	Initial consultation started - Draft status
Construction product	A.3	Products	Pr	Published July 2015
Construction agent	A.4	*see digital plan of work*		
Construction aid	A.5	Construction aids	CA	Initial consultation started - Draft status
Management	A.6	Project management	PM	Initial consultation started - Draft status
Construction process	A.7	*see digital plan of work*		
Construction complex	A.8	Complexes	Co	Consultation ongoing - Beta status
Construction entity	A.9	Entities	En	Consultation ongoing - Beta status
Built space	A.10	Spaces/ locations	SL	Published July 2015
Construction element	A.11	Elements	Ee	Published July 2015
		Systems	Ss	Published July 2015
Work result	A.12	Work Results		Removed from discussion
Construction Property	A.13	?		unknown
		CAD	Zz	Published July 2015
		Activities	Ac	Consultation ongoing - Beta status

Fig. 4 – Tables titles and classification principles between the two versions. [19].

From this results that UK is being pushed to develop a new classification system that can support the BIM strategy. These developments are being made setting priority to some tables that are found more urgent. Elements and Spaces fit with the trend pointed on the survey. Construction products also. A curious fact occurs with tables such as Work Results and Properties that on the survey are identified as the most used/more important and are not foreseen at this point of development. The need on the development of the Complexes and Entities table is understandable as they constitute the higher levels for the built environment characterization.

4.3 National situation – analysis and trends

Over the last years, the construction related legal framework has suffered big changes. The establishment of specific rules and deliverables for the design stage and the mandatory use of electronic procurement can be identified as major efforts towards the sector progressive modernization. From the lessons learned, it is possible to state that these processes promoted very positive changes. Yet,the absence of continuous improvements on the tools and on the framework, as well as the economic crisis, tend to stop an endeavour that would lead to consistent improvements on the industry. Nowadays, this situation deserves attention has there are signs of recovery. The construction industry must overcome the crisis and reinvent itself in order to be more sustainable and effective. From the classification systems point of view it is essential to gather all the information and follow the trends towards the achievement of an improved information consistency and coherency. Therefore national and international efforts should be conciliated towards this objective.

As mentioned, the ProNIC project developed an extensive Work results table geared for specific types of construction. The ongoing developments point to a review and spread of all the contents in order to achieve an improved structure and to integrate other construction types, as railways, water supply infrastructures, among others. This effort should attend the specificities of each type of construction as well as traditions, and yet set a table that could be consistent. Also, a mapping process with other systems such as Uniclass 2015, Omniclass or BuildingSmart Data Dictionary should be foreseen. This endeavour will conduct to an improved Work results table, but it will also allow to structure contents for others, such as Properties, Built space, Construction aids and Construction products.

Related with the last table mentioned; Construction products and as previously mentioned, there are already some non-construction exclusive systems that are mandatory or are commonly used by different tools, namely the CPV and the UNSPSC. The development of a Construction products table

specific for the industry should be encouraged. Systems as the Uniclass 2015 or Omniclass are performing it. Yet, these developments should foresee a mapping process that may allow a mutual understanding between them. The authors were involved on the development of a Construction products data warehouse. The MaterialOn tool gathers construction products data in Portuguese and English. Each construction product is classified in accordance with two systems, a simple system of groups of products set many years ago by the product manufacturer association (national system that will be reviewed) and UNSPSC. During the development of the MaterialOn tool, the authors set a mapping process between this classification system and the CPV. The tool is prepared to receive other systems such as the already mentioned. On this specific issue the contents of the Construction Products Directive as well as the mandates set by CEN – European Standardization Committee for construction products, should be considered.

In terms of Construction Entities there are also systems already in use. The CPV is used on public works tender notices and the EUROSTAT – CC is used for the production of construction statistics. Both can fit on the mentioned table. During the author master thesis a comprehensive study of these systems has been performed and the result was the definition of a mapping process between them [2]. Future work to detect possible flaws and to identify the ability of the systems to answer to all the types of constructions should be performed. The development of the construction complexes table can benefit from this work. The legal framework, namely Portaria n.º 701-H/2008 has also relevant information related with these topics.

In what relates the construction process, the legal framework and namely the Public Procurement Code, sets some activities. Other specific legal diplomas define also actions that should be performed. The ISO 12006-2:2015 on the introductory part of the Basic principles sets four main steps for the Construction process; pre-design, design, production and maintenance. Uniclass 2015 endorses this table to the Digital Plan of Work. Ongoing study is being made by the authors to set links between the higher levels of the British digital plan of work and the Portuguese construction stages set by the legal framework.

The identification of construction elements or systems, by their form, function or position is very important to several agents. The information technologies tend to use this approach as well as the construction products to produce improved models and drawings. As mentioned, from the Work results hierarchic tree it is possible to set an Elements table. The Elements approach is also found very useful in terms of budgeting. Uniformat, as presented, followed this philosophy. This is one other aspect where construction needs to be improved. Taking in consideration previous studies, the authors set a specific systems and elements table geared for buildings. The scope was to verify the evolution of building construction in terms of budgeting of its parts [20]. The following step is to expand this table to other types of constructions.

In what regards the Construction agents, the legal framework sets a substantial part of the involvements and roles. The latest diploma was published in August 2015, and therefore the work of collecting all the information can now be performed.

5 CONCLUSIONS

It is undeniable the role and importance of the construction classification systems for the information coherency of the sector productive chain and their contribution for the sustainability of the construction processes. As observed, the construction industry across its processes interacts with several other economic activities and there are specific tasks that are common. One of them is the procurement process. Therefore, attention should be given to other classification systems that are not construction exclusive, but play a role on the global process. The development of mapping processes or the integration of their information on the construction systems should be therefore evaluated.

The second version of ISO 12006-2 presents major changes, leading to new requirements, restructuring and development needs. The ongoing development of Uniclass 2015 is a proof of this. The conciliation effort along with the development trends in order to implement the BIM strategy are found essential to be followed, as it is possible to take high benefits of this practical process.

At national level, the initiatives had lead the industry to a point where the information and tools are more or less set. Strategic effort must be made with the Government in order to get a stable legal framework, a set of reference documents and guidelines that can structure all the information needed. New developments in order to streamline the existent tools, implement communication protocols between them and develop new ones that can fit the holes of information technologies across the

productive chain must be encouraged. In what regards the construction classification systems, the two first topics are found essential for the evolution and structuring of a classification system of reference, with several tables, integrating national needs mapped with international systems and, when appropriate, adopting parts or entire tables from other international systems. As presented, most of the tables have already initial strategic trends and base of information for their development.

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ENERGY REDUCTION MEASURES IN OFFICE BUILDINGS CONVERGING TO NZEB: THREE CASE STUDIES

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Abstract

The present paper is mainly focused on the energy performance of three office buildings [1], [2], [3], with different floor areas and ages, located in different geographical provinces of Portugal: Coimbra, Castelo Branco and Setúbal.

On a first stage the study consisted on the characterization of the real energy consumption of each building, and the energy consumption partition between HVAC, lighting and equipment. On a second stage several proposals for energy consumption improvement were simulated for each building using Energy Plus/Sketch up models. The simulation models have considered changes in some construction systems and additionally the installation of solar energy generation systems in the buildings. Therefore the best approaches for the reduction of energy consumption in each building were obtained. The analysis of results and related conclusions were focused not only in effective reduction of energy consumption but also in the relationship between the benefits resulting of the implementation of each proposal and respective costs. For each proposal the return on the investment period is also presented.

Based on real cases the present paper pretends to emphasise the need to implement the reduction of energy consumption in buildings and specifically emphasises that some reductions can be developed without stopping the regular operation of the buildings. Some interventions are attractive regarding the factor cost/benefit.

Keywords: Energy Efficiency, NZEB, Energy Efficient Rehabilitation, Office Buildings, Energy Plus model, Sketch up model.

1 INTRODUCTION

The unsustainable way how the world's population currently uses the disposable energy resources has been the focus of major concern in the last decade. Buildings are globally responsible for significant energy consumption, with more expression during its regular operation. The main reason for this scenario in developed countries can be explained by the period of time that occupants spend inside buildings during their daily work life. Therefore significant actions have been carried out in order to intend to reduce energy consumption during the regular operation of buildings [4], [5].

The NZEB (Nearly Zero Energy Building) concept defined in the directive 2010/31/EU [6] transposed into national law by Dec-Lei 118/2013 of 20 August [7] is one of the most recent EU Initiatives in order to achieve reduction of energy consumption in buildings. NZEB concept applies both to new buildings and to renovated ones [7]. This concept can be considered as a milestone because a significant number of buildings in Europe and particularly in Portugal need some kind of renovation [5]. There are great expectations for reduction of energy consumption as result of the sustainable buildings renovation. On 25 October 2012 the Directive 2012/27/EU on energy efficiency was published, which requires Member States to establish a long-term strategy for mobilizing investment in the renovation of the national commercial and residential buildings, both public and private [8].

With regard to the dynamic simulation of energy consumption, EnergyPlus is one of the most sophisticated and commonly used model for this purpose. However, EnergyPlus is incapable to develop the formation of a building in a clear manner. The Google SketchUp software was used to assist these studies, which together with the Legacy OpenStudio (a SketchUp plug-in, with connection to the EnergyPlus), allows a 3D modelling of the building.

2 METHODOLOGY

On a first stage the presented study consisted on the characterization of the real and global energy consumption during the years 2011, 2012 and 2013 of each of the three buildings. Additionally the partition of energy consumption was considered for HVAC, Equipment and Lighting.

The real situation was simulated for each building using Energy Plus/Sketch up models and the validity of the simulation model was evaluated through its calibration comparing it with the real data of consumption.

On a second stage several proposals for energy consumption improvement that is, envelope improvement, LED lighting and solar Photovoltaic generation among others, were simulated. The simulation models have considered changes in some construction systems and additionally the installation of solar energy generation systems in the buildings.

The evaluation of several measures was considered and the correspondent reduction of energy consumption was evaluated. The analysis of results and related conclusions were focused not only in effective reduction of energy consumption but also in the relationship between the benefits resulting of the implementation of each proposal and respective costs as well as maintenance costs. Finally a simple analysis on return of each investment was carried out.

Based on the results, the energy consumption and the annual savings resulting from the implementation of each measure were compared. The practical viability of each implementation measure in order to improve the energy performance of the building was assessed.

3 RESULTS

3.1 Building in Coimbra

The building under consideration is an office building constructed in the year of 2000. Located in the outskirts of Coimbra, at a distance of 38 km of coastline it is deployed to a height of 44m, in a climatic zone I2V2. The ceiling height is 3.6 m and the floor area is 9465 sqm [1]

Tables 1, 2, 3 and 4 regarding the building in Coimbra (Fig. 1) presents summary of the energy consumption in recent years, the partition of energy consumption, measures considered for energy reduction, respective costs and return on the investment periods (ROI).

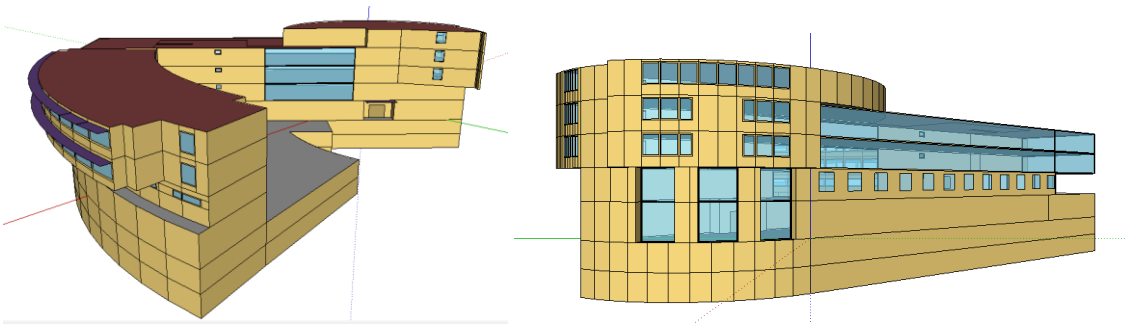


Fig. 1 – Modelling of the building in Coimbra [1].

Table 1 – Energy consumption between 2011 and 2013 [1].

Energy consumption		
Year	(kWh/year)	kWh/sqm.year
2011	850 957	90
2012	798 842	84
2013	741 260	78

Energy partition in 2013

Table 2 – Energy partition in 2013 [1].

Energy partition in 2013	
HVAC	43%
Equipment	33%
Lighting	24%

Table 3 – Energy reduction proposals [1].

Energy reduction proposals	
1	Glazing improvement in Block A
2	Thermal insulation of vertical and horizontal building envelope
3	LED lighting
4	Solar Photovoltaic generation system

Table 4 – Conclusions about simulation results [1]

Conclusions about simulation results					
Proposals		Reduction of energy consumption and generation	Savings or revenues yearly	Costs (€)	ROI (years)
A	Implementation of **measures 1+2**, simultaneously	Reduction of 20% in HVAC energy consumption	10 000.00 € savings	300 000.00	30,0
B	Implementation of **measure 3**	40% reduction of energy consumption in indoor lighting and of 30% in outdoor private space lighting	13 000.00 € savings	30 000.00	2,3
C	Implementation of **measure 4**	Generation of 100 000 kWh annually	revenue: 16 000.00 €	200 000.00	12,5
A+B+C - Implementation of all **measures: 1 + 2 + 3 + 4**		Energy consumption of the building: **47 kWh/sqm.year**	39 000.00 € savings	530 000.00	

3.2 Building in Castelo Branco

The building under consideration, built in 2009, consists only of a ground floor with a floor area of 525 sqm and a weighted ceiling height of 4.8m. It is located in the Castelo Branco industrial area on the outskirts of the city. The building is implanted at an elevation of 349 m at a distance to the coastline of about 120 km and is located in a climate zone I2V3N. The average density of occupancy is 14 sqm per person [2]

Tables 5, 6, 7 and 8 regarding the building in Castelo Branco (Fig. 2) presents summary of the energy consumption in recent years, the partition of energy consumption, measures considered for energy reduction, respective costs and return on the investment periods (ROI).

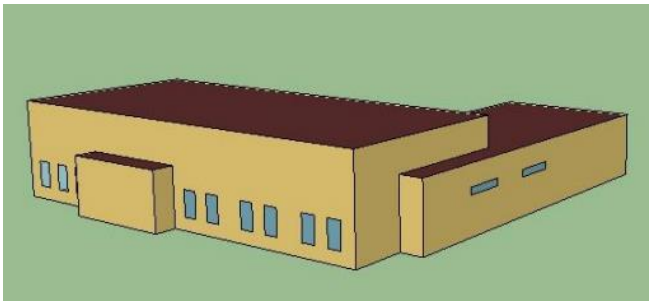


Fig. 2 – Modelling of the building in Castelo Branco [2].

Table 5 – Energy consumption between 2011 and 2013 [2].

Energy consumption		
Year	(kWh/year)	kWh/sqm.year
2011	55 527	106
2012	55 374	105
2013	54 205	103

Table 6 – Energy partition in 2013 [2].

Energy partition in 2013	
HVAC	45%
Equipment	27%
Lighting	28%

Table 7 –Energy reduction proposals [2].

Energy reduction proposals	
1	Replacing desktop computers for laptops
2	Substitution of Glazing
3	LED lighting

Table 8 –Conclusions about simulation results [2].

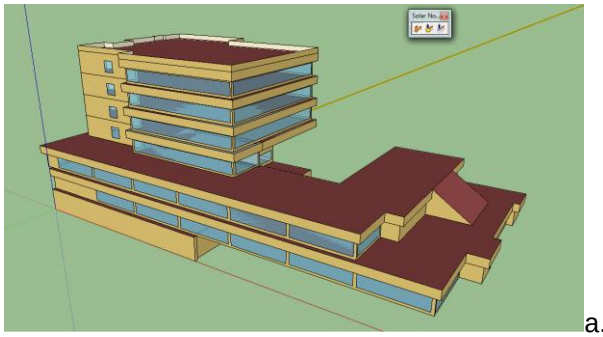
Conclusions about simulation results					
Proposals		Reduction of energy consumption and generation (kWh/year)	Savings yearly	Costs (€)	ROI (years)
A	Implementation of **measure 1**	Reduction of 20% in energy consumption	1 300.00 €	12 800.00	10
B	Implementation of **measure 2**	Reduction of 5,5% in energy consumption	360.00 €	4 000.00	11
C	Implementation of **measure 3**	Reduction of 5% in energy consumption	300.00 €	1 700.00	6
A+B+C - Implementation of all **measures: 1 + 2 + 3**		Energy consumption of the building: **72 kWh/sqm.year**	1 960.00 €	18 500.00	

3.3 Building in Setúbal

The office building was constructed in the 90´s and consists of seven floors above ground and one floor under ground, with 4041 sqm of floor area [3], [8].

The average density of occupancy is 47 sqm / person [3].

Tables 9, 10, 11 and 12 regarding the building in Setúbal (Fig. 3) presents summary of the energy consumption in recent years, the partition of energy consumption, measures considered for energy reduction, respective costs and return on the investment periods (ROI).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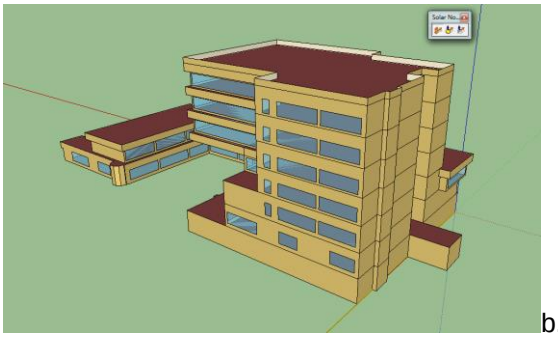
b.

Fig. 3 – Modelling of the building in Setúbal [3].

Table 9 – Energy consumption between 2011 and 2013 [3].

Energy consumption		
Year	(kWh/year)	kWh/sqm.year
2011	452 000	112
2012	439 000	108
2013	442 500	109

Table 10 – Energy partition in 2013 [3].

Energy partition in 2013	
HVAC	57%
Equipment	21%
Lighting	22%

Table 11 – Energy reduction proposals [3].

Energy reduction proposals	
1	Solar Photovoltaic generation system
2	LED lighting
3	Substitution of Glazing
4	Thermal insulation of vertical and horizontal building envelope

Table 12 – Conclusions about simulation results [3].

Conclusions about simulation results					
Proposals		Reduction of energy consumption and generation	Savings and revenues yearly	Costs (€)	ROI (years)
A	Implementation of **measure 1**	Generation of 33 000 kWh annually	revenue: 4 500.00 €	47 100.00	10
B	Implementation of **measure 2**	Reduction of 7% in energy consumption	4 200.00 € savings	4 000.00	1
C	Implementation of **measure 3**	Reduction of 20% in energy consumption	12 200.00 € savings	102 000.00	8
D	Implementation of **measure 4**	Reduction of 13% in energy consumption	7 900.00 € savings	97 000.00	12
A+B+C - Implementation of all **measures: 1 + 2 + 3 + 4**		Energy consumption of the building: **57 kWh/sqm.year**	28 800.00 € savings	250 000.00	

4 CONCLUSIONS

The energy dependence of Portugal to external energy sources makes it necessary to look to the future with a different perspective of energy consumption. Therefore, energy efficiency plays a key role in this matter.

These three simulation studies make it possible to obtain the following practical conclusions:

- The implementation of LED lighting is the most efficient measure considering the relationship cost-benefit.
- The implementation of a solar photovoltaic generation system is also to be considered since the return on the investment period is approximately 12,5 years, less than the life time period of a solar photovoltaic system (15 to 20 years).
- Measures to reduce energy consumption must be accurately studied using an adequate simulation model.
- Changes of the opaque envelope and also the glazing are measures with a return on the investment period generally very high for this type of architecture.
- Significant energy reductions may imply relatively significant costs.
- An accurate analysis on cost-benefit relationship must be performed.

- Some of reduction measures, according to [7], are not economically viable because they have a return on the investment period of more than eight years. But if those measures allow a significant reduction in the annual building energy consumption they should be accurately evaluated.

Based on real cases the present study pretended to emphasise the need to implement the reduction of energy consumption in buildings and specifically emphasises that some reductions can be developed without stopping the regular operation of the buildings. Some interventions are attractive regarding the factor cost/benefit.

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