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NEW TRENDS IN GREEN CONSTRUCTION

CORDOBA 2020

Editors

Antonio Roderó Serrano

José Ramón Jiménez Romero

José María Fernández Rodríguez

Enrique Fernández Ledesma

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Editors

Antonio Rodero Serrano
José Ramón Jiménez Romero
José María Fernández Rodríguez
Enrique Fernández Ledesma

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CONTENTS

AUTHORS.....	9
PREFACE	17
CIRCULAR ECONOMY	19
HIGH PERFORMANCE SELF-COMPACTING CONCRETE WITH RECYCLED AGGREGATES FROM THE PRECAST INDUSTRY	21
DURABILITY OF CEMENT MORTARS WITH ARCHITECTURAL RESIDUES INSULATED FROM MINERAL WOOL.....	23
RECYCLING OF ‘ALPERUJO’ (OLIVE POMACE) AS A KEY ADDITIVE IN THE MANUFACTURE OF LIGHTWEIGHT AGGREGATES	25
INFLUENCE OF DIFFERENT CHEMICAL ADMIXTURES ON CEMENT BASE MORTAR PROPERTIES.....	27
ANALYSIS OF MECHANICAL PROPERTIES AND DURABILITY OF SELF-COMPACTING CONCRETE WITH MINERAL ADDITIONS.....	29
BIKE LANE MADE WITH SCREENING WASTES AND MIXED RECYCLED AGGREGATES FROM CDW	31
PAVED ROAD SECTION BUILT WITH CONSTRUCTION AND DEMOLITION WASTE MIXED WITH EXCAVATION SOIL.....	33
ESTIMATION OF THE PHYSICAL-MECHANICAL PROPERTIES OF RECYCLED AGGREGATES FROM THEIR COMPONENTS	35
EFFECT OF COMPOSITION OF MIXED RECYCLED AGGREGATES ON PHYSICAL- MECHANICAL PROPERTIES	37
FEASIBLE USE OF ELECTRIC ARC FURNACE DUST AS A SECONDARY RAW MATERIAL IN SELF-COMPACTING MORTAR PRODUCTION.....	39
CHARACTERIZATION OF MORTARS CONTAINING RUBBER FROM TYRES OUT OF USE	41
SUSTAINABLE GEOPOLYMERS FROM METAKAOLIN AND OLIVE-PINE BOTTOM ASH.....	43
MULTISCALE LABORATORY INVESTIGATION INTO GEOPOLYMERIZED CONSTRUCTION AND DEMOLITION WASTE AGGREGATES IN STRUCTURAL ROAD PAVEMENT LAYERS	45
STUDY OF VITRIFICATION OF HIGHLY POLLUTED MINE BY-PRODUCTS INSIDE CERAMICS MATERIALS	47
APPLICATION OF THE CIRCULAR ECONOMY IN THE RECOVERY OF WASTEWATER TREATMENT SLUDGE FROM WWTP AND PAPER MILLS TO OBTAIN SUSTAINABLE BRICKS	49
KEY CONCEPTS AROUND THE CIRCULAR ECONOMY AND THE AREAS OF URBANISM, ARCHITECTURE AND CONSTRUCTION.....	51
A STATE-OF-THE-ART REVIEW ON CONCRETE WITH PLASTIC AND RECYCLED PLASTIC MACRO FIBERS.....	53
FROM 150 mm CUBIC TO Φ 150 mm X 300 mm CYLINDRICAL COMPRESSIVE STRENGTH OF COARSE RECYCLED AGGREGATE CONCRETE SPECIMENS.....	55
INCORPORATION OF GFRP WASTE IN MORTARS	57
RENDERING CEMENTITIOUS MORTARS WITH NATURAL FIBERS WASTE	59
TOXICITY OF RECYCLED CONCRETE AGGREGATES: LEACHING TESTS	61
USAGE OF RECYCLED WATER IN A VENEZUELAN PREMIXED CONCRETE PLANT. TOWARDS THE CIRCULAR ECONOMY.....	63
PROPERTIES OF ULTRA-HIGH PERFORMANCE CONCRETE MADE WITH GRANITE CUTTING WASTE	65



APPLICATION OF MIXED RECYCLED AGGREGATES IN CONCRETE FOR BIKE LINE DITCHES 67

STUDY OF THE APPLICABILITY OF FLY ASHES FROM OLIVE POMACE COMBUSTION AND GEOSILEX® IN SUSTAINABLE CONSTRUCTION MATERIALS 69

DOSAGE ADJUSTMENT DUE TO THE USE OF RECYCLED AGGREGATE IN THE MANUFACTURE OF CONCRETE..... 71

PERFORMANCE OF SELF-COMPACTING MORTARS MADE WITH GRANITE SLUDGE WASTE AS SUPPLEMENTARY SILICEOUS MATERIAL 73

DIFFERENCE BETWEEN TREATED ABACA FIBERS IN CEMENTITIOUS MORTAR..... 75

THERMAL BEHAVIOUR OF PLASTER COMPOUNDS WITH PLASTIC CABLES WASTE ADDITIVE..... 77

STAINLESS STEEL SLAG WASTE. FROM WASTE TO RAW MATERIAL FOR THE MANUFACTURE OF SELF-COMPACTING CONCRETE..... 79

POSSIBLE USE OF FINE RECYCLED CONCRETE AGGREGATES IN THE IMMOBILIZATION OF ELECTRIC ARC FURNACE DUST (EAFD)..... 81

ENERGY EFFICIENT BUILDING 83

SIGNIFICANCE OF VARIABLES ON REAL MEASURED ENERGY CONSUMPTION OF RESIDENTIAL STOCKS 85

CLIMATE CONTROL DEMAND ANALYSIS IN A DWELLING WITH PASSIVES STRATEGIES: ENERGY SIMULATION 87

ENERGY SAVING POTENTIAL OF GREEN ROOFS IN SOUTH EUROPEAN CLIMATES 89

EFFECT OF INTERNAL SKIN-PANELS METAL FRAMEWORK IN THE VENTILATED FAÇADES INSULATION..... 91

SELECTION OF CRITERIA FOR THE GREEN ROOF DECISION SUPPORT SYSTEM 93

QUANTIFICATION OF NATURAL LIGHT USE IN FACADES..... 95

DEVELOPMENT OF INSULATING MATERIALS FOR THE CONSTRUCTION BASED ON EXPANDED AGGREGATES IN A GEOPOLYMERIC MATRIX..... 97

STUDY OF TWO VARIABLES ASSOCIATED WITH THE RADIATIVE EXCHANGE OF WINDOWS AND THE DEGREE OF VISUAL COMFORT..... 99

ASSESSMENT OF EARLY DEGRADATION OF GLAZING SYSTEMS WITH DAMAGED SOLAR CONTROL FILMS 101

NUMERICAL SIMULATION OF THE PERFORMANCE OF GLAZING SYSTEMS WITH SOLAR CONTROL WINDOW FILMS..... 103

THERMODYNAMIC BEHAVIOR OF TRANSITIONAL SPACES IN ARCHITECTURE. REVIEWING THE MAIN THERMAL TEMPERING PARAMETERS..... 105

IMPACT OF HEIGHT/WIDTH PROPORTIONS ON THE THERMAL COMFORT OF COURTYARD TYPOLOGY FOR SPANISH CLIMATE ZONES..... 107

THERMAL PERFORMANCE EVALUATION IN HIGH SCHOOL BUILDINGS: METHODOLOGY CALIBRATION AND CASE STUDY ANALYSIS..... 109

BIBLIOGRAPHIC ANALYSIS OF CLIMATIC CLASSIFICATIONS AND THEIR APPLICABILITY IN BUILDING..... 111

ENERGY SOURCE AND RENEWABLE ENERGY113

PUMP-AS-TURBINES FOR ENERGY RECOVERY: AN ATTRACTIVE SOLUTION FOR AUTO CONSUMPTION IN AGRICULTURAL FARMS 115

TESTING OVERHEATING IN AN UNGLAZED TRANSPIRED COLLECTOR IN THE SUMMER SEASON 117

COVERAGE OF ELECTRICITY DEMAND THROUGH PHOTOVOLTAIC PRODUCTION IN THREE TYPES OF



BUILDINGS IN THE CITY OF CORDOBA (SPAIN)	119
CALIBRATION AND PERFORMANCE OF TWO PYRANOMETERS PLACED ON TWO-AXIS SOLAR TRACKERS OF A PHOTOVOLTAIC PLANT	121
SUPPORTING THE SMALL HYDROPOWER SYSTEMS MANAGEMENT THROUGH SEASONAL FORECAST OF RIVER STREAMFLOW	123
PHOTOVOLTAIC TECHNOLOGIES APPLIED TO WATER HEATING SYSTEMS	125
MONITORING PHOTOVOLTAIC FACILITIES IN BUILDINGS BASED ON INTERNET OF THINGS AND COMMUNICATION USING LORAWAN TECHNOLOGY	127
REDUCTION STRATEGY OF THE ENVIRONMENTAL IMPACT IN TERTIARY SECTOR BUILDINGS THROUGH LIFE CYCLE ASSESSMENT	129
ADVANCED CONSTRUCTION MATERIALS AND TECHNOLOGIES	131
NEW NANOMATERIALS FOR SOIL STABILIZATION IN CIVIL ENGINEERING.....	133
USING GRAPHENE OXIDE AS MEANS OF IMPROVEMENT OF CONCRETE: A BRIEF REVIEW.....	135
ECO-CEMENT CLINKER DESIGN VALORIZING WASTES FROM DIFFERENT INDUSTRIES	137
INORGANIC GEOPOLYMERS SYNTHESIZED USING BLACK CLAY AS PRECURSORS BASED ON KAOLINITE SYSTEM	139
ALKALI-ACTIVATED MATERIALS FORMULATED FROM OLIVE GROVE BIOMASS FLY ASH	141
THE CHEMICAL TREATMENT OF NATURAL STONE INFLUENCES ON INFRARED SPECTRA	143
COLLOIDAL NANOSILICA AS ADVANCED EXTERNAL REPAIR METHOD FOR CONCRETE STRUCTURES	145
IMPROVING THE BIOCIDAL PROPERTIES OF THE RESTORATION MORTARS BY CARBENDAZIM ADSORBED ON INORGANIC SUBSTRATES.....	147
INFLUENCE OF HIGH TEMPERATURES ON PHYSICO-MECHANICAL AND DECORATIVE PROPERTIES OF LABRADORITE	149
SENSORS FOR THE NON-DESTRUCTIVE CHARACTERIZATION OF CONCRETE DURABILITY.....	151
PRODUCTION OF NANOSILICA, NANOALUMINA AND NANOTITANIA DISPERSIONS FOR EXTERNAL APPLICATION ON HARDENED MORTARS.....	153
RAW EARTH APPLIED TO MODERN MASONRY CONSTRUCTION SYSTEMS: PROPOSAL OF AN INNOVATIVE EXTERIOR ENCLOSURE	155
NATURAL FIBERS FOR SUSTAINABLE CEMENT REINFORCEMENT	157
CO ₂ CAPTURE WITH HYDROTALCITES OF MGAL-CO ₃ AND ORGANOHYDROTALCITES FOR APPLICATION AS SINK URBAN GREENHOUSE GAS.....	159
DETERMINATION OF THE REPEATABILITY AND REPRODUCIBILITY OF THE SOLUTIONS PROVIDED BY AN ACTIVE GEODETIC NETWORK: APPLICATIONS TO CONSTRUCTION	161
CLEAN ENVIRONMENT	163
APPLICATION OF COMPLEX NETWORKS TO THE DESCRIPTION OF OZONE DYNAMICS.....	165
VERY LOW ENERGY CONSUMPTION HVAC SYSTEMS FOR NZEB BUILDINGS. THE POTENTIAL OF INDIRECT EVAPORATIVE COOLERS IN SOUTH EUROPEAN CLIMATES	167
INDOOR AIR QUALITY IN BUILDINGS: MONITORING WITH LOW-COST DEVICES FOR RISK PREVENTION	169
APPROACH TO THE ANALYSIS OF THERMAL COMFORT IN EXISTING PUBLIC EDUCATIONAL BUILDINGS FOR THE IMPROVEMENT OF ENERGY EFFICIENCY: SMARTPOLITECH.....	171
FROM THE QUALITY OF INTERIORS ENVIRONMENTS TO SUSTAINABLE DEVELOPMENTS	173



AN ARGON NON-THERMAL MICROWAVE PLASMA FOR TREATMENT OF BETX CONTAMINATED WATER
VIA OH RADICAL OXIDATION 175

SOCIAL INMOTIC TO IMPROVE ENERGY EFFICIENCY IN PUBLIC BUILDINGS: EFIPUBLIC PROJECT 177

HUMIDITY, TEMPERATURE AND NOISE IN CONFERENCE ROOMS 179

PRELIMINARY STUDY ON INDOOR AIR QUALITY IN THE ANTENATAL CLASSES..... 181



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PREFACE

This book collects the extended contributions of International Conference on Green Construction 2019 (ICGC 2019) celebrated in Cordoba (Spain) on April 8-9, 2019. ICGC 2019 was an international forum for the exchange of ideas and information on green construction. This conference offered an important opportunity for researchers, students and professional workers to discuss a wide variety of topics related to the use of environmentally friendly technology in the field of building and construction, what leaves a lighter footprint on the environment through a good management, a rational utilization and conservation of energy and material resources.

Construction sector is responsible for a significant share of global consumption of energy, electricity, water and materials. According to Intergovernmental Panel on Climate Change (IPCC) of the United Nations, the CO₂ production of this industry is almost 20% of global emissions. Development of new more efficient construction methods and technologies with a reduced level of environmental impact is necessary. ICGC 2019 pretends to be a forum to study possibilities of these new technologies and the state of research about this field.

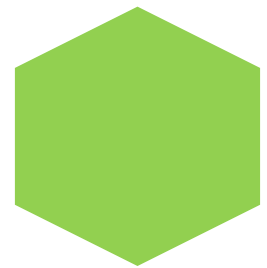
Book has been divided in five parts according topics of the Conference:

- Circular Economy
- Energy Source and Renewable Energy
- Energy Efficient Buildings
- Advanced Construction Materials and Technologies
- Clean Environment

The Conference ICGC 2019 and this book have been supported by European Commission within the Erasmus+ Project 2016-1-PL01-KA203-026152 “Virtual and Intensive Course Developing Practical Skills of Future Engineers (VIPSKILLS)” and the University of Cordoba.

THE EDITORS





CIRCULAR ECONOMY





HIGH PERFORMANCE SELF-COMPACTING CONCRETE WITH RECYCLED AGGREGATES FROM THE PRECAST INDUSTRY

Tiago Barroqueiro, Pedro Raposeiro da Silva, Jorge de Brito

Keywords: *high performance self-compacting concrete, recycled aggregates, precast industry*

1. Introduction

In this short paper we present the results of an experimental campaign whose final objective was to produce high performance self-compacting concrete (HPSCC) using recycled aggregates (RA) from the precast industry (PI). This work intended to evaluate the potential of self-compacting concrete with RA to achieve similar performance as high-performance concrete. We present the results of the tests, which were carried out on six concrete mixes, wherein the first one corresponds to a mix using natural aggregate (NA) only (100% NA) and the remaining five mixes in which the percentage of fine recycled aggregate (FRA) and coarse recycled aggregate (CRA) in the concrete composition varies, namely: 1st FRA/CRA%: 25/25% (25% RA); 2nd FRA/CRA %: 50/50% (50% RA); 3rd FRA/CRA %: 100/100% (100% RA); 4th FRA/CRA %: 0/100% (100% CRA); 5th FRA/CRA %: 100/0% (100% FRA).

The cement replacement percentage with mineral additions was kept constant in all the mixes and included 5% of limestone filler (LF) and 30% of fly ash (FA) (instead of cement). The amount of silica fume (SF) and cement (C) was also kept constant in all mixes: 10% SF (relative to the cement weight) and 450 kg/m³ of C. The a/c ratio of all the mixes was 0.44. A value of the ratio, in absolute volume, between the total amount of fine material (cement and additions) and fine aggregates in the mixes (V_p/V_s) was set. According to the results obtained by Silva et al. (2011), a value $V_p/V_s=0.80$ was considered.

2. Material and methods

The fine natural aggregate used in all the mixes was silica sand, in two sizes: fine sand (0- 2 mm) and coarse sand (0-4 mm). Two types of limestone CNA were used: medium gravel ($D_{max} = 11.2$ mm) and coarse gravel ($D_{max} = 22.4$ mm). The RA came from crushed precast concrete elements of 65 MPa class strength. Type I cement of class 52.5R, limestone filler and fly ash (used as a partial replacement for the cement) were used in ternary mixes. A high-performance superplasticizer was used as admixture.

3. Results and conclusions

Table 1 shows a summary of the results obtained, where a negative sign corresponds to a decrease and a positive sign to an increase in the value of the property under analysis. The comparisons are made in relation to the 100% NA mix. The results in Table 1 show that the 25% RA mix performs best, with losses of less than 10%. The mixes with 50% RA and 100% CRA present similar performances even though the first one tends to have worse results than the second one. The 100% RA mix shows the highest losses. The registered differences may be justified by the nature of the CRA and the water absorbed by them.



Table 1 - Hardened-state properties results overview at 28 days

Hardened-state properties	Mix and respective increase/decrease compared to the reference HPSCC (100%NA)				
	25% RA	50% RA	100% RA	100% CRA	100% FRA
Compressive strength in cubes	-1%	-3%	-8%	-2%	-5%
Splitting tensile strength	-10%	-23%	-32%	-19%	-28%
Modulus of elasticity	-5%	-12%	-26%	-11%	-21%
Ultrasonic pulse velocity	-1%	-4%	-8%	-2%	-6%
Abrasion resistance	+6%	+13%	+39%	+10%	+36%
Shrinkage	+3%	+13%	+23%	+13%	+20%
Creep	+20%	+34%	+97%	+30%	+84%

The need of correction of the mixing water volume due to the high absorption by the RA means that, in particular CRA can retain (during the initial stage of mixing) large quantities of water. This water, which is neither used for workability nor for any hydration process in the initial stage, is available to contribute to the later reaction of FA with calcium oxide or calcium hydroxide (products from the cement hydration). The substitution of NA with RA causes a decrease of the hardened-state properties (namely compressive strength and splitting tensile strength). This is explained by the poor quality of RA, which has its origin in the adhered mortar and is responsible for increasing the porosity and cracking of the aggregates, making connections in the transition zone between the RA and the new binder weaker. After 28 days, decreases of 1% to 8% in the compression strength were recorded and from 10% to 32% in the splitting tensile strength.

According to the NP EN 206-1 (2007) standard classification, the 100% RA mix belongs to the C50/60 class resistance and the remaining mixes to the above class: C65/67. Thus, according to the mentioned standard, all concrete produced can be classified as high performance. A decrease in the modulus of elasticity is observed with RA increase, which is explained by the lower stiffness of RA (compared to NA), given the presence of old mortar adhered in RA and also to the lower deformability of the binder. At 28 days, there is a reduction of 5% to 26% in the modulus of elasticity. The lower stiffness of RA, compared to NA, decreases the overall stiffness of the concrete and, therefore, increases the shrinkage and creep behavior. There is also an increase in shrinkage and creep at 91 days larger than the one registered at 7 days due to the internal healing phenomenon triggered by RA. After 28 days, reductions of less than 23% of shrinkage occurs.

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DURABILITY OF CEMENT MORTARS WITH ARCHITECTURAL RESIDUES INSULATED FROM MINERAL WOOL

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Barriguete**

Keywords: *Cement mortars, mineral fibres, recycling, durability, construction and demolition waste*

1. Introduction

Mineral wool is currently the most used insulation in the European Union, and the quantities of this waste have increased alarmingly in the last decade (Papadopoulos 2005), making it essential to recycle or reuse the material, which is not current practice.

This study is part of a research that analyses the viability of the mineral wool from the construction and demolition waste (CDW) as reinforcement of cement matrixes. The objective is to analyze the durability of a material composed of a cement mortar matrix to which the aforementioned waste is incorporated.

2. Materials and methods

The materials used in this study are Portland cement Cem II/B-L 32,5 N (supplied by the company Cementos Portland Valderrivas, Madrid, Spain), river sand of 4 mm sieve diameter, and three types of mineral wool waste: fibreglass, rockwool, and mixed mineral wool waste.

The three types of mineral fiber waste underwent a pretreatment in this study: they were crushed in a machine of 550W power at 50 Hz, for three intervals of 3 min each, putting them into a suitable form for incorporation into the mortars. A series of test samples were made with the three types of fiber waste, adding them to replace a 50% of the river sand measured by volume. According to the bibliography reviewed and previous tests the dosage for all samples was 1:3:0.6 (cement:sand:water).

As mortars that incorporate 50% of fibers are more porous (Piña et al. 2018), they may also present problems of durability. Therefore, if these compounds can guarantee their durability, they can also be used for those with a lower percentage of residue.

For this purpose, an experimental plan is made in which cement mortar specimens are made with 50% of different types of mineral wool waste, on which freezing, crystallization of salts, determination of water vapor permeability of hardened mortar, and resistance to adhesion tests are carried out, to evaluate their viability as a reinforcement material (López-Buendía et al. 2013).

3. Results and conclusions

Regarding the frost resistance test of mortars, the results of losses of flexural and compressive strength are not significant when comparing mortars with additives to reference mortars. A visual inspection was also carried out after the cycles of ice and thaw, with no significant deterioration in the surface of the specimens. For all these reasons, the mortars made in the present investigation can be considered as non-frozen.



As for the salt crystallisation test, a great deterioration of the mechanical behavior of the specimens with mineral wool residues can be observed with respect to the reference specimens. Up to 20% more loss of strength is produced in the case of the rock wool test specimens, which are the ones that show the worst behavior in this test, even leading to collapse after cracking.

It has been observed that the values of water permeability are lower for mortars that incorporate mineral fiber residues with respect to the reference batch without fibers.

The mortars made with residues of fibers slightly decrease their resistance to adhesion, in relation to the reference mortar. The mortars with residues of fiberglass are those that lower resistance value present, this may be due to the fact that the adhesion, among other factors, is a consequence of the formation of crystals produced in the hydration of the binder, so the dosages with greater amount of fiber in mass develop lower resistance to adhesion.

In any case, all the mortars analyzed are above the minimum value set by the UNE EN-998-1 standard of 0.30 N / mm², which makes them suitable for use.

The results show that the incorporation of mineral residues to a cement mortar matrix is a viable alternative for recycling.

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RECYCLING OF 'ALPERUJO' (OLIVE POMACE) AS A KEY ADDITIVE IN THE MANUFACTURE OF LIGHTWEIGHT AGGREGATES

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Keywords: *alperujo, olive pomace, lightweight aggregates, Circular Economy, waste recycling*

1. Introduction

The circular economy model is based on the intelligent reuse of waste, so that it becomes a raw material to feed natural cycles or simply to be transformed into new technological products with a minimum energy expenditure (Lett, 2014). The growing concern on sustainability and environmental issues has led many researchers around the world to focus their efforts on the investigation of wastes as possible raw materials for the production of lightweight aggregate (Dondi et al., 2016). Lightweight aggregate (LWA) is a very low density granular material with enormous applications in construction, agriculture or civil and environmental engineering. The objective of this study was to recycle a waste that is widely used in the Mediterranean agricultural sector, such as the so-called *alperujo* (olive pomace). The aim is to find out whether this material could favor the bloating and decrease in density typical of LWAs, thus transforming a waste into a highly technological material when mixed with different types of clay.

2. Materials and methods

Both the three clays used in this study - black (BC), yellow (YC) and white (WC) - and the olive pomace (OP) came from the province of Jaén (Spain). The samples were oven-dried at 105°C and ground below 200 µm in the case of the clays and below 500 µm in the case of OP. A complete characterization of the raw materials has been carried out, including their main physical, chemical, mineralogical and thermal behavior properties. After that, mixtures containing 2.5% OP and 97.5% of each of the clays have been prepared. The material was blended with its optimum water content, and after a maceration period of 24 hours it was extruded and pelletized. The resulting granules were dried and then fired in a tubular rotary kiln for 4 min at the maximum temperature that the material was able to withstand without melting. The firing process has also been carried out on the clays without OP, in order to know how the addition of this residue affects the properties of the sintered material. A complete characterization of the aggregates has been conducted, including density, porosity, water absorption and mechanical strength tests.

3. Results and conclusions

Although for WC the addition of OP has not affected the working temperature (1180°C), OP has favored a decrease in the firing temperature of the YC and BC clays, which have changed from firing at 1205°C without OP to 1180°C and 1190°C with the residue, respectively. This would be interesting from an economic and environmental perspective, as it would mean an improvement in energy saving.

On the other hand, it has been observed that the addition of OP has affected differently depending on the clay used. In the case of BC, this is a clay that is capable of producing LWAs without the



need for any additive (particle density = 1.53 g/cm^3), so the addition of OP has led to a slight increase in density in this material (1.67 g/cm^3). However, both WC and YC are non-expansive clays, whose aggregates present a relatively high density, very close to the limit established by the standard EN-13055-1:2002 (2.0 g/cm^3). Unlike what was observed in BC, the addition of the olive pomace residue in YC and WC has allowed us to obtain LWAs of excellent quality. It is remarkable the variety manufactured with 97.5% YC + 2.5% OP, which has expanded more than 20%, resulting in a highly porous structure of very low density (1.00 g/cm^3), and an acceptable mechanical strength (2.3 MPa).

These results would demonstrate that the olive pomace could have great potential as an additive in non-self-expanding raw materials to obtain very low density LWAs, whose applications are far superior to those of natural aggregates and traditional ceramics.

4. Acknowledgment

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INFLUENCE OF DIFFERENT CHEMICAL ADMIXTURES ON CEMENT BASE MORTAR PROPERTIES

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Keywords: *recycled aggregates, admixtures, plasticizer, superplasticizer, mortar*

1. Introduction

The use of the fine fraction of construction and demolition waste (CDW) is a viable alternative for masonry mortar production. Ledesma et al. (2015) concluded that it is possible to replace up to 50% of natural sand with recycled sand from CDW without affecting the mechanical properties in a significant manner. Workability, shrinkage and freeze-thaw resistance are the most limiting properties; hence we recommend the use of recycled sand from CDW only for masonry mortar production in indoor environments.

Currently, there are different types of chemical admixtures in the market for mortar and concrete that allow to improve properties such as workability, the time of setting, mechanical strength and durability.

The objective of this work was to study the effect of different types of commercial admixtures on the properties of cement-based mortars made with natural and recycled aggregates from CDW.

2. Material and methods

Two 0/4 mm sands were used: a natural siliceous sand (AN) as a reference and the fine fraction (recycled sand) from a mixed recycled aggregate whose components according to UNE-EN 933-11: 2009 were: concrete and mortar (38.24%); unbound natural aggregates (31.47%); ceramic materials (28.85%); bituminous materials (1.14%); gypsum (0.15%); 0.01% glass and others like wood, plastic, etc. (0.4%). A cement CEMIV / B (V) 32.5 N was used. Four types of admixtures were tested: an air entrainers & plasticizers (Mastercast 934), an air entrainers & water retainer (Mastercast 930), a set retarding & plasticizers (Mastercast 560) and a superplasticizers & water reducer (Mastercast 205 MA).

Table 1 shows the mortar mix proportions. The amount of water was adjusted experimentally until achieving a consistency of 175 ± 10 mm (EN 1015-3: 1999). Aggregates were used at room temperature (20 °C) and humidity. The recycled sand moisture was around 2.68% while the natural sand moisture was around 0.2%.

The following properties were studied: workability (UNE-EN 1015-9: 2000), compression strength (UNE-EN 1015-11: 1999) at 28 and 180 days and shrinkage (UNE 83831: 2010) at 28 days.



Table 1. Mortar mix proportions

Mortar	RA (g)	NA (g)	CEM (g)	Admixture (g)	(w/c)t	(w/c)e	
MSIV	-	3641	610	-	-	0.79	0.76
MSIV1	-	3641	610	Air Entrainers & Plasticizers	4.88	0.75	0.73
MSIV2	-	3641	610	Air Entrainers & Water Retainers	4.88	0.84	0.81
MSIV3	-	3641	610	Set Retarding & Plasticizers	4.27	0.75	0.73
MSIV4	-	3641	610	Superplasticizers & Water Reducers	15.25	0.6	0.58
MRIV	3335	-	610	-	-	1.26	1.04
MRIV1	3335	-	610	Air Entrainers & Plasticizers	4.88	1.23	1.01
MRIV2	3335	-	610	Air Entrainers & Water Retainers	4.88	1.32	1.1
MRIV3	3335	-	610	Set Retarding & Plasticizers	4.27	1.32	1.1
MRIV4	3335	-	610	Superplasticizers & Water Reducers	15.25	1.09	0.87

3. Results and conclusions

The Air Entrainers & Plasticizers admixture reduced the amount of mixing water, improved the workability, decreased the mechanical strength and increased the shrinkage of mortar. This admixture would not be advisable to produce mortars with recycled sand from CDW, at least with the dosage tested.

The Air Entrainers & Water Retainers admixture did not reduce the amount of mixing water, improved workability, reduced the mechanical strength and increased the shrinkage of mortars. This admixture would not be advisable to produce mortars with recycled sand from CDW, at least with the dosage tested.

The Set Retarding & Plasticizers admixture reduced the amount of mixing water, it was very effective in improving workability, slightly improved mechanical strength and slightly reduced shrinkage. At the doses tested, this additive would be recommendable to produce mortars with recycled sand from CDW.

The Superplasticizers & Water Reducers admixture was shown to be the most effective in reducing the amount of mixing water, although the use of recycled sand without without pre-saturating previously reduced the workability time, significantly increased the mechanical strength and decreased the shrinkage of mortars. This admixture in the doses tested could be a good option to improve the masonry mortar properties, although the aggregates should be used previously pre-saturated in order to improve the workability of the mixture.

4. Acknowledgment

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ANALYSIS OF MECHANICAL PROPERTIES AND DURABILITY OF SELF-COMPACTING CONCRETE WITH MINERAL ADDITIONS

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Keywords: *Durability, Precast industry, Chlorides, Self-compacting concrete, sustainability.*

1. Introduction

Precast concrete industry appears as a necessity for the construction industrialization, acting both in reducing the materials wastes and construction time, besides present a better-quality control. Thus, this industry appears as an important ally in the manufacture of basic infrastructure elements, such as power distribution poles. However, an early deterioration of these conventional reinforced concrete power poles it is observed, when it is subjected to hard conditions, such as marine zones and heavily regions industrialized, showing as the most common pathological manifestation, the armature corrosion.

The concrete armature corrosion is a result of concrete carbonation process combined with the penetration of chloride ions, these processes can act separately or jointly. Supplementary cementitious materials can minimize this process, such as fly ash, metakaolin, and silica fume, which have the capacity to bind them to chloride ions, contributing significantly to prolong the useful life of armatures once that improve the concrete ability to resist the penetration of chloride ions (Wongkeo et al., 2014). The use of supplementary cementitious materials such as metakaolin can mitigate the problem, since these materials contribute significantly on the concrete's ability to resist penetration of chloride ions, consequently prolonging the useful life of the armature, since these materials have the ability to bind them to chloride ions (EFNARC, 2005).

This study aims to examine the durability of self-compacting concretes compared to conventional ones used in precast industry, which main product are power distribution poles. To this end, the properties in state hardened, as to compressive strength and diffusion coefficient of chloride ions were analyzed.

2. Material and methods

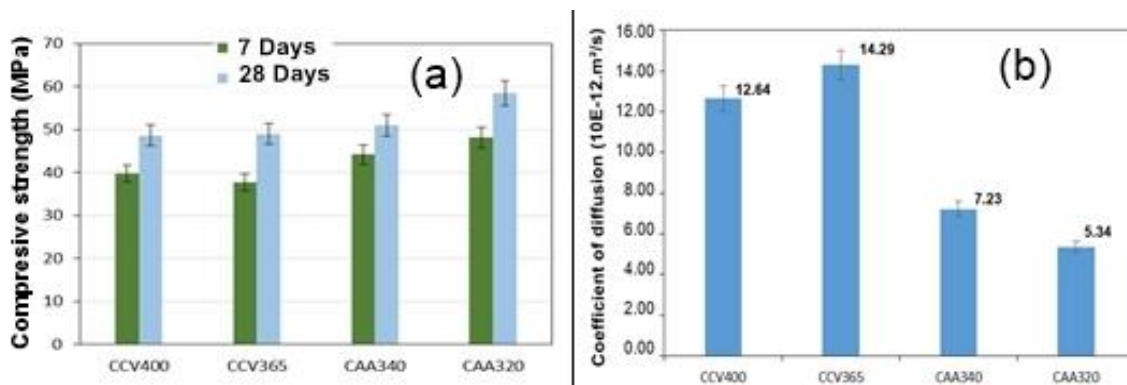
Four mixtures of concrete were produced, two of self-compacting concrete (SCC), and two of conventional concretes (CCV), as showed on Table I. The choice of conventional concrete features was based on features used by the precast industry. The definition of SCC features was based on studies of cement consumption reduction of SCC of Anjos et al. (2014) and EFNARC (2005). The properties of the SCC studied were evaluated through the tests of compressive strength (ABNT NBR 5739:2015) and diffusion of chloride (LNEC E-463:2004).

Table 1: Concrete compositions (kg/m³).

Materials	Concrete compositions			
	CCV400	CCV365	SCC340	SCC320
Cement	400	365	340	320
Metakaolin	-	-	19	32
Filer	-	-	78	99
Fine aggregate	770	801	825	846
Coarse aggregate	950	994	761	781
Water	200	190	238	214.4
Additive: Pf	1.4	1.3	2.0	1.9
Additive: Sp	-	-	3.9	5.0

3. Results and conclusions

Figure 1-a shows that it is possible to obtain SCC's with higher compressive strengths as the amount of cement in the blend is reduced. Besides contributing to the mechanical improvement in use, these results contribute to the environment due to the reduction of cement consumption. Figure 1-b showed it is possible to make SCC with better durability over conventional concrete, decreasing to 20% the cement consumption with the aid of mineral additions, even though, show higher compressive strengths.

Figure 1 – (a) Compressive strength (MPa) and (b) coefficient of diffusion ($10^{-12}m^2/s$).

4. Acknowledgment

To the CNPq process 488337 / 2013-5 for the financial support to the project.

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BIKE LANE MADE WITH SCREENING WASTES AND MIXED RECYCLED AGGREGATES FROM CDW

Javier Tavira, José Ramón Jiménez, Jesús Ayuso, Antonio Jesús González-Barrios, Enrique Fernández-Ledesma, Antonio López-Uceda,

Keywords: *recycled mixed aggregates, screening wastes, construction and demolition waste, backcalculation, Falling Weight Deflectometer.*

1. Introduction

Construction Demolition Wastes (CDW) are still mainly used as a fill material or dumped in land areas, these practices harms the environment and makes it impossible to reach the 70% limit of CDW recovered by 2020 by the Waste Framework Directive, it is a must for every agent involved in the management of these wastes to find new ways to reuse CDW. No other study was found regarding the usage of screening wastes (SW) in unbound pavement layers. As a result of its high fine fraction and impurities, SW are not used as granular bases and subbases of roads and placed in landfills deteriorating our environment. The main objective of this study was to perform a long time study of its use in the granular layers of a bike lane. This experimental bike lane validates the use of these recycled materials as granular base-subbase layers, these recycled materials do not satisfy the chemical and physical specifications to be used in roads (PG-3, 2015). Elastic moduli of pavement layers are basic parameters used to estimate durability, in this research was determined along the two years period of the study through backcalculation. These moduli can be used to compare bearing capacities of pavement sections built with recycled materials or natural aggregates. Ecological footprints caused by road infrastructures can be reduced by the use of recycled materials instead of natural materials (Vieira and Pereira, 2015). To the best of our knowledge, there were no previous studies regarding the use of SW obtained from CDW as unbound layers materials in the construction of roads or bike lanes.

2. Material and methods

The experimental bike lane (EBL) was built using two recycled materials from CDW: a recycled mixed aggregate (RMA-1) and a recycled mixed material from screening waste (RMSW-1). The first step after arrival of CDW was to reduce bigger fragments that could not be crushed, then primary screening (0/20 mm) removed the finest particles with more impurities and improved the quality of the recycled aggregates subsequently obtained. Then, RMSW-1 was collected. An impact crusher ground particle greater than 20 mm. The ground materials were screened by a 40-mm sieve. At this point, materials larger than 40 mm were returned to the impact crusher to reduce their size. After passing through the sieve, a magnetic belt conveyor was used to remove metallic elements. Finally, a blower removed light particles (Fig. 1). Deflections were measured with an FWD to evaluate the mechanical behaviour of the structural layers and to determine the Young's modulus of the natural and recycled materials (Fig. 2).

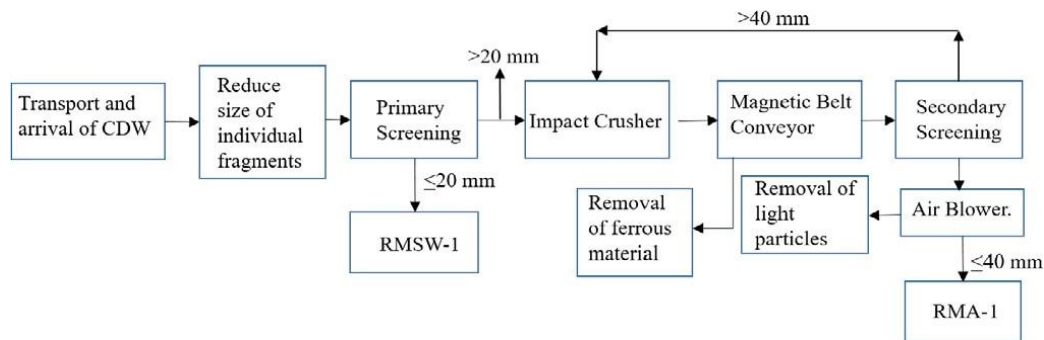


Figure 1. Recycling process of CDW



Figure 2. Images of the Experimental Bike Lane

3. Results and conclusions

The bearing capacity and its evolution during a period of two years was more than acceptable. It exceeded the limits established by regulations for the construction of bike lanes. Moreover, its bearing capacity increased after two years to ensure the use of these two recycled materials as granular layers in bike lanes. Over the two-year study subbase layers made with screenings wastes obtained a mean modulus of 200 MPa, granular bases made with recycled aggregates obtained a mean modulus of 420 MPa, these moduli value increase for the mixed recycled materials can be explained by certain latent hydraulicity of the cement particles or by various pozzolanic activities of the ceramic particles.

4. Acknowledgment

The author would like to thank the FEDER for financial support via projects (in Spanish): CICLOVÍAS.

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PAVED ROAD SECTION BUILT WITH CONSTRUCTION AND DEMOLITION WASTE MIXED WITH EXCAVATION SOIL

Javier Tavira, José Ramón Jiménez, Jesús Ayuso, Antonio López-Uceda, María José Sierra, Enrique F. Ledesma

Keywords: recycled mixed aggregates, excavation soil, construction and demolition waste, backcalculation, forward calculation, Falling Weight Deflectometer.

1. Introduction

530 million tonnes of Construction Demolition Wastes (CDW) were produced in the European Union (Rodríguez et al, 2015). Spain produced 26 million tonnes in 2012 (Eurostat, 2015). If the excavation soils from construction activities were included, the total waste would be 1350 to 2900 million tonnes (Mudgal et al, 2011).

2. Materials and methods

Two recycled materials were produced in a recycling plant located 5 km North of the Experimental Section (ES), Mixed Recycle Soil (MRS-1) used in granular subbases and Recycled Mixed Aggregates (RMA-1) used in both granular bases and subbases.

There were laboratory studies to characterize the properties of recycling aggregates. The ES tested these materials under real traffic and weather conditions. During its construction, several density, plate load, and falling weight deflectometer tests were performed to determine the bearing capacity of all the layers. A laser profiler determined the international roughness index. After the road was opened to traffic, a follow up of deflections and surface roughness was performed during the following seven years of the study.

Elastic moduli of each layer studied was calculated using two different methods: back calculation and forward calculation.

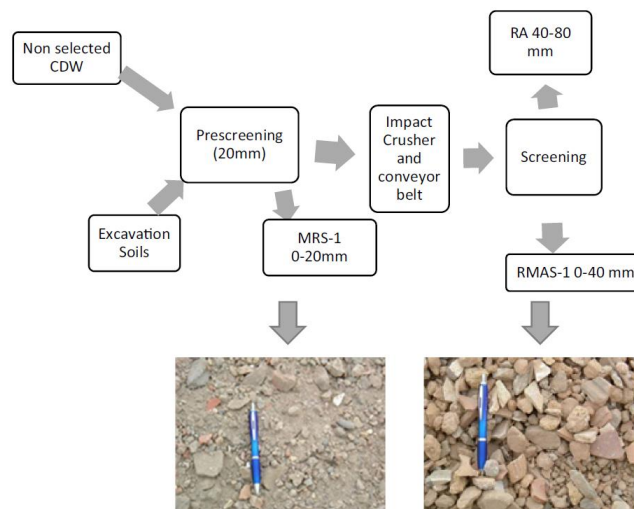


Figure 1. Recycling process of CDW



Figure 2. Images of the FWD and Profiler a) and FWD b) in the Experimental Section

3. Results and conclusions

Low quality recycled mixed aggregates can be used as substitutes for natural aggregates as unbound layers. The mechanical performance and surface roughness values obtained from the experimental road shown an acceptable behaviour. Backcalculation and Forward calculation of moduli shown acceptable values for recycled granular layers. Moduli value for RMA-1 averaged 349 MPa and MRS-1 averaged 158 MPa, these recycled materials can be used as unbound layers in low volume traffic roads. International Roughness Index (IRI) was similar in the three sections obtaining values under 3 m/km which according to World Bank it corresponds with a new pavement (Sayers, 1986).

4. Acknowledgment

The authors would like to thank the Civil Works Agency of the Regional Government of Andalusia (Agencia de la Obra Pública de la Junta de Andalucía), for its encouragement and support of this research study. We would also like to thank the construction companies Azvi and Geocisa, who made the lab tests, and the pavement survey company GYA.

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ESTIMATION OF THE PHYSICAL-MECHANICAL PROPERTIES OF RECYCLED AGGREGATES FROM THEIR COMPONENTS

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Keywords: *Statistical analysis, circular economy, recycled aggregate, physical-mechanical properties.*

1. Introduction

Every day, huge amounts of construction and demolition waste (CDW) are produced worldwide as a result of the upgrade in the construction sector. This results in environmental problems directly related, like the constant consumption of non-renewable raw materials and the problems derived from their storage in landfills. An alternative to solve these problems is to recover these waste materials. Since the 80's of the previous century, there has been considerable progress in CDW recycle systems (Tam et al., 2018), not only in the methods of recovery from CDW into recycled aggregate (RA) but also on the ways and techniques of its utilisation in construction industry.

Until a few years ago, most of the studies focused on recycled concrete aggregates (RCA), which provide better structural characteristics in the produced concrete. However, mixed recycled aggregates (MRA) are the majority RA; the main components of these aggregates are concrete, mortar, unbound natural aggregates and ceramic particles, although small percentages of gypsum, asphalt and wood could be present. The study of the composition of RA and their main properties have been widely studied in the literature. Silva et al. (2014) performs a statistical analysis of the main properties of recycled aggregates for use in concrete. However, a few authors like Barbudo et al. (2012) studied from a statistical point of view the relationship between the composition of RA and their physical-mechanical properties.

The aim of this study is to analyse the influence of components on the RA physical-mechanical properties.

2. Materials and methods

Thirty-five RA were studied, nineteen were RCA and sixteen MRA. The samples were collected from different recycling plants. A composition test was performed to each aggregate, separating the main components of RA: concrete (R_{c1}), mortar (R_{c2}), unbound natural aggregates (R_u) and ceramic particles (R_b) as independent variables. Six physical-mechanical properties of RA were selected as dependent variables: oven-dried particle density (ρ_{rd}), apparent particle density (ρ_a), saturated and surface dried particle density (ρ_{SSD}), water absorption after 24 hours (WA) (UNE-EN 1097-6: 2014), resistance to fragmentation by Los Angeles test (LA) (UNE-EN 1097-2: 2010) and aggregate crushing value (ACV) (BS 812-110:1990).

An analysis of variance was carried out to determine the relationships between the independent variables and the six dependent variables. In the cases where a dependency relationship was found, a regression analysis was conducted (multiple linear correlation, polynomial or exponential function).



3. Results and conclusions

An analysis of variance and a regression analysis were realised to each pair of variables to correlate with the aim, to demonstrate whether it is possible or not, to obtain a correlation between each physical-mechanical property of RA and its composition.

As a result of the variance analysis, it has been evidenced that there is a significant influence between the composition of the RA and the six physical-mechanical properties studied. In every analysis, the p-value of the F-Test were less than 0.05, with a confidence level of 95%.

Moreover, the results of the six regression analyses realised showed that four of the physical-mechanical properties studied have significant correlation with the composition of aggregates: ρ_{rd} , ρ_{SSD} , WA and ACV. In all of them, the determination coefficient (R^2) was greater than 0.8 using multiple linear regression.

The following equations show the best fit obtained from each multiple linear correlation between the different physical-mechanical properties studied and the independent variables.

$$\rho_{rd} = 1813.9641 - 1.0892 R_b + 4.6918 R_{c1} + 2.7025 R_{c2} + 5.8361 R_u \quad (\text{p-value} = 7.8\text{e-}15; R^2 = 0.904)$$

$$\rho_{SSD} = 2073.2551 - 0.4959 R_b + 3.4583 R_{c1} + 2.1597 R_{c2} + 4.2775 R_u \quad (\text{p-value} = 5.5\text{e-}14; R^2 = 0.891)$$

$$WA = 13.0670 + 0.0446 R_b - 0.0712 R_{c1} - 0.0430 R_{c2} - 0.0900 R_u \quad (\text{p-value} = 2.5\text{e-}14; R^2 = 0.896)$$

$$ACV = -79.6951 + 1.1746 R_b + 1.2219 R_{c1} + 1.2785 R_{c2} + 0.9550 R_u \quad (\text{p-value} = 1.1\text{e-}8; R^2 = 0.860)$$

Therefore, it is deduced from this study that there is an influence of the RA composition in the following physical-mechanical properties: oven-dried particle density, saturated and surface dried particle density, water absorption and ACV. In addition, this relation can be expressed with a multiple linear correlation with a very high significance ($R^2 > 0.8$). These results will allow to predict the physical-mechanical properties of recycled aggregates from their composition.

4. Acknowledgment

Pilar Muñoz-Moreno would like to thank the Spanish Government (MECD- FPU16/04253) for its funding support.

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EFFECT OF COMPOSITION OF MIXED RECYCLED AGGREGATES ON PHYSICAL- MECHANICAL PROPERTIES

Antonio López-Uceda, Pilar Muñoz-Moreno, Enrique Fernandez-Ledesma, José Ramón Jiménez.

Keywords: *Circular economy, mixed recycled aggregate, physical properties, statistical analysis.*

1. Introduction

The use of secondary raw materials like construction and demolition waste (CDW), which amounts to a third of the total waste generated in the EU, face the environmental demands required by European policies (Directive 2008/98/EC). However, the recycling rate in Spain is far from the target established (70%) by the Directive for 2020, having one of the lowest ones (European Commission, 2011). CDW after being processed in a recycling plant becomes recycled aggregates (RA). The main components of the RA are unbound natural aggregate (Ru), concrete (Rc1), masonry mortar (Rc2), ceramic particles (Rb), and, to a lesser extent asphalt, gypsum, glass, plastic, wood, and metals among others. Generally, there are two main RA from CDW according to their nature; one from demolition of concrete (RCA); and other from demolition and rehabilitation of buildings called Mixed Recycled Aggregate (MRA), with a heterogenous composition. In Spain, the latter represents 70-80% of the total RA produced.

Authors like Silva et al. (2014) and Barbudo et al. (2028) classified RA according to their composition and their mechanical-physical properties such as density, water absorption and Los Angeles tests. These classification does not distinguish between concrete and masonry mortar components.

The aim of this study has been to have a deeper understanding of the influence of RA's components on physical-mechanical properties of RA. For this purpose, different RA were collected and each of their components were tested separately.

2. Materials and methods

Different aggregates from five recycling plants were studied: eight MRA and six RCA samples. Four crushed natural aggregates (CNA) with different nature (siliceous, granite and limestone) were used as reference. The main components of RA (Rb, Ru, Rc1, Rc2) were separated in laboratory. The following physical-mechanical properties were tested: dry density and water absorption after 24 hours (UNE-EN 1097-6: 2014), resistance to fragmentation by Los Angeles Test (UNE-EN 1097-2: 2010) and aggregates compressive strength by the Aggregate Crushing Value (ACV) (BS 812-110:1990).

3. Results and conclusions

One-way ANOVA (Statgraphics Centurion XVI) was conducted on each test result to check the component factor influence. This factor had five levels, one for each main component (Rb, Ru, Rc1, Rc2) and the corresponding to the CNA. As expected, the p-value of the F-Test were less than 0.05, with a confidence level of 95%, for the component factor on the test results, meaning there were statistically significant differences between the mean values. Figure 1 shows Fisher's Least Significant Difference (LSD) tests to check whether there was a significant difference



between the factor levels, examining the mean plot and identify the LSD intervals. Ru presented similar performance than CNA, due to the overlapping between their corresponding bars. Rb presented better behavior in terms of resistance to fragmentation and compression than cementitious particles (Rc1 and Rc2). Rc1 and Rc2 did not show any similarity in any of the test results studied according to the statistical study. Determination of the RA composition Standard (UNE-EN 933- 11:2009) does not distinguish between masonry mortar and concrete particles. Based on these results, this differentiation could be helpful for better characterization of the RA

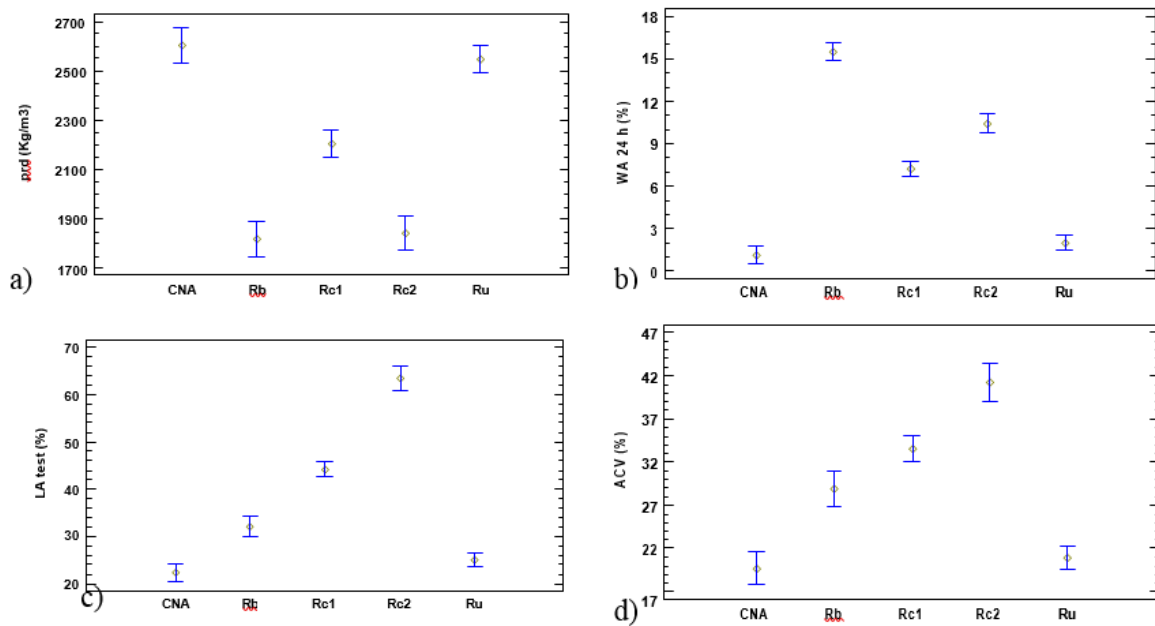


Figure 1. Mean values of dry density (prd) (a), water absorption after 24 h (WA 24 h) (b), Los Angeles test (LA test) (c), and ACV (d) and 95% LSD intervals.

4. Acknowledgment

The authors would like to thank the PAIDI research group TEP 227-Construction engineering from Universidad de Córdoba (Spain).

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FEASIBLE USE OF ELECTRIC ARC FURNACE DUST AS A SECONDARY RAW MATERIAL IN SELF-COMPACTING MORTAR PRODUCTION

Angélica Lozano-Lunar, Pedro Raposeiro da Silva, Jorge de Brito, José María Fernández, José Ramón Jiménez

Keywords: *Electric arc furnace dust, self-compacting mortar, secondary raw material, circular economy,*

1. Introduction

The new model of Circular Economy has the aim of a closed cycle of waste management in which these are reintroduced into the productive process. Construction materials, specifically the mortar/concrete industry, stand out for a high consumption of raw materials (Rattanashotinunt, 2018). Therefore, these materials are the focus of implementation in the search for a more environmentally sustainable material. One of these actions is the partial or total use of secondary raw materials (SRM) to replace natural raw materials. In the production of steel, during the scrap fusion, a pulverulent by-product named electric arc furnace dust (EAFD) is generated (Issa, 2013). These materials have a high heavy metal content and their management is by landfill. This action is not consistent with the Circular Economy. Therefore, this research uses two EAFD as SRM in obtaining self-compacting mortars to avoid their deposit in landfill. The viability of using EAFD was analysed through the mechanical and leaching behaviour of mortars. The results obtained contribute to waste management through its valorisation as SRM in the self-compacting mortar production, addressing an unexplored research line.

2. Materials and methods

The self-compacting mortar dosage was defined by the Nepomuceno method (Nepomuceno, 2005). A reference self-compacting mortar (SCM) was produced using cement CEMI/42.5 R (CEM), siliceous filler (SF), two natural sand (NS0/2 and NS0/4) and a superplasticizer (Sp). Four self-compacting mortars were produced by replacing the SF by two EAFD (R1 and R2) in percentages of 25% and 100% by mass (SC1-25, SC1-100, SC2-25 and SC2-100). From each mix, prismatic specimens (40 mm x 40 mm x 160 mm) were manufactured and stored under climatic conditions (95% ± 5% relative humidity and 20 °C ± 2 °C of temperature) up to the test age. The mechanical viability was analysed through compressive strength evolution at 7, 28 and 56 days (UNE-EN 1015-11:2000). The environmental assessment was carried out through leaching tests in monolithic (XP X31-211: 2012) and granular states (UNE-EN 12457-4: 2003). The metal release results were compared with the "Non-Hazardous" limit of the European Directive 2003/33/EC to self-compacting mortars classification.

3. Results and conclusions

The compressive strength decreased with the EAFD incorporation (Fig. 1 a) and b)), due to the detriment produced by heavy metals in the cementitious matrices (Lasheras-Zubiata, 2011). However, SC2-25 (65.28 MPa) only recorded a loss of 1.4% compared to SCM (66.20 MPa). In monolithic state (Fig. 1 c) and d)), metal releases remained below the limit in all elements. Therefore, all self-compacting mortars were classified as "Non-hazardous". In granular state (Fig. 1 e) and f)), SC1-25, SC1-100 and SC2-100 were classified as "Hazardous" because the Pb release



exceeded the limits of the European Directive 2003/33/EC ($> 10 \text{ mg/kg}$). It is known that Pb is released to a greater extent in the alkaline environment formed by the hydration of cement ($\text{pH} > 12$) (Ledesma et al., 2018). SC2-25 was classified as "Non-hazardous" because the self-compacting matrix allowed Pb encapsulation. This study proved the mechanical and environmental viability of using EAFD up to 25% as secondary raw material in self-compacting mortar production, addressing an unprecedented line of research.

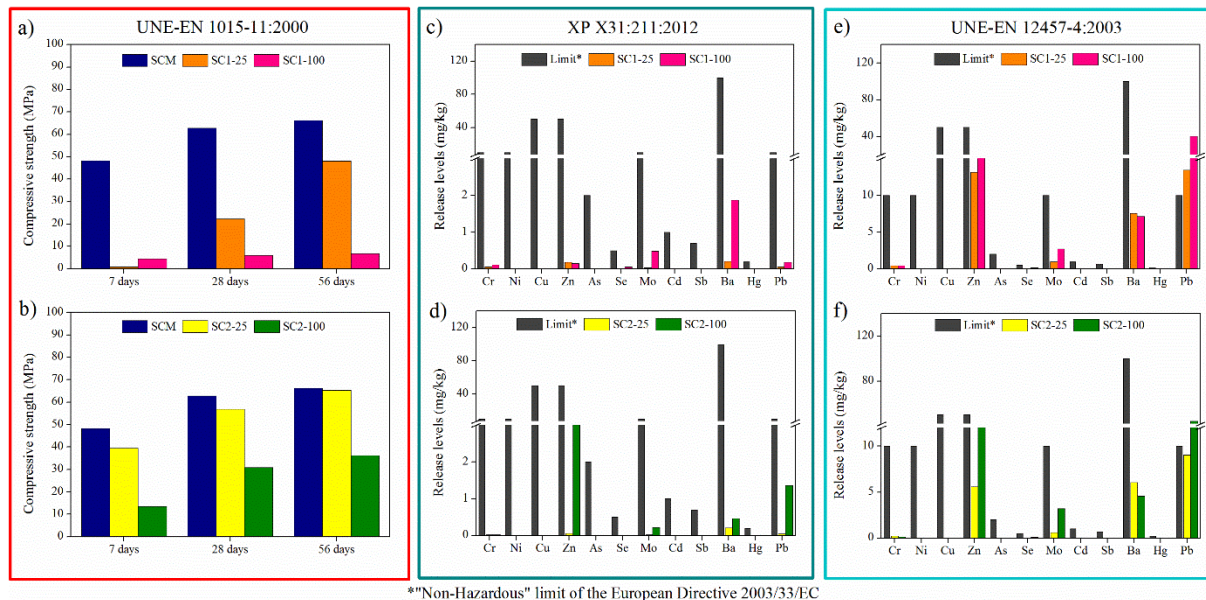


Figure 1. a) y b) Compressive strength, c) y d) Leaching in monolithic state y e) y f) Leaching in granular state.

4. Acknowledgment

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CHARACTERIZATION OF MORTARS CONTAINING RUBBER FROM TYRES OUT OF USE

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Keywords: *Crumb rubber, concrete, mortars*

1. Introduction

Due to the increase in the number of motor vehicles, environmental pollution caused by the used tires has also increased. Vehicle tires are made of rubbers which, after completing their useful life, turn into a waste that needs to be destroyed in the environment (Gonen, 2018). Taking into account both the environmental risks presented from used tire as well as the scarcity of natural mineral aggregates, a lot of recent research has focussed on utilizing used tire in concrete as a partial replacement of its natural aggregates (Youssf, 2016). The inclusion of waste rubber in concrete has significant effects on the physical and mechanical properties of the concrete. Thus, some researchers have used the waste particles in the concrete mix and have studied the effects of these particles on the characteristics (Topçu, 2007). The aim of this study is to **assess** the environmental benefits of the use of waste rubber from out of use tires. For this purpose, a replacement in volume of standardized sand by crushed rubber was made in mortars. At the same time, the inclusion of an air-entrainment / plasticizing additive to mortars (to improve cohesion) was studied.

2. Materials and methods

The raw materials used in this investigation were Portland cement type CEM II/A-V 42.5 R, supplied by Holcim (Spain), crumb rubber from Renean (Jaén, Spain) as partial replacement of sand, air-entrainment/plasticizing additive, Sikamor A, from Rescatec MC (Almería, Spain) natural sand CEN DIN-EN-196-1 from Instituto Torroja (Madrid, Spain). To simulate the granulometry of the sand, a mixture of two different ranges of rubber 0-0.6 mm and 0.6-2 mm were added in 70% and 30% respectively.

The chemical composition of the raw materials was determined by X-ray fluorescence (XRF) by a spectrometer Philips Magix Pro (PW-2440). Crystalline phases were evaluated in an X-ray diffractometry with a X'Pert Pro MPD automated diffractometer (PANanalytical) equipped with Ge (111) primary monochromator, using monochromatic Cu K α radiation ($\lambda = 1.5406 \text{ \AA}$) and an X'Celerator detector. The content of carbonates was determined by calcimetry Blaine method. The relative density value was obtained by the Le Chatelier's volumetric method. The pH was determined by a solid pH-meter PCE-PH20S, (PCE Instrument).

Mortars were prepared according to EN standards with natural sand CEN DIN-EN-196-1. The mortars were made with Portland cement type CEM II/A-V 42.5 R and the water relation (W/C) was 0.5 by weight. The sand was replaced in volume by crumb rubber and nine different percentages of substitution were used: 0, 5, 10, 20, 30, 40, 50, 75 and 100 %. The air-entrainment / plasticizing additive, Sikamor A, was added into the mortars mixture by 0.05% on the weight of cement. The mixing procedure used was defined by the standard EN 1015-3 (1999). Two series of three prismatic specimens were prepared for each mortar mixture, 40 x 40 x 160 mm size, by casting them in steel forms. They were cured in environmental chamber at



22 °C and humidity of 80 % up to 7 and 28 days and dried before testing.

Physical and mechanical properties after 7 and 28 days of curing were determined. Apparent density determination tests were carried out according to the standard EN 1015-10 (2000), capillary water absorption tests according to EN 1015-18 (2003). The compressive and flexural strength were determined using the Universal Testing Machine MTS 810 according to EN 1015-11 (2007). The mortar samples and their microstructures were observed using Scanning Electron Microscopy (SEM) with JEOL SM 840

3. Results and conclusions

The results indicated that the crumb rubber content increased, while apparent density, water absorption and the compressive and flexural strength decreased. As regards of the curing time apparent density and water absorption decreased to further curing time. Compressive and flexural strength increased (except substitution of 0, 10 and 30 %) to longer curing. Finally, the influence of the additive on the properties was compared with a previous study (Puerma, 2017). The resulting values showed that, in general, properties were improved with this addition (except compressive strength). At 7 and 28 curing days, bulk density and water absorption values were lower with the additive (except to 28 days in the control mortar and 10% of rubber). The flexural resistance, at 7 and 28 days, increased (except control mortar in 28 days). However, compressive resistance decreased. The SEM images, showed that the cohesion of the rubber in the cement matrix was improved with the additive. This analysis displayed more ettringite in the union area.

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SUSTAINABLE GEOPOLYMERS FROM METAKAOLIN AND OLIVE-PINE BOTTOM ASH

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Keywords: *geopolymers, biomass bottom ash, mechanical properties, thermal properties, sustainability*

1. Introduction

The manufacture of Portland cement involves the usage of a large amount of energy resources and the use of fuels which implies an environmental impact (Deja et al., 2010). The search for new alternative or green cements is necessary to limit such emissions. The most promising green cement is alkaline cement, or geopolymeric cement, due to its properties and low environmental impact. As a result, it is considered as the cement of the future. They are obtained by the chemical interaction between strongly alkaline solutions and silicoaluminates of natural origin, as clays, or artificial, as industrial by-products (Duxson et al., 2007).

Olive crop and its associated industry generate a series of wastes or by-products such as olive pruning, olive bone and olive pomace that, given their energy potential, can be used as fuel, generating another residue, ash. Most of the ash generated are deposited in landfill, causing a negative effect on the environment. This work proposes a new potential application for olive-pine bottom ash through its valorization in new geopolymeric cements as a substitute for the metakaolin.

2. Materials and Methods

The raw materials used in this work were metakaolin (MK), obtained by calcining, at 750°C for 4 hours, kaolin from Caobar, whose mines are located in the province of Guadalajara, Spain and olive-pine bottom ash (OPBA) supplied by the plant Aldebarán Energía del Guadalquivir S.L., located in Andújar (Jaen, Spain). For alkaline activation, a mixture of aqueous sodium silicate was used (Panreac S.A.; 8,9 wt % Na₂O, 29,2 wt % SiO₂ and 61,9 wt % H₂O) and NaOH (reactive grade, 98 wt %, Panreac S.A). The NaOH solution (8.0 M) was prepared by dissolving 400-841 µm sodium hydroxide beads in distilled water. The liquid/ solid ratio used was 0.85. MK was replaced by different amounts of OPBA (25-100 wt%). Pure MK was used as control. The Si/Al molar ratio varies from 1.6 to 5.3 from pure MK up to 100 wt % OPBA. The samples were cured under controlled conditions (60 °C and 99% relative humidity) for 24 h. The specimens were then demolded and kept at ambient conditions for 7 days of curing. Bulk density was determined by Archimedes method. Tests on compressive strength were performed according to UNE-EN 772-1 (UNE-EN 772-1, 2011) on a MTS 810 Material Testing Systems laboratory press. Thermal conductivity was determined at 10 °C using a FOX 50 Heat Flow Meter to TA Instruments accordance with ISO 8301.

3. Results and Conclusions

The bulk density data of the geopolymers after 7 days of curing indicated that the bulk density of the pure MK, control geopolymers was 1269 kg/m³. The replacement of MK by increasing amounts (25-100 wt%) of olive-pine bottom ash produced an increase in the bulk density of the geopolymers, increasing up to 1324 kg / m³ with the incorporation of 25 wt% of waste up to 1437



kg / m³ with the replacement of 100 wt% of MK by OPBA. The increase in bulk density with greater OPBA incorporations could be due to the higher relative density of the ash (2699 kg / m³) compared to the MK (2569 kg / m³).

Compressive strength is a key factor in structural construction materials. Compared to the reference sample (with 0 wt % OPBA) (17.5 MPa), the compressive strength of the samples with 25 and 50 wt% of OPBA was higher than that of all other geopolymers (22.7 MPa). As the substitution of MK by OPBA increased up to 75 wt % a gradual decrease in compressive strength was observed (16.7 MPa), however the addition of 100 wt % of waste produced a significant decline in compressive strength. Geopolymers 100 wt % OPBA reached values of 4.6 MPa.

Thermal conductivity is an important property in construction materials that affects its insulation capacity. The control geopolymers (100 wt % MK) presented a thermal conductivity of 0.292 W/mK. Only the incorporation of 25 wt % of MK gave rise to geopolymers with lower thermal conductivity (0.253 W/mK). The incorporation of 50 and 75 wt % of waste produced a slight increase in this properties (0.307 and 0.321 W/mK, respectively). However the geopolymers 100 OPFA wt % had a thermal conductivity higher (0.402 W/mK).

It can be concluded, therefore, that the substitution of a 25 wt % of MK for the OPBA waste produced geopolymers with better mechanical and thermal properties than the control geopolymers, also present economic and environmental advantages.

4. Acknowledgments

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MULTISCALE LABORATORY INVESTIGATION INTO GEOPOLYMERIZED CONSTRUCTION AND DEMOLITION WASTE AGGREGATES IN STRUCTURAL ROAD PAVEMENT LAYERS

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Keywords: *stabilized road pavement layers, construction and demolition waste, alkali-activation.*

1. Introduction

Construction and demolition wastes (CDW) are produced on a large scale in the European Union (EU) with negative consequences for the environment. The EU Commission has developed several policies aimed at maximising the reuse of CDW in civil constructions as an alternative aggregate source. The main use of CDW aggregates is in road constructions. However, due to their limited physical/mechanical properties, they are generally used in backfilling applications and where the deteriorating effects of traffic and the environment are lower (i.e., road embankments, subgrades). In recent years, they have also been used in the formation of subbases for low-traffic volume roads (Jiménez et al., 2012). Their employment in subbases and granular bases of trafficked roads has been made possible with an improvement in their mechanical properties (through stabilization) which serve to enable an adequate response to higher stress conditions and more severe degradation phenomena (Bassani et al., 2016; Mohammadinia et al., 2014).

This paper introduces a new stabilization technology based on the alkali-activation (AA) of aluminosilicates present in the finest size class of CDW mixed recycled aggregate (MRA). The AA was triggered by adding an alkaline solution (AS-100%) to CDW aggregates. The AS-100% was obtained by diluting sodium silicate and sodium hydroxide in water. This technology avoids the use of common industrial solid binders (i.e., Portland cements, lime) as well as other by-products (i.e., fly ash, blast furnace slags) to limit costs and environmentally harmful consequences.

2. Materials and methods

CDW aggregate obtained from a recycling plant close to Turin (Italy) was investigated. A preliminary chemical characterization (XRD, Table 1) of fine particles ($< 63 \mu\text{m}$) included in the CDW (named UND) revealed the presence of significant amounts of aluminosilicates (56.8%), and a lower content of minerals from the mica group (22.7%), carbonates (11.8%), and quartz (14.7%). The same analysis was carried out on powders (Figure 1) obtained from the four main CDW constituents: recycled concrete (RC), recycled asphalt (RA), brick and tiles (BT), and natural aggregate (NA). UND, RC, RA, BT, and NA fines smaller than 0.125 mm were mixed with the AS-100%. Flexural and compressive strength tests on hardened samples (with a liquid/solid mass ratio equal to 0.4) were carried out on prismatic (80×20×20 mm) specimens after 28 days of curing at room temperature.

A mechanical characterization (i.e., unconfined compression strength UCS, resilient modulus RM) was also carried out on a larger scale on cylindrical specimens of 100×200 mm (d×h) made up of CDW aggregates in the particle size range 0-25 mm. In this case, CDW aggregates were stabilized by adding a quantity of AS-100% within $\pm 2\%$ of the optimal moisture content ($w_{w,opt} = 8.6\%$). The mechanical properties of the mixtures were measured after 7, 28 and 60 days of curing at



room temperature. A Field Emission Scanning Electron Microscopy (FESEM) analysis was also carried out on fragments of hardened samples.

3. Results and conclusions

A strength test on small-scale prismatic specimens revealed that fines (constituents and UND) react well in an alkaline environment, achieving acceptable strength values without any thermal treatment (Figure 2). RC, and UND were the most reactive powders, achieving 14.0 and 12.0 MPa compressive strength values, respectively.

Compacted cylindrical specimens revealed that when the AS-100% content increases, the UCS decreases (Figure 3). The mechanical properties of AS-stabilized mixtures were significantly higher than those for the reference material (CDW aggregates compacted with water only) and improve with curing time, thanks to the AA process. The RM (Figure 4) and UCS values for AS-CDW aggregates are comparable to those of reference stabilized granular materials from literature. FESEM images (Figure 5) confirm the presence of a thin layer of alkali-activated products enwrapping larger aggregate particles, with the presence of the former being responsible for the stabilization of the full CDW aggregate mixture.

The results of this multiscale laboratory investigation revealed that the finer particles in CDW mixtures react in accordance with the alkali-activation theory. The proposed stabilization method demonstrates that CDW aggregates achieve mechanical properties similar to those of cement-stabilized granular aggregates. Moreover, it avoids the use of cementitious products and promotes the sustainability of road infrastructures.

4. Acknowledgment

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STUDY OF VITRIFICATION OF HIGHLY POLLUTED MINE BY-PRODUCTS INSIDE CERAMICS MATERIALS

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Keywords: *tailings dyke, vitrification, ceramics, lixiviation, mine by-products.*

1. Introduction.

The mining industry produces a series of by-products of low commercial value which are discarded during the process of concentration of ores. These by-products include the so-called tailings dyke, large deposits of small granulometry materials, that produce an important visual impact, as well as negative effects on the environment due to possible dragging of contaminants in runoff, since, in most cases they still contain chemical elements from the ore and other truly contaminants.

In this paper, vitrification of these industrial by-products inside ceramics matrix will be studied; achieving with this method to retain the possible lixiviation of the polluting elements and getting a material with commercial value and the same qualities as traditional ceramics. The studied by-products belong to tailings dyke from the old lead extraction Factory of San Roque, which is located in the mining district of Linares-La Carolina.

For this purpose, the lixiviation of the unaltered by-product will be studied firstly, paying attention to the chemical elements such as iron, gallium, manganese, chromium, nickel, etc., and subsequently the presence of them in the lixiviation of the different ceramics materials conformed to increasing percentage of this by-product, being able to faithfully determine its influence on possible runoff waters. At the same time, mechanical and colorimetric tests will be conducted to determine the optimal percentage addition of by-product that makes possible the creation of a ceramic material with similar characteristics to the commercial ones.

2. Materials and methods.

As stated above, the main materials used for the present work, come from the mining district of Linares- La Carolina, specifically, from the tailings dyke of the mine called 'San Roque'. At the same time, clay materials will be studied from the vicinity of the district of Linares, base material for the traditional ceramic industry in the area.

Therefore, once the materials and the relevant tests have been described, the methodology to be followed will be detailed in a more specific manner:

- Physical and chemical characterization of the materials in the tailings dyke of the mine called 'San Roque', from the mining district of Linares- La Carolina
- Studies of the lixiviation from the specified industrial by-products and its possible effect on runoff water in the environment.
- Physical and chemical characterization of the clay from the district of Linares and its use



in the manufacture of ceramic materials.

- Conform of ceramic test tubes with different percentages increasing the amount of industrial by-product addition, from 0% to 100% with an increasing order of 10%.
- Sinterization of ceramic test tubes to perform its lixiviation, mechanical and colorimetric studies.
- Study of the physical properties of the ceramic materials.
- Study of the colorimetric properties of the different families of tests tubes conformed.
- Study of the mechanical resistance of the different families of test tubes conformed.
- Establishment of a maximum addition limit of the by-products, starting from the previous mechanical and colorimetric tests.
- Study of the lixiviation produced by all the by-products addition percentages conformed inside the ceramic matrix, up to the permissible limit.
- Analysis of the results obtained, establishing possible improvements in the process and determining an informative feedback scheme.

3. Results and discussion

The monitoring of the detailed methodology, as well as the determined study, has shown that the analysed by-product shows a high amount of polluted elements that are diluted in water. Furthermore, it has been observed that the addition of the previously mentioned by-product, to the clay studied to conform the ceramic material, has created a series of decreasing mechanical resistance materials. Nevertheless, it is necessary to emphasise that the conformation of ceramic material was not delimited for its mechanical resistance, but for the colorimetric properties which could be quantified and determined as a result of the colorimetric tests.

Finally, to conclude the present work, the limitation in the by-product addition percentage to the ceramic material for the test tubes conformation and its following lixiviation analysis, shows a drastic decrease of polluted elements for all the possible solutions. That is to say, the most part of diluted polluted elements from by-products are erased, creating a stable material which retains them.

4. Acknowledgments.

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APPLICATION OF THE CIRCULAR ECONOMY IN THE RECOVERY OF WASTEWATER TREATMENT SLUDGE FROM WWTP AND PAPER MILLS TO OBTAIN SUSTAINABLE BRICKS

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Keywords: *MSW sludge, Cotton linters sludge, Sustainable bricks, Circular Economy*

1. Introduction

The Circular economy model is based on the intelligent reuse of waste, which becomes raw material to feed natural cycles, or simply to be transformed into new technological products with minimum energy expenditure (Lett, 2014). One of the most important types of waste produced as a result of human activity is sludge from the purification of both urban and industrial wastewater. If these wastes are not managed properly, they can contribute significantly to environmental pollution. The use of the ceramic process as a technique for recovering sludge from urban and industrial wastewater treatment plants for the manufacture of traditional bricks as construction materials opens up a reuse route for these wastes, with a marked environmental advantage (Elías and Bordas, 2017).

In the present work, sludge from the purification of wastewater from the cleaning, firing and bleaching system of cotton linters used in a paper money and security factory, and sludge from the purification of urban wastewater together with a mixture of clay traditionally used by the ceramic industry of Bailén, to obtain bricks for partition walls, have been used. The results show that the products obtained comply with current regulations in terms of mechanical resistance and have better insulating properties compared to traditional bricks.

2. Materials and methods

Specimens of a mixture of clay (30 % red clay, 30 % blond clay and 40 % black clay), with different percentages of sludge, have been produced in the range between 5-20 % by weight of residue. Previously, both the clays and the sludge used have been characterized. The prepared mixtures have been formed by extrusion using a laboratory extruder NANNINI RENATO MACHINERY S.R.L., at a working pressure of 2.2 bars, and has been sintered in laboratory electric furnace at a maximum temperature of 950 °C. The pieces obtained have been tested for weight loss, water absorption (UNE 772-21), water absorption by capillarity (UNE-EN 772-11), determination of open porosity and apparent density (ASTM-C373-14a) and resistance to compression (UNE-EN 772-1:2011+A1). A porosity characterization study has also been carried out using mercury intrusion porosimetry.

3. Results and discussion

The addition of both residues has not been a problem at the time of manufacturing the pieces, that is to say, in the process of extrusion, drying and sintering. For both types of waste, the weight loss of the piece increases with the percentage of waste added, due to the amount of organic matter they contain. The values of this parameter for both wastes are of the same magnitude, as both have similar organic matter contents, as indicated by the LOI values. The results obtained for the



suction, cold absorption and porosity tests show that as the percentage of added waste increases, the porosity content (open and total) of the manufactured materials increases, decreasing the apparent density values of the samples. The observed increase in porosity significantly affects the quality of the manufactured materials, causing an instability of the ceramic structure that produces a drastic decrease in the values of resistance to compression. However, the pieces made with 5 % of paper sludge, and 5 and 10 % of EDAR sludge comply with the limit established by the AENOR Standard for unglazed ceramic bricks. In view of the results obtained in this work, the manufacture of sustainable or ecological bricks in which part of the traditional raw material is replaced by the waste studied may be a viable alternative from an economic and environmental point of view to the traditional product that currently exists on the market.

4. Acknowledgements

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KEY CONCEPTS AROUND THE CIRCULAR ECONOMY AND THE AREAS OF URBANISM, ARCHITECTURE AND CONSTRUCTION

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Keywords: *circular economy, urbanism, architecture, construction, concepts*

1. Introduction

The Circular Economy (CE) is in full apogee, due to the international push that is taking as a measure in favor of sustainability. However, the same intensity that the concept is now experiencing makes it diffuse (Kirchherr et al., 2017). It is necessary to understand and delimit this concept to apply it later. In addition, in the areas of urbanism, architecture and construction, where it can be implemented from the point of view of the macro level, meso level and micro level respectively, another series of concepts arise from the concept of CE, such as those linked to cities, buildings or materials. On the one hand, policies -both at the national level (Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente, Ministerio de Economía, Industria y Competitividad. Gobierno de Spain., 2018) and international one (European Commission, 2014) - promote CE in these areas, but another research shows the need to continue developing knowledge in this conceptual space (Pomponi and Moncaster, 2017).

2. Materials and methods

In order to distinguish the key concepts around the CE and the areas of urbanism, architecture and construction, a literature search is carried out, employing both basic and updated in journals indexed through ScienceDirect and Web of Science, and publications of reference entities in CE such as Ellen MacArthur Foundation.

3. Results and conclusions

As a result, a conceptual framework is obtained in which the CE is the central point. Regarding the concept of CE, several authors that provide updated definitions are highlighted such as Kirchherr, Reike and Hekkert (2017) or Prieto Sandoval, Jaca and Ormazabal (2018). However, although the origins of the EC are based on Industrial Ecology (Iung and Levrat, 2014), from this concept other schools of thought related to the fields of study are developed (Ellen MacArthur Foundation, 2013), such as Cradle to Cradle, Performance Economy and Shearing Layers created by architects (Bote Alonso et al., 2018). In addition, following the line of the implementation of the CE at its various levels, emerge concepts such as the Circular City (CC) and from it emerge a series of principles (Prendeville, Cherim and Bocken, 2018) and objectives (Petit -Boix and Leipold, 2018), in addition to other associated concepts such as urban metabolism or the eco-city (Prendeville, Cherim and Bocken, 2018). In the medium level of architecture, Circular Buildings (CB) are included in few CE studies, but authors such as Pomponi and Moncaster (2017) provide a definition. At this meso level, other linked concepts also appear, such as green buildings. Regarding the micro level of materials, studies are generally carried out from a more technical point of view (Pomponi and Moncaster, 2017), although the term Circular Material (MC) is also mentioned in organizations such as Ellen MacArthur Foundation (2013). It is drawn as a conclusion the breadth of the concept of CE, as well as its application in the areas of urbanism, architecture and construction, besides the need to continue expanding and defining more precisely these concepts and this conceptual framework.



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A STATE-OF-THE-ART REVIEW ON CONCRETE WITH PLASTIC AND RECYCLED PLASTIC MACRO FIBERS

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Keywords: *sustainable construction, macro plastic fibers, circular economy, plastic waste recycling, mechanical properties, durability.*

1. Introduction

One of the current priority objectives of the EU is to move from a take-make-waste extractive industrial model to a circular economy. In the EU, above 25 millions of tons of plastic wastes are generated per year and just 30% by weight is recycled, far from the 50% in 2025 and 55% in 2030 established by European (European Parliament, 2018). This fact clearly indicates how important is to look for innovative technologies such as to consider this stream waste as a raw-second material. Construction sector is in continuous evolution, and fibers-reinforced concrete is an example of innovative solutions. The plastic fibers are useful in providing greater resistance to plastic shrinkage cracking and service-related cracking, and numerous research studies on fibers reinforced concrete have been developed (Li, 1998). The studies demonstrated that concrete made from macro plastic fibers is a composite material that could replace a part of the steel reinforcement in upstream concrete. Therefore, the exploration of the possibilities of reusing different types of plastic wastes in concrete manufacturing would lead to unbeatable results while plastics are daily consumed worldwide and the production this waste has increased immensely during the past 50 years (Gu, 2016).

2. Materials and methods

The present short communication summarizes the current published literature discussing the physical and mechanical properties of concrete with plastic macro fibers. Thus, the performance of the concrete with macro plastic fibers (PF), including the recycled ones are mainly influenced by the following variables: type of plastic, dosage of plastic fibers introduced into the mixture, dimensions and shape of fibers and water to cement ratio. In addition, the assessment of environmental exposure and the most important physical and mechanical properties of concrete containing PF: workability, air content, density, elastic modulus, compressive strength, flexural tensile strength durability have been evaluated.

1.1. Physical properties of concrete containing plastic fibers

Workability: according to various researchers, the workability, with the same water to cement ratio, depends on the amount of recycled PF used. To determine the workability of the fresh concrete was used the slump test. The results obtained were that the slump decreases with the increase in the percentage in volume of PF (Pelisser, 2012).

Air content: most of the studies (Richardson, 2006) indicated that the PF do not significantly affect the air content of reinforced concrete with PF.

Density: the density of the concrete with PF have a not significative reduction respect to the conventional concrete due to the small volume of the PF added in concrete (Karahan, 2011).

1.2. Mechanical properties of concrete containing plastic fibers

Elastic modulus: the modulus of elasticity of a concrete made with PF it is not very different from that of ordinary concrete, due to the low percentage by volume of PF (Pelisser, 2012).

Compression strength: many studies have shown that the compressive strength of concrete containing PF improved upon addition of plastic fibers (Kakooei, 2012). On the contrary, other experiments reported reductions in the compressive strength of concrete containing PF (Fraternali, 2014).



Flexural tensile strength: the studies conducted to evaluate the flexural tensile strength in concrete with PF led to the conclusion that the resistance decreases as the amount of added fibers increases (López-Buendía, 2013, Pelisser, 2012). This decrease tends to be reduced using low percentages of plastic fibers (Ruiz-Herrero, 2016).

Durability: the addition of plastic fibers in the concrete, affects the durability of the mixture and, particularly, on shrinkage, porosity, and the possibility of entering gaseous or liquid substances into the concrete. Regarding the shrinkage, the results of the tests carried out by various scholars are conflicting. Some showed a decrease in shrinkage of the concrete with PF with an increase in the fibers content (Karahan, 2011). On the contrary, others have seen an increase in shrinkage with the increase of the plastic aggregate (Kim, 2010). The tests conducted on the porosity of the concrete contained PFs shows that the porosity increase as the amount of PF rises (Karahan, 2011). According to the previous studies (Kakooei, 2012), the dosage of PF not have a significant influence on the possibility of entry of gaseous or liquid substances into concrete.

3. Results and conclusions

The use of plastic and recycled plastic macro fibers certainly leads to positive results with regard to the protection of the environment as it significantly reduces the amount of waste taken to landfill. As it has been shown, many research works have been developed with the main objective of reusing recycled plastic fibers as a construction material. This research field is gaining widespread attention due to the large amount of plastic materials that our society consumes daily. The conclusions of the present work are that it is feasible to revalue plastic wastes as recycled plastic fibers for being used in concrete manufacturing, improving the concrete properties. More conflicting (and certainly to be continued and deepen) are the research on the physical and mechanical characteristics of the mixture between concrete and plastic fibers. In order to obtain univocal results, thus realizing a fully usable material in the field of structural and non-structural constructions, and with characteristics equivalent or superior to concrete made only with natural aggregate. Thus, the road ahead is to continue in the investigations and experiments in this framework.

4. Acknowledgment

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FROM 150 mm CUBIC TO Φ 150 mm X 300 mm CYLINDRICAL COMPRESSIVE STRENGTH OF COARSE RECYCLED AGGREGATE CONCRETE SPECIMENS

João Pacheco, Jorge de Brito, Carlos Chastre, Luís Evangelista

Keywords: recycled aggregate concrete, laboratory testing, compressive strength, size effects

1. Introduction

The compressive strength (f_c) is arguably the most tested and relevant concrete property, serving as the basis for quality control and conformity testing. Structural design codes specify most load-bearing and serviceability clauses as directly dependent on f_c .

The acceptance of recycled aggregate concrete (RAC) by designers, clients, and contractors requires solid knowledge of its f_c , the proper constitutive modelling of RAC properties, and the definition of specific code clauses for RAC applications. Since RAC has been mostly tested in 150 mm cubes ($f_{c,cube}$) and codes define f_c as the compressive strength of Φ 150 mm x 300 mm cylinders ($f_{c,cyl}$), research on the conversion of $f_{c,cube}$ to $f_{c,cyl}$ of RAC specimens is needed.

This paper concerns a factor (K) that converts $f_{c,cube}$ to $f_{c,cyl}$, by comparing laboratory experiments in which the f_c is tested simultaneously on cubes and cylinders (Eq. 1). K is analysed for natural aggregate concrete (NAC) and coarse recycled aggregate concrete (CRAC) whose recycled aggregates were sourced from concrete.

$$K = f_{c,cube}/f_{c,cyl} \quad (1)$$

2. Ethodology and database

This paper concerns CRAC produced with total replacement of natural aggregates (NA) with recycled coarse aggregates sourced from concrete. Recycled aggregates produced from other sources of waste have been tested less often, especially in what concerns the simultaneous testing of $f_{c,cube}$ and $f_{c,cyl}$; the same is valid for intermediate incorporation ratios of NA by coarse recycled concrete aggregates. A database was built from all publications known to the authors and statistical analyses were performed. The publications were the following: Gull (2011); Kheder & Al-Windaw (2005); Muhammad & Sankaranarayanan (2016); Paul (2011); Pedro et al. (2014); Rao & Desai (2014); Santos et al. (2017).

The K values obtained from the database were compared with those resulting from the $f_{c,cube}$ and $f_{c,cyl}$ of the strength class definitions of EN206 (2000) / Eurocode 2 (2008). Coefficients of correlation between K and other parameters (binder content, w/b ratio, and f_c) were calculated. Since K is also intended for reliability analyses, a probabilistic version of the K factor is proposed. This required probability goodness-of-fit tests.

3. Results and conclusions

Fig 1. plots K vs. the $f_{c,cube}$ and binder blend. Two observations are noteworthy: the K values of NAC are closer to EN206 (2000)/Eurocode 2 (2008) assumptions than those of CRAC, and if the underlying conversion of EN206 (2000)/Eurocode 2 (2008) is used to convert $f_{c,cube}$ to $f_{c,cyl}$ of CRAC specimens, the CRAC cylinder strength is overestimated.



No significant correlations between the w/b ratio and the binder content with f_c were found: the respective correlation coefficients were below 0.3. K was defined as independent of f_c for convenience and because the coefficient of correlation between K and f_c was also not meaningful also - 0.35 (NAC) and 0.36 (CRAC). Scatterplots did not show evidence of nonlinear correlations.

Normal distribution plots agree with K being modelled as normally distributed (Fig. 2). The proposal of the deterministic and probabilistic versions of K is shown in Table 1.

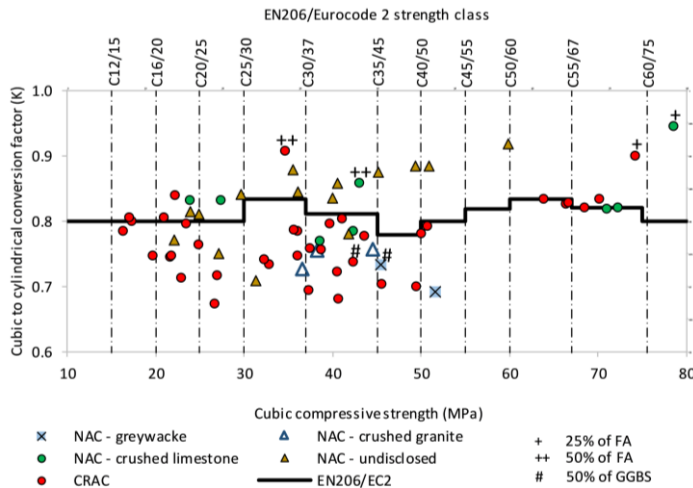


Figure 1 K vs. cubic compressive strength and type of binder

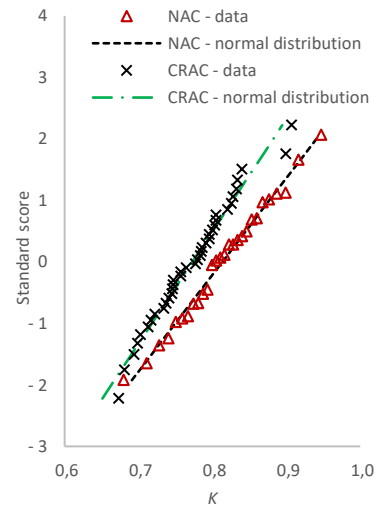


Figure 2 Goodness-of-fit: normal distribution

Table 1 Proposed K factor

Model	Parameter	NAC	CRAC
Deterministic factor	Mean	0.81	0.77
	Conservative factor	0.79	0.76
Probabilistic model (Normal)	Mean	0.81	0.77
	Standard deviation	0.065	0.055

4. Acknowledgments

The authors gratefully acknowledge the support of the CERIS research centre, of IST - University of Lisbon, and of the EcoCoRe doctoral program (grant PD/BD/113643/2015) financed by FCT.

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INCORPORATION OF GFRP WASTE IN MORTARS

Catarina Brazão Farinha, Jorge de Brito, Rosário Veiga

Keywords: mortar, reuse, sustainability, eco-mortars, landfill avoidance

1. Introduction

The consumption of natural resources and energy has increased, following the path of the growth of the world's population. With the increase in consumption, daily-produced wastes are also increased. The amount of waste produced is no longer sustainable. It is therefore necessary to reduce this amount and, when it is no possible, it is essential to find new solutions to recycle or reuse the wastes, improving the waste management worldwide.

The use of composites in the construction industry is increasing due to their properties such as lightness, high mechanical strength and versatility. Fiber reinforced polymers are an example of the composites that have been more intensively used. However, these composites are thermosetting polymers, therefore they are non-recyclable materials. In this sense, it is essential to find solutions for the waste management of these materials.

This research is focused on the introduction of a GFRP waste from the polymer industry in mortars. The main objective is to reduce the amount of waste sent to landfill and contribute to the advancement of knowledge in the area of the incorporation of residues in renders.

2. Materials and methods

Glass fiber reinforced polymer (GFRP) waste comes from a polymer industry. This waste is composed of glass fibers and polyester resin. The particles used came from the cutting process of floor pieces and the particles used are below 63 μm . GFRP was incorporated as a filler at 10%, 15%, 20% and 50% of the volume of sand. The binder used in these mortars was CEM II/B-L 32.5 N. The mortars have a volumetric ratio of 1:4 (cement: aggregates).

In this research the flexural strength and compressive strength tests were performed, according to European Standard EN 1015-11 (1999) and the water absorption by capillary test, according to EN 1015-18 (2002).

3. Results and conclusions

The incorporation of the GFRP waste improves the workability of mortars, reducing the amount of water/binder ratio for the same workability level (Farinha *et al.*, 2018).

The incorporation of GFRP waste increased the mechanical strength of the mortars (Farinha *et al.*, 2018). In Figure 1, is noticed that the flexural strength increased 155% in the mortar with 50% of GFRP and the compressive strength in 164%, when compared with a reference mortar at 365 days. These mechanical strengths were improved with the incorporation of the waste.

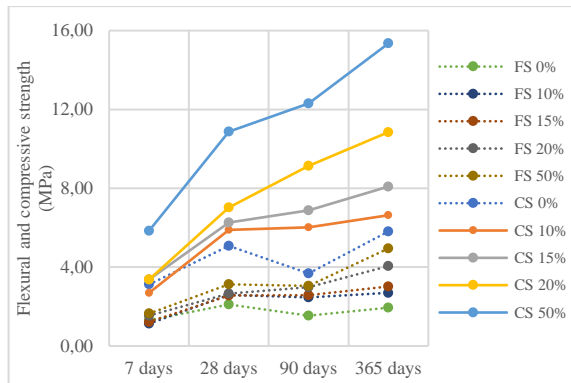


Figure 1. Flexural and compressive strength over time

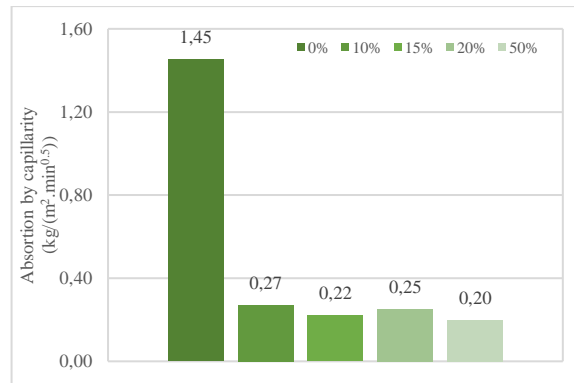


Figure 2. Coefficient of water absorption (28 days)

Concerning the water behavior, the incorporation of GFRP improved the water absorption by capillarity, decreasing the corresponding coefficient from 1.45 to 0.20-0.27 (kg/m².min^{0.5}), depending on the mortars, in comparison with the reference mortar (Figure 2).

In this research the main conclusions are that the incorporation of this waste improves the mechanical behavior of the mortars and reduces their water absorption coefficient. In fact, it is possible to find solutions to reuse the GFRP waste reducing, on the one hand, the amount of natural resources present in mortars and, on the other hand, landfill deposition.

4. Acknowledgment

The authors would like to acknowledge the support of the Portuguese Foundation for Science and Technology for the financial support of this research (PD/BD/113639/2015).

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RENDERING CEMENTITIOUS MORTARS WITH NATURAL FIBERS WASTE

Cinthia Maia Pederneiras, Maria do Rosário Veiga, Jorge de Brito

Keywords: *natural fiber waste, rendering, performance, recycling, mortar*

1. Introduction

Fiber-reinforced composites are considered a potential alternative to improve the durability of construction materials. Fibers addition may also increase the deformation capacity and the energy absorption of the rendering. Besides increasing the coating durability, recycled fibers may promote environmental gains.

The incorporation of different kinds of recycled fibers could achieve better performance of cement mortars in terms of cracking resistance and impact strength, without significant decrease in mechanical strength and change in water absorption. The present research investigates cement mortars for non-structural uses, incorporating recycled natural fibers waste. The fibers are from coconut, wool and flax.

2. Materials and methods

The materials used in the experimental programme were: cement, sand and natural fibers waste. The binder used on these mortars was CEM II/B-L 32.5 N. The sand used was previously washed and calibrated.

Two incorporation ratios of recycled fibers waste have been considered, 10% and 20%. This research also studied two lengths of fiber, 15mm and 30mm. All the mortars were produced at the volumetric ratio of 1:4, cement to aggregate.

3. Results and conclusions

The incorporation of natural fibers waste improves properties of the mortars related to cracking resistance and presents a post-cracking binding behavior.

To ensure an adequate workability and to improve the comparability of the mortars the value of consistency was fixed in the range 140 ± 5 mm. Mortars with incorporation of 10% of fibers (in volume) presented an increase of water/binder ratio to achieve the defined consistency. In contrast 20% of incorporation showed a slight reduction of water/binder ratio.

Fiber-reinforced mortars had a lower bulk density of fresh mortar and dry bulk density of hardened mortar than the control mortar. This could be due to the reduction of the mortars' main constituents.

All modified mortars presented a lower dynamic modulus of elasticity. It can be seen that the reference mortar exhibits higher stiffness. The fibers contribute to a better deformability of the mortar, which leads to a lower risk of failure.

The modified mortars presented an improvement of the mechanical strength, except mortars with coconut fiber that showed a slight decrease in flexural strength. Mortar with 20% of wool fiber



30mm long had the highest increase (40%) compared to the plane mortar. Compression strength was not significantly reduced with the addition of fibers. After the failure, it could be seen the balling effect in some specimens as shown in the figure 1.



Figure 1. Mortars with coconut fiber specimens after failure.

The results suggest that the deformability of fiber-reinforced mortars is greater than the reference mortar. The incorporation of natural fiber waste on mortars could be a feasible solution to improve mortars' performance of cracking behavior. A more ductile mortar may be achieved with the incorporation of fibers. Although it is necessary to investigate drawbacks, the recycled fibers can be seen as a potential alternative for the incorporation in mortars, in order to contribute positively in technical, economic and environmental terms.

4. Acknowledgment

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TOXICITY OF RECYCLED CONCRETE AGGREGATES: LEACHING TESTS

Margarida Braga Maia, Jorge de Brito, Isabel M. Martins, José Silvestre

1

Keywords: *Eluate, Leaching, Recycled concrete aggregates (RCA), Sustainability, Toxicity*

1. Introduction

The toxicity of building materials can be addressed in the areas of occupational and environmental toxicology. In the first case, the harmful effects to workers caused by exposure to a specific substance during building materials production are analysed. In the latter case, the toxic effects of that substance on living organisms in the biosphere is examined.

From an environmental perspective, only a few studies are focused on toxicity assessment. Some of the traditional constituents of concrete may be potentially hazardous, presenting different levels of toxicity. Still, and in order to reduce its potential environmental impact, studies on the incorporation of alternative raw materials have already started, which may affect concrete's toxicity (Roque *et. al.*, 2016).

Depending on their origin, recycled concrete aggregates (RCA) from construction and demolition waste (CDW) have different characteristics (Bestgen *et. al.*, 2016). If the recycling plant does not carry out an adequate management, CDW can be contaminated, impairing their recovery as aggregates (Saca *et. al.*, 2017).

The use of recycled aggregates has been evaluated in several applications, namely when in direct or indirect contact with soil and groundwater. Leachates resulting from the leaching of the aggregates can toxically affect all the surrounding elements, and may put ecosystems and human health at risk (Directive 2013/39/EU). Thus, the exhaustive characterization of the RCA eluates and of the concrete incorporating them is essential (Engelsen *et. al.*, 2010; Newman and Unger, 2003; Butera *et. al.*, 2014).

The ecotoxicological characterization of materials is based on the analysis of the eluates resulting from leaching tests, comparing the released contents with the legal limits defined in national or international legislation.

Several researchers apply different experimental leaching procedures according to existing standards, while others change the standard test conditions, in particular particle size and duration of the test.

Most leaching tests are performed in laboratory to reduce costs, and to guarantee an easier control as well as faster results (Van der Sloot *et. al.*, 1997).

2. Conclusions

- Considering RCA's heterogeneity, it is important to analyse their eluates and check whether they are appropriate for the intended use and comply with existing legislation;
- Leaching tests' results depend on the RCA's source, size, and previous exposure, and on the l/s ratio test used;



- The pH value of the leachant affects directly anion and cation releases' behaviour;
- Some common critical compounds of recycled concrete aggregates are sulphate, chromium, antimony and selenium. On the other hand, cadmium, mercury and lead usually present lower concentrations relative to their critical values.

Taking into account leaching tests currently used in RCA, it is important to define the purpose of the intended study prior to the definition of the test to be applied.

3. Acknowledgements

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USAGE OF RECYCLED WATER IN A VENEZUELAN PREMIXED CONCRETE PLANT. TOWARDS THE CIRCULAR ECONOMY

Henry A. Blanco, Aura Navas.

Keywords: *Ready-mix concrete, Recycled water, Compressive strength, Curing time, Sustainable development*

1. Introduction

Nowadays the concept of Circular Economy, defined as a production and consumption model which implies sharing, renting, reuse and recycle the existent materials and products whenever possible, in order to create an added value; it backs and consolidates the movement that some companies have begun to the sustained development. The production of premixed concrete has promoted actions aimed to generate changes that allow framing among those objectives that lead to be compatible with the environment.

2. Materials and methods

Since 2016, a premixed concrete plant located in one of the main cities of Venezuela decided to set actions in its productive process that allows them to lead on the road of sustained development and with that assume the circular economy in the midterm. It began with one of its main raw material: the water used for mixing, by installing an infrastructure that allows reusing residual water originated in the washing of trucks, diminishing thus the usage of potable water, making it available to the neighbors who need this resource. Therefore, it also contributes to social responsibility. The use of potable and residual water were among the first actions. In order to make later tests in fresh and hardened concrete, guaranteeing its quality and verifying the fulfillment, not only of the local standard quality rule, COVENIN 2385:2000, but also with the international requirements ASTM C 1602 and the BS EN 1008; in order to finally generate the associated procedures to this activity.

3. Results and conclusions

The characterization of recycled water, after filtration by cut stone and sedimentation, yields a density of 0,993 g/l, total solids of 2818 mg/l, chlorides 290 mg/l, sulfates 580 mg/l and alkalis of 272 mg/l NaO. The content of oil, fat and the presence of organic matter, in DQO, was relatively low, 22 mg/l and 15 mg/l respectively. All these values fulfill the requirements of water quality imposed by local and international regulations. The requirements of the forging and compression resistance were also satisfied. Using 100% of recycled water (most unfavorable case), the time of forging concrete was 5 h 33 minutes, and with potable water 5 h con 21 minutes, barely 12 minutes difference. On the other side, the resistance to compression was lower than 10%, the established requirement in the different regulations, being 352 kg/cm² and 403 kg/cm², for a time of 7 y 28 days of concrete with recycled water, comparing it with the 356 and 414 kg/cm², obtained by concrete with potable water.

In order to employ recycled water in the production process, the concrete quality was verified. The process procedures used guarantee the zero download of residual water. The concrete plant achieved the goal and in doing so, obtained results in the circular economy model, on one of the



main raw material: water.

The following procedures were validated and implemented: quality control of the produced concrete with recycled or combined water; usage of recycled water in the production of concrete, truck washing and maintenance system of recycled water. These procedures adjust to the existing regulations and establish the steps to follow for the recycling of water and allow recording the data and using the information, so the concrete plant can show its operational practices associated to this activity.

In the procedure of concrete quality control, the data obtained by the quality of water and the concrete properties, adjusting to the local and international regulation requirements, the forging time and compression resistance shows on a calculation sheet, along with documentation ready to be revised and audited. Regarding the usage of recycled water in the concrete production, the daily data is transformed, using a calculation sheet, showing the amount of recycled water used, and its proportion according to the potable water, which can help develop strategies to increase recycling and diminishing the usage of potable water as raw material. Additionally, it allows us to estimate the daily concrete production with the storage of recycled water, and even the possibilities of sharing this water with other concrete plants, in cases of low demand of concrete production. The disposal of residual water sedimentation, originated from truck washing are also accounted in these procedures. They are the main reasons to move in the road of sustainability. By turning this dried mud into sub-products inside and outside the premixed concrete plant, there is no doubt that the concrete plant is moving in the road towards circular economy.

4. Acknowledgements

To La Bandera Plant and the CSC, and really special to our students: Gerardo, Eric, Felymar, Yenifer y Gerardo, by having accepted the challenge.

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PROPERTIES OF ULTRA-HIGH PERFORMANCE CONCRETE MADE WITH GRANITE CUTTING WASTE

Íñigo López Boadella, Fernando López Gayarre, Jesús Suárez González, Carlos López-Colina Pérez, Miguel Serrano López, José Manuel Gómez-Soberón

Keywords: *ultra high performance concrete; steel fibers; granite cutting waste; recycled concrete.*

1. Introduction

In recent decades, the overexploitation of the natural resources has reached unsustainable levels. Overexploitation depletes resources, destroys natural habitats and pollutes the environment. For these reasons, the European Union (EU) is enforcing policies to reduce the impact of waste materials on the environment while improving the efficiency of re-source management within the common territory. In 1973, the EU launched a corrective policy, called the Environment Action Program, currently in its seventh edition (European Union, 2013).

For these reasons, and because the UHPC, from an ecological point of view, could not be a sustainable material since it requires high amounts of cement, that contribute to a high energy consumption. The development of a more sustainable UHPC incorporating waste materials that requires a smaller manufacturing energy consumption is currently being investigated (Pyo, 2017; Randl, 2014).

The use of micronized quartz (SiO_2 crystalline) in the manufacture of UHPC allows to reduce the volume of cement and complete the granulometric curve in the smallest sizes thanks to the size of its particles ($<40 \mu\text{m}$). So it is achieved by increasing the packing density of the matrix and achieving greater compactness, stability and durability in the concrete. However, the utilization of micronized quartz, have a high energy cost and increase the CO_2 footprint, due to their grinding process. It can also cause serious health problems, such as silicosis, due to its repeated inhalation. For these reasons, different studies have been carried out to replace them with other materials (Burroughs, 2017; Soliman, 2016; Vaitkevicius, 2014).

Due to these reasons and because, after the building sector, the mining industry sector is the activity that generates the largest amount of waste, the viability of using waste from a granite quarry as a partial or total substitution of the micronized quartz to produce a more sustainable UHPC has been analyzed.

2. Materials and methods

The cement used was CEM I 42.5 R/SR. Two silica sands with size fractions of 0/0.5 mm and 0.5/1.6 mm were used. As additions, densified silica fume and micronized quartz powder were used. To achieve optimal workability, polycarboxylate superplasticizers were used. The short steel fibers used in this study had a diameter of 0.2 mm and a length of 13 mm. Finally, granite powder waste (FG) obtained from the cutting process of granite blocks was used as a supplementary material.

To carry out this study, a reference mix was designed that ensures a self-compacting fresh concrete with a compressive strength above 115 MPa. Once the characteristics of the control concrete were verified, 35%, 70% and 100% of the micronized quartz was replaced by the same volume of granite powder. Table 1 shows the UHPC composition.

Finally, the experimental program was developed. Hardened density of UHPC, compressive strength and flexural strength test were carried out. To characterize the mortar matrix, a scanning



electron microscope (SEM) with magnifications of $\times 30$, $\times 200$ and $\times 500$ was used.

Material	Control	35% FG	70% FG	100% FG
Cement	1	1	1	1
Sand 0/0.5	0.378	0.378	0.378	0.378
Sand 0.5/1.6	0.706	0.706	0.706	0.706
Harina sílice	0.281	0.183	0.084	-
Silica fume	0.219	0.219	0.219	0.219
Granite powder	-	0.098	0.197	0.281
Water	0.214	0.214	0.214	0.214
Superplasticizer	0.0125	0.0125	0.0125	0.0125
Steel fibres	0.200	0.200	0.200	0.200

Table 1. UHPC

3. Results and conclusions

Table 2 shows a summary of the results obtained in this work. The incorporation of granite cutting waste, as a replacement of micronized quartz, has not impact on the hardened density of UHPC. The variations are very small, less than 1.5%, and they are due to the variability of the experimental results.

The average compressive strength in all the mixes with granite waste is increased. This increase in compressive strength oscillates between 8.5%, for ratios of 35% and 70% and 4.5% for 100%. These slight increases can be due to the better compactness of the mixes when the granite cutting waste is incorporated.

The flexural strength increase when the substitution ratio is 35%, and even the values obtained for 100% substitution are acceptable. These good results obtained may be due to the better adhesion with the cement paste, as a consequence of the more irregular shape of the granite particles and the presence of the short steel fibres.

Table 2. Experimental results.

Serie	Control	35% FG.	70% FG	100% FG
Density (kg/m ³)	2410	2380	2390	2410
Compressive strength (MPa)	117,2	127,8	127,6	122,5
Flexural strength (MPa)	23,0	24,4	23,1	21,6

In view of the results obtained in this study, granite cutting waste, instead of the micronized quartz powder usually used, is a viable alternative for the manufacture of expectedly more sustainable UHPC.

4. Acknowledgment

The authors also want to thank the support to carry out this study to ArcelorMittal, Elkem, Basf, Sika AG, Granites Cabaleiro S.L. and the Ministry of Economy and Competitiveness of the Government of Spain.

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APPLICATION OF MIXED RECYCLED AGGREGATES IN CONCRETE FOR BIKE LINE DITCHES

Antonio López-Uceda, Jesús Ayuso, José Ramón Jiménez-Romero, Antonio Jesús González

Keywords: *Sustainability, mixed recycled aggregate, mechanical performance, low cement content, ditch.*

1. Introduction

Regarding the increase in environmental awareness, the integration of the use of secondary raw material like construction and demolition waste (C&DW) face the environmental demands by European policies (Directive 2008/98/EC). Spain has one of the lowest CDW recycling rates in the EU (10-15%). Indeed, recycling rates of EU member states vary between 10 and 90%, with an average of 46% (European Commission. 2011), which is far from the 70% target established by the Directive for 2020.

Generally, there are two main Recycled Aggregates (RA) from C&DW; one from demolition of concrete (RCA); and another one from the demolition and rehabilitation of buildings, which is called Mixed Recycled Aggregate (MRA) with a heterogenous composition. In Spain, the latter one represents 70-80% of the total recycled aggregate (RA) produced.

The most common applications of MRA are normally for road layer construction such as backfilling, subgrade, subbase and base. In Spain, the regulatory framework that sets the concrete requirements (Structural Concrete Code EHE-08) forbids the use of MRA in concrete. The use of MRA for non-structural applications with low cement content such as ditches, ground slabs, levelling surfaces, subgrades for foundations and similar civil works could contribute to the sustainability of construction sector. Hence, this research tries to prove the feasibility of using MRA as coarse fraction in non-structural concrete applied in a ditch of a bike lane (Figure 1). Samples were casted during the pouring concrete, and mechanical and capillarity tests were conducted on the samples after curing.

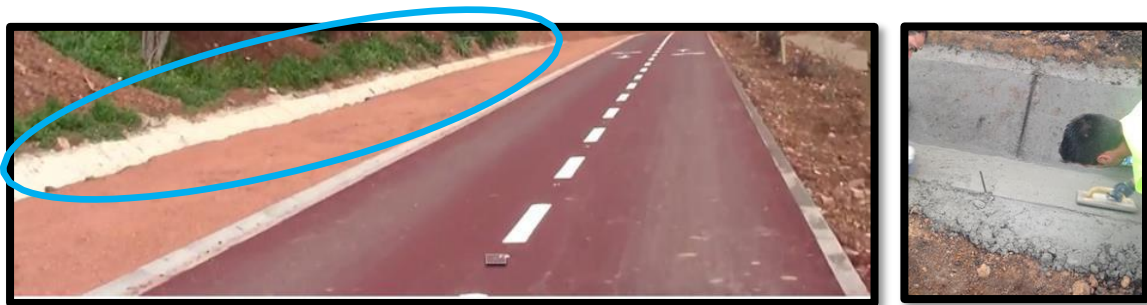


Figure 1. Location of ditch of recycled aggregate concrete and placing detail.

2. Materials and methods

Natural siliceous sand (NS), with a maximum size of 4 mm, and Portland cement-type CEM II/A-V 42.5 R, were used in the two mixes. Two types of coarse aggregate with similar particle size distribution were used: a siliceous gravel (NG) and a mixed recycled aggregate (MRA) from a recycling plant of CDW, which was used exactly as it came out of the plant. A plasticizer (Pl.) and a superplasticizer (Spl.) were used to reduce the water content and increase workability. A nearby ready-mix concrete plant supplied the two concrete mixes (Table 1).



During the pouring, samples were casted and after 24 hours, stored in humid chamber. Tests such as compressive and splitting tensile strength were conducted after 90 days, and modulus elasticity and sorptivity (UNE-EN 1925:1999) were performed after 28 days of curing. Three specimens were used for each test.

Table 1. Composition of the concrete mixes.

CC=Control concrete, RC= Recycled Concrete, R.R. = Coarse Ratio Replacement.

Samples	R.R. (%)	Proportions (kg/m ³)								Abrams Cone (cm)
		Cement	A/C	Water	NS	NG	MRA	Pl.	Spl.	
CC	0	200	0.45	90	1100	950	0	1.92	2.15	4
RC	100	202	0.45	91	1100	0	720	1.92	2.15	6

3. Results and conclusions

Figure 2 shows the results of the mechanical tests carried out. RC presented a gain of 22% between 90 days and 28 days, whereas CC presented lower increase (14%) in compressive strength. The decreases in splitting tensile strength in CC were lower than 20% respect to those of RC for the ages studied. A greater reduction took place in modulus of elasticity comparing CC with RC results, 19.1 GPa in RC versus 11.1 GPa in CC. In the sorptivity test results, 0.42 mm·h^{-1/2} and 0.80 mm·h^{-1/2} were obtained for CC and RC respectively. The data obtained was in accordance to the bibliography (López-Uceda et al., 2016, Etxeberria et al., 2013). No inconveniences were found during placing the RC mix. These results support the feasibility of the use of MRA in concrete applied in non-structural purposes like ditches.

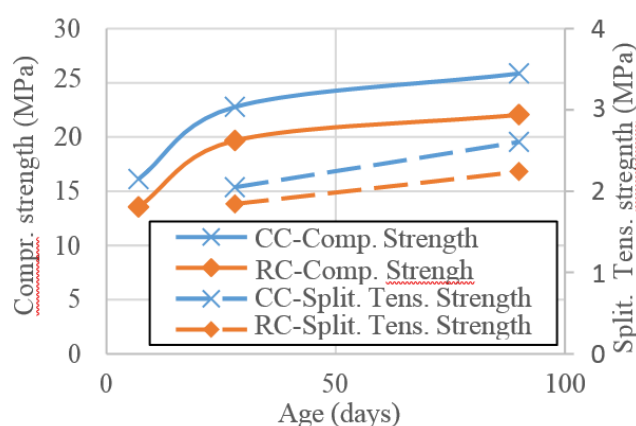


Figure 2. Compressive and splitting tensile strength over time in samples.

4. Acknowledgment

The authors would like to thank the Regional Ministry of Public Works of the Government of Andalusia, and PREBESUR SL, for its support in the concrete mix supply.

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STUDY OF THE APPLICABILITY OF FLY ASHES FROM OLIVE POMACE COMBUSTION AND GEOSILEX® IN SUSTAINABLE CONSTRUCTION MATERIALS

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Keywords: Pomade fly ashes, GeoSilex®, mortars

1. Introduction

The Portland cement production is carried out at high temperature, which requires high energy and fossil fuels consumption. This process is considered very polluting due to the high emission of CO₂ into the atmosphere, increasing greenhouse effect (Velasco, 2009). This situation leads to the search for new siliceous materials to replace cement, so the use of industrial wastes is a beneficial option for environmental and economic sustainability (Criado *et al.*, 2006).

GeoSilex® is an additive that is obtained from the industrial waste generated in the acetylene production, whose energy and environmental cost has practically been amortized in the production phase of the waste by the product main (acetylene).

The main objective of this study is to analyze the use of fly ashes (FA) from the combustion of olive pomace and GeoSilex® (GX) as partial substitutes of Portland cement (CP) in the manufacture of mortars.

2. Materials and methods

The raw materials used in this investigation were Portland cement type CEM II/A-V 42.5 R (Holcim, Spain), sand CEN DIN-EN-196-1 from Instituto Torroja (Madrid, Spain), fly ashes from the olive pomace combustion supplied by the biomass Plant “La Loma” (Jaén, Spain) and GeoSilex® from Trenza Metal S.L. (Madrid, Spain). The fly ashes and the GeoSilex® were used in different percentages to partial replacement of cement.

The chemical composition of the raw materials was determined by X-ray fluorescence (XRF) by a spectrometer Philips Magix Pro (PW-2440). Crystalline phases were evaluated in a X-ray diffractometry with a X’Pert Pro MPD automated diffractometer (PANanalytical) equipped with Ge (111) primary monochromator, using monochromatic Cu K α radiation ($\lambda = 1.5406 \text{ \AA}$) and an X’Celerator detector. The content of carbonates was determined by calcimetry. Blaine method. The relative density value was obtained by the Le Chatelier’s volumetric method. The pH was determined by a solid pH-meter PCE-PH20S, (PCE Instrument).

This work studied the effect of the addition of different proportions of wastes (20-60% wt), ratios fly ashes/GeoSilex® (1/1 and 2/1) and the curing time (7 and 28 days) on the final properties of mortars. The mortars obtained have been tested in accordance with the different international standards to obtain physical properties (apparent density and water absorption by capillarity) and mechanical properties (flexural and compressive strength). Likewise, the mineralogical composition of the samples has been analyzed by X-ray diffraction (XRD) and Infrared Spectroscopy (FT-IR) techniques.



The mortars were made with Portland cement type CEM II/A-V 42.5 R and the water relation (W/C) was 0.6 by weight. The cement was replaced in weight by fly ashes and GeoSilex®. The mixing procedure used was defined by the standard EN 1015-3 (1999). Two series of three prismatic specimens were prepared for each mortar mixture, 40 x 40 x 160 mm size, by casting them in steel forms. They were cured in a climatic chamber at 22 °C and 80 % of humidity up to 7 and 28 days; dried before testing.

Physical and mechanical properties after 7 and 28 days of curing time were determined. Apparent density and capillary water absorption determinations were carried out according to the standard EN 1015-10 (2000) and EN 1015-18 (2003) respectively. The compressive and flexural strength were determined using the Universal Testing Machine MTS 810, according to EN 1015-11 (2007).

3. Results and conclusions

The results show that the bulk density, compressive and flexion strength decrease as the Portland cement is replaced by fly ashes and GeoSilex® for both ratios (FA/GX =1/1 and FA/GX =2/1). However, the water absorption by capillarity is increased. The physical and mechanical properties are much more influenced for the FA / GX ratio = 2/1.

The mortars that incorporate 20% and 40% of residues for a FA/GX =1/1 ratio have suitable physical and mechanical properties, achieving important environmental benefits with their manufacture.

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DOSAGE ADJUSTMENT DUE TO THE USE OF RECYCLED AGGREGATE IN THE MANUFACTURE OF CONCRETE

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Keywords: *construction and demolition waste, recycled aggregate, concrete, dosage adjustment, properties*

1. Introduction

The use of recycled aggregates (RA) from recovering and recycling of construction and demolition waste in the manufacture of concrete has shown the highest impact in their properties, both in fresh and hardened state, mainly due to the rougher and porous nature of the mortar adhered to the surface of the RA (Agrela et al., 2011). Usually, the same dosing methods that for conventional concrete manufacture have been used. Nevertheless, it is necessary to make some adjustments in the dosages due to the higher water absorption of RA, which can cause a loss of fluidity (Poon et al., 2002).

Therefore, the production of recycled concrete (RAC) requires some procedure modifications with respect to the conventional concrete manufacture (NAC), such as: (i) adding an additional amount of water; (ii) pre-wetting the RA; (iii) adding an extra amount of superplasticizer additive; or (iv) using mineral additives. For all the above, the objective of this research has been to get a dosage that allows to obtain a recycled concrete with similar characteristics to those of NAC. The use of higher quantities of RA will be guaranteed, in addition to the reduction in the NA consumption and the volume of waste in landfills, in the framework of the circular economy (COM 614/2015).

1. Materials and methods

The granular materials used in the study were NA and RA, both in 0/4 mm and 4/16 mm fractions, a white cement (BL II / AL 42.5R UNE 80305) and a water-reducing admixture (Chryso ® Fluid Optima 227). The RA used was mainly composed of crushed concrete and natural stone (98%), with a low content of ceramic material (0.2%). The water absorption (5.2 wt% in fine fraction and 2.1 wt% in coarse fraction), as well as the quantity (2.1 wt%) and quality of fines (100) of RA fulfilled the Spanish Concrete Code requirements (EHE-08, 2008).

As usual, due to the greater water demand of RA and in order to achieve a RAC soft-type consistence, the pre-soaking treatment of RA was carried out, since it reduces the exchange of water between RA and cement paste. The studies consulted showed no consensus regarding to the most suitable pre-soaking method. For that, a comparative study of different pre-soaking methods were proposed (Sánchez-Roldán, et al., 2016). In addition to a NAC used as a reference, six types of RAC in which NA coarse fraction was replaced by RA, were manufactured. In five of them RA were pre-soaked according to different methods, and in the other one RA was not pre-soaked. The dosage provided by a concrete manufacturer in weight per m³ for a concrete of compressive strength 35MPa was: 50% of coarse aggregate, 33% of fine aggregate, 17% of cement (400 kg/dm³), 0.8% of admixture (on weight in cement) and an effective water/cement ratio (a/c) of 0.48.

2. Results and conclusions



After the comparative analysis of the different pre-soaking methods, the results obtained have shown that RA pre-soaking only benefited the early age resistances. Moreover, workability was improved when RA was pre-soaked for 10 minutes with an additional content of pre-soaking water (according to its greater water demand). The use of not pre-soaked RA gave rise to low workable concretes.

Consequently, and in order to get RAC of adequate durability subjected to any type of exposure (EHE-08), an adjustment in the dosage provided by the manufacturer should be made. In this sense, an optimization in the a/c ratio and in the cement content to minimize the environmental impact, have been recommended. In addition, an adjustment in the additive content was necessary, both to compensate the loss of free water in the mixture due to the greater water absorption of the RA and to ensure a soft consistence. Finally, the use of not pre-soaked RA was recommended, due to the greater complexity and the higher costs involved in the implementation of pre-soaking technique on the concrete manufacturing plants.

3. Acknowledgment

We would like to thank the Departments of Building Construction and Civil Engineering of Granada University for their cooperation in this study.

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PERFORMANCE OF SELF-COMPACTING MORTARS MADE WITH GRANITE SLUDGE WASTE AS SUPPLEMENTARY SILICEOUS MATERIAL

Angélica Lozano-Lunar, Evgeny Dubchenko, Antonio Rodero, José Rarmón Jiménez, José María Fernández and Serhiy Bashynskiy

Keywords: *Granite sludge waste, self-compacting mortar, supplementary siliceous material, mortar performance, Circular Economy,*

1. Introduction

Ornamental stone (granite, marble, slate, etc.) is a material widely used in construction industry (floors, pavements, retaining walls, cladding, etc.). Granite blocks are cut into smaller sizes and during this process, a granite sludge waste (GSW) is generated, comprising splitter cooling water and the particles originated in stone processing (Rana et al., 2016). Overall, this waste has no use and its accumulation in landfills leads to a heavy environmental impact especially due to its adverse effect on soil permeability and the crystalline silica percentage that, if inhaled, may cause lung diseases (Singh et al., 2016). The waste reuse in construction materials is the trend towards a new Circular Economy model. Therefore, GSW valorization as supplementary siliceous material (SSM) in the production of self-compacting mortars could contribute to the Circular Economy implementation at the construction industry reducing the raw material consumption and achieving the waste management.

2. Materials and methods

The self-compacting mortars were made with cement CEMI/52.5 R (CEM), siliceous filler (SF), siliceous sand (SS), super plasticizing additive and water. In addition, GSW was used, which particle size distribution allowed partial replacement of SF and SS. The siliceous aggregates were replaced by GSW in percentages of 0%, 20% and 40% by volume and the self-compacting mortar nomenclature was GSM0, GSM20 and GSM40, respectively. The Nepomuceno method was used to determine the self-compacting mortar dosage. The water/cement ratio (w/c) was set at 0.64, 0.66 and 0.68 for GSM0, GSM20 and GSM40, respectively. From each mix, prismatic specimens (40 mm x 40 mm x 160 mm) were manufactured and stored under climatic conditions (95% ± 5% relative humidity and 20 °C ± 2 °C of temperature) up to the test age. The self-compacting mortars performance was evaluated by compressive and flexural strength (UNE-EN 1015-11:2000), water absorption by capillarity (UNE-EN 1015-18:2003), open porosity for water (UNE 83980:2014) and shrinkage (UNE 83831:2010 EX).

3. Results and conclusions

The mortar's performance was not greatly affected by the GSW incorporation registering small differences compared to GSM0. The behaviour of all the studied properties was related to each other. The compressive strength and flexural strength values decreased slightly with the GSW increased in mortars (Table 1). GSW has particles with a more rough and angular texture than SF and SS which could increase the friction between the paste components, leading to a worse mortar compactness and hence opening the microstructure (Vijayalakshmi et al., 2013). This fact was in accordance with the slightly higher water absorption by capillarity and open porosity for water (Table 1) experimented in GSW mortars. The changes in shrinkage were minimal compared to the GSM0 (Fig. 1). The greatest difference in shrinkage was experimented in mortar with the highest



w/c ratio (GSM40) since it is known that it is the most influential factor in this property (Alrifai et al., 2013). This study analyzed the performance of self-compacting mortar made with GSW and the results reported about minimal differences compared to mortar without GSW.

Table 1. Properties of self-compacting mortars.

	Days	SM0	SM20	SM40
Compressive strength (MPa)	28	2.98	1.48	7.82
	56	4.06	1.69	9.52
Flexural strength (MPa)	28	0.85	3.61	3.52
	56	0.22	3.92	3.53
Absorption by capillarity (kg/(m ² ·min ^{0.5}))	28	162	1.177	1.201
Water absorption (bleed porosity for water) (%)	28	1.23	1.73	2.62

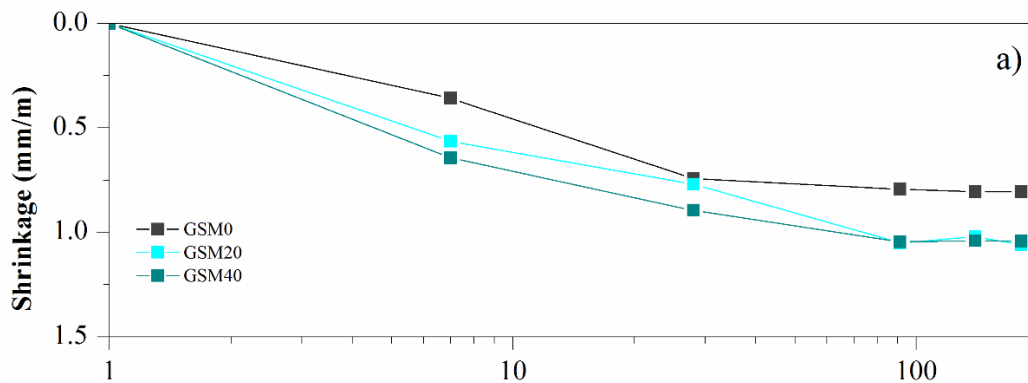


Figure 1. Shrinkage results.

4. Acknowledgment

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DIFFERENCE BETWEEN TREATED ABACA FIBERS IN CEMENTITIOUS MORTAR

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Keywords: natural fibers, abaca, NaOH treatment, cementitious mortar

1. Introduction

This paper has the purpose of analyzing the influence of different treatments of abaca fibers used in cementitious mortars. Three different treatments were made to abaca fibers before applying them to the mortar. The results indicated that these treatments did not increase the results in the mechanical properties; however, they showed a better behavior when trying to split its parts.

2. Materials and methods

The mortar used in this research corresponds to a relation cement - sand of 1:3 with a water flow of 105±5% according to NTE INEN 2518:2010. The cement corresponds to a hydraulic cement M type named GU provided by HOLCIM ECUADOR, the sand accomplishes the granulometric analysis required by ASTM C144-04. The abaca fiber was produced and collected in Santo Domingo-Ecuador by FURUKAWA PLANTATION. The amount of water varies according to the flow test determined for each treatment.

Three different treatments were applied to the abaca fibers: hornification (HR) (Ferreira et al. 2017), sodium hydroxide solution (3%) and water (HS) (Jiang et al. 2018) and finally an adherent solution of natural latex with a coating of silica fume (LS) (Silva et al. 2017). The fiber's length was determined by previous authors using 25 mm (Zukowski et al., 2018) (Ferreira et al. 2018) with a dosage of 0.2% of the mortar' solid weight. The amount of water required per each treatment is: HR 362g, HS 380g and LS 355g. These quantities were obtained after applying the flow test per sample.

Different tests were performed, such as: water absorption, setting time through Vicat Needle and bending and compression tests. A total of 34 samples were performed and tested.

3. Results and conclusions

Water absorption was measured drying the samples in a uniform way in a thermal balance (OHAUS). For this test the different treated fibers were immersed water for 8 hours. After this time, the test was performed. Sample with no fiber (NF) showed 70.74%, HS 74.71%, LS 52.59% and HR 73.20%. The results show that the treatment with natural latex and silica fume has the lowest absorption capacity and the two other treatments have almost the same percentage of humidity as the sample without fiber.

In order to measure the setting time, the VICAT Needle test was performed to a cementitious paste performed with 650 g of cement and the leaching water after leaving the fibers immersed for 8 hours in water. Samples with no fiber had an initial setting time of 136 min and a final one of 535min. while HS 148 and 497min; LS 137 and 479 min and HR 156 and 461min respectively. The results show that there is no critical variation between the different treatments.



The Bending and Compression test was performed applying the UNE-EN 1015-11 and the results are showed in table 1:

Sample	AGE					
	7 days		14 days		28 days	
	B (MPa)	C (MPa)	B (MPa)	C (MPa)	B (MPa)	C (MPa)
NF	2.3	14.5	5.9	17.8	8.5	19.3
HS	2.3	12.5	5.5	14.2	7.4	16.7
LS	4.7	12.5	6.2	17.2	6.5	15.9
HR	4.3	12.3	4.4	17.1	6.9	19.7

Table 1. Bending and compression test

The results show that the sample without fiber shows better results for both tests; however, the behavior of the samples with abaca fiber were more difficult to split for performing compression and flexural test, because there was a bonding action between the fibers and the cementitious composites. At day 28 the treatment with LS shows the poorest results, on the other hand the one with HS increases its strength. According to these results. None of the treatments were the appropriated in order to gain resistance; however, the visible behavior was that the treatment with NaOH was the hardest one to split its parts for compression test.

4. Acknowledgment

Special thanks to HOLCIM ECUADOR for materials, laboratory and equipment for the development of this research and CONSTRULADESA for laboratory tests.

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THERMAL BEHAVIOUR OF PLASTER COMPOUNDS WITH PLASTIC CABLES WASTE ADDITIVE

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Keywords: *Plaster compounds, Plastic waste, Thermal properties, Recycling, Construction waste*

1. Introduction

One of the main focus of construction material's industries is achieving sustainability, economic progress and social welfare (Gómez-Zamorano, Iñiguez-Sánchez, & Lothenbach, 2015). The use of alternative materials --which covers both the study and the development of their properties -- is one of the most important factors in the evolution of the construction sector (San-Antonio González, Río Merino, & Viñas Arrebola, 2013).

On the other hand, the production of large quantities of waste is generally linked to the current "throw-away" society. However, the capacity to dispose this waste is decreasing. Therefore, it is essential to influence the proper management of waste leading to procedures that transform it into a generating resource, in order to minimize the amount and reduce the use of raw materials (Jiménez Rivero, Guzmán Báez, Garcia Navarro, & González Cortina, 2011).

In this respect, the addition of waste in the so-called "traditional materials" becomes -- for materials manufacturers-- an alternative to achieve environmental sustainability indicators. This paper presents the obtained results of the study performed in the addition of plastic waste cables in gypsum matrices based in the Waste Framework Directive 2008/98/CE that prioritizes the prevention and reuse against the elimination and recovery of waste (del Río Merino, Garcia Navarro, & Villoria Saez, 2011).

2. Materials and methods

The matrix used was Placo Iberyola plaster, manufactured in San Martín de la Vega (Madrid), with European denomination A, fast setting and granulometry of 0-2 mm; the plastic waste (PR) is obtained at Lyrsa Álava recycling company after the cable recycling process. This added PR -- with a maximum particle size of 3 mm -- is easily obtained from the recycling plant and is composed of a heterogeneous mixture of thermoplastic and thermostable polymers (Barriguete, del Río Merino, Sánchez, Ramírez, & Arrebola, 2018). The PR is added to the plaster mix in three different percentages of 50% -60% -70% with a water/plaster ratio of 0.8. Subsequently the data obtained in the tests is analysed and compared with the values previously obtained in the reference specimens (without PR). All the specimens are manufactured according to the UNE EN 13279-2 (102, 2014).



Figure 3. Plastic Residue addition to plaster mix in 50%, 60% and 70%

Initially, the thermal conductivity coefficient was determined using the modified transient flat-bed



procedure defined in ASTM D7984 (2016, 2016). In the second phase, it was determined by the heat flow methodology defined in UNE-EN 12667 (2002).

3. Results and conclusions

The coefficient of thermal conductivity, λ , resulted from both methodologies, is similar in the compounds with PR and in the reference. It differs 25%, in the first experiment with the generic value assigned to the high hardness plaster (900- 1200kg/m³) in the Technical Building Code (0.43 W/mK) and 40-50% in the second experiment.

After comparison of the outcome values from the different mixtures, it is observed that thermal conductivity coefficient does not follow an increasing or decreasing relationship: the results are random even with an increase of the quantity of PR

In general terms, the thermal conductivity coefficient depends on the density: it is observed that the increase in the number of pores do not reduces the thermal conductivity (Villanueva & García Santos, 2001). However, the study of these compounds this property is not fulfilled by not observing an increasing or decreasing relationship between the two variables.

Although significant results were not achieved in terms of reduction of the thermal conductivity coefficient, the fact that it remains stable is also interesting.

Therefore, it could be considered that the material studied presents an interesting option to increase sustainability in the construction process:

- On one hand, the use of natural resources is reduced: the higher the percentage of residue is used in the mixture, the less amount of gypsum and water is needed;
- On the other hand, the amount of plastic waste is minimized by applying circular economy criteria. Hence, the plastic waste becomes a resource.

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STAINLESS STEEL SLAG WASTE. FROM WASTE TO RAW MATERIAL FOR THE MANUFACTURE OF SELF-COMPACTING CONCRETE

Julia Rosales, Manuel Cabrera, Adela P. Galvín, Ester Quirós, Juan Almagro, Francisco Agrela

Keywords: *stainless steel slag waste, self-compacting concrete, treatments, mechanical behavior, durability*

1. Introduction

The production of stainless steel is currently one of the most dynamic sectors of the manufacturing industry, due to a large increase in the use of this product. Considerable amounts of waste are generated from these factories (Huaiwei, 2011). This large amount of waste generated is not only a quantity crisis but also an environmental problem (Shen, 2004). The feasibility of using stainless steel slag waste (SW) as a substitute for cement (Rosales, 2017) has been demonstrated, improving the mechanical characteristics and demonstrating the feasibility of using the large amount of waste generated.

This study evaluates the cementing properties of stainless steel slag as a substitute for limy filler in self-compacting concretes (SCC). Based on other studies that analyze the use of industrial by-products for the production of recycled SCC (Felekoğlu, 2006). The limy filler was completely replaced with untreated slag and slag processed by crushing and calcination to evaluate its mechanical and durability properties.

2. Materials and methods

The present study evaluated three different SW processes, including unprocessed SW (SW-NP), crushing and sieving to obtain the fraction 0/125 μm (SW-C) and SW burned at a temperature of 800 ° C for 18 h (SW-B) to evaluate the influence of SW as a substitute for the filling in self-compacting concrete. To make a comparison of results, a control mixture was added (CONTROL). The physical and chemical properties of SW were analyzed, as well as, a mechanical behavior and durability studies were performed.

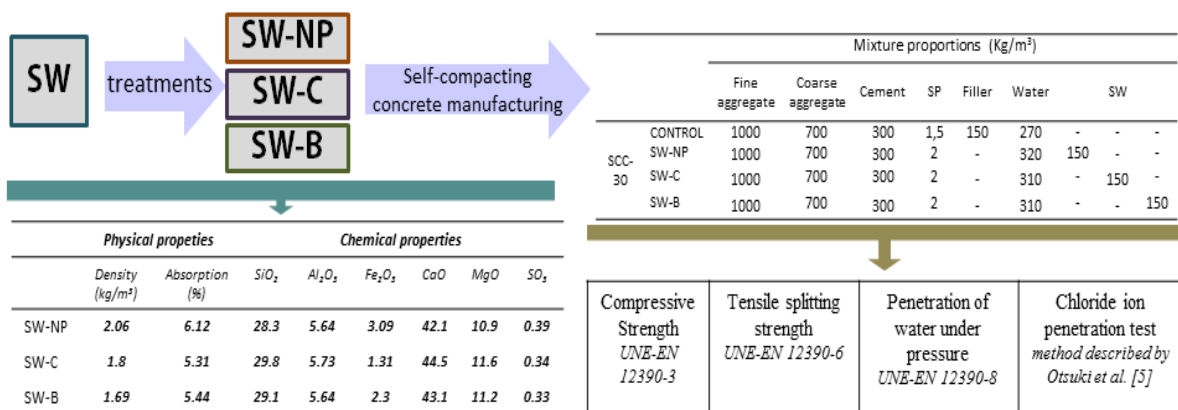


Figure 1: Experimental program



3. Results and conclusions

The following figure and table show a list of the results obtained more characteristic of all of the materials tested. Figure 2 shows mechanical properties and Table 1 shows durability properties.

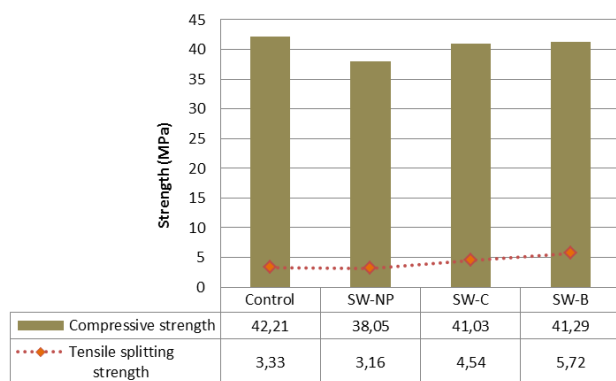


Figure 2: Mechanical properties

	Control	SW-NP	SW-C	SW-B
Water penetration (cm)	2.8	8.35	4.4	3.5
Chloride penetration (C)	6055	2242	2021	4146

Figure 2 shows that the loss of compressive strength respect to the control concrete was reduced. The compressive strength values improved when the SW were subjected to crushing and burned processes. On the contrary, the values of tensile splitting strength were higher in the SCC manufactured with processed SW compared to the Control.

Respecting the durability of concrete manufactured with SW, the results showed an improved performance compared to conventional SCC. The water absorption results were increased with the use of SW, mainly due to the absorption that characterizes this material. However, lower results were obtained regarding the penetration of chloride ion. The use of SW as a replacement of limy filler improves certain durability parameters obtained for SCC manufactured.

4. Acknowledgments

This work is part of the results obtained in the "Escorinox2 project", which received financial support from Acerinox Europa S.A.U.

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POSSIBLE USE OF FINE RECYCLED CONCRETE AGGREGATES IN THE IMMOBILIZATION OF ELECTRIC ARC FURNACE DUST (EAFD)

Enrique F. Ledesma, Angélica Lozano-Lunar, José Ramón Jiménez, José María Fernández, Ruan L. S. Ferreira

Keywords: *immobilization, recycled aggregates, electric arc furnace dust, circular economy*

1. Introduction

The Europe 2020 strategy aims to generate smart, sustainable growth and bet on an efficient economy in the use of natural resources. The concept of "circular economy" appears whose objective is to make efficient the use of resources based on the principle of "closing the life cycle" of the products.

Another type of waste generated is the powder of the electric arc furnace (EAFD) from the manufacture of steel from scrap. This waste is generated during steelmaking, and is toxic due to the zinc, lead and cadmium content (Tahir Sofilić et al., 2004). According to Decision 2014/955/EU of the European Union, gaseous effluents containing hazardous substances are classified as hazardous waste.

Decision 2003/33 / EC of the Council of the EU establishes the criteria for classifying materials according to the concentration of heavy metals and anions in: inert, non-hazardous and dangerous. Sometimes, the concentration of some metals exceeds the limits even to be classified as dangerous, so it must be reduced so that they can be disposed of in landfills for that purpose. To reduce this concentration, the EAFD must be immobilized. There are several studies in which cement-based materials are used to immobilize hazardous materials (Jin and Al-Tabbaa, 2014, Navarro-Blasco et al., 2013).

The objective of this study is to study the feasibility of using the concrete recycling aggregate (ARH) for the immobilization of the EAFD and its deposit in landfills.

2. Material and methods

Two families of mortars have been manufactured: (i) from natural aggregate as a reference, and (ii) with recycled concrete aggregate.

The mortar was dosed in weight with the following percentages of its components: 30% cement (CEMI 42.5 R / SR), 40% aggregate (natural or recycled-depending on the family in each case) and 30% siliceous filler. Table 1 shows the dosages that have been used. The amount of water was added experimentally to achieve a liquid consistency of the mortar within the limits of 230 ± 10 mm on shaking table (UNE-EN 1015-3: 2000). To evaluate the properties of the manufactured mortars, the following tests were carried out: i) density of the hardened mortar; ii) mechanical properties of the mortars, for this purpose cylindrical specimens of 80mm in height and 40mm in diameter have been used; iii) the rate of delitescence (XP X31-212) and iv) the study of environmental risk through the leaching test.



Tabla 1. Mortar mix proportions

Mortar type	CEM (g)	NA (g)	ARH (g)	SF (g)	EAFD (g)	Water (g)	w/c	Consistency (mm)
NA-REF	1200	1600	-	1200	-	1050	0.88	236
NAFD/2:1	799	1065	-	799	1337	1194	1.49	224
ARH-REF	1200	-	1600	1200	-	1233	1.03	234
ARHFD/2:1	799	-	1065	799	1337	1628	2.04	236

3. Results and conclusions

The conditions that the mortar must have to be considered a solid at 28 days of age must be at least 1 MPa of compressive strength, 0.1 MPa of indirect tensile strength and the rate of delitescence after immersion must be lower of 10%.

With the use of ARH for the immobilization of EAFD compression resistances of 7.35 MPa were obtained, well above the 1 MPa required. The density of the mortar hardened only under 17% with respect to the reference mortar.

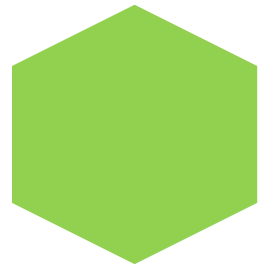
The concentration of heavy metals was reduced and allows these types of waste to be landfilled. In conclusion we can say that the use of ARH is a viable alternative for the immobilization of EAFD

4. Acknowledgment

The authors would like to thank the spanish public company ENRESA (Empresa Nacional de Residuos Radiactivos S.A.) for financial support this research via project ([035-ES-IN-0140](#)). This work was partly supported by the Andalusian Regional Government (Research Groups FQM-391 and TEP-227) and XXI Own Program for the Promotion of Research at the University of Córdoba – Modality 4.2.

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ENERGY EFFICIENT BUILDING



SIGNIFICANCE OF VARIABLES ON REAL MEASURED ENERGY CONSUMPTION OF RESIDENTIAL STOCKS

Marta Braulio-Gonzalo, M. Dolores Bovea, Pablo Juan, Andrea Jorge

Keywords: residential building stock, energy use, building features, statistical analysis

1. Introduction

The increase in energy consumption in the residential building sector has significant consequences in terms of environmental impacts and energy dependence. Numerous models exist in the literature that attempt to evaluate the buildings' energy use (Kavgic et al., 2010), but they are mainly based on estimations obtained from dynamic simulation tools. However, there is a gap between the real energy consumption and the estimated energy use that need to be analyzed in more detail. Also, recent literature explored the variables that influence the energy performance and thermal comfort in residential buildings (Braulio-Gonzalo et al., (2016). The aim of this work is to identify the variables related to building type, construction features, technical systems and usage habits that affect the energy performance of existing residential stocks based on real measured energy consumption data.

2. Materials and methods

To carry out the study, a survey was firstly designed to collect data about dwellings: real energy consumption, building/construction characteristics, technical systems and usage habits. For modelling the dwellings, energy consumption will be considered as a response variable, while the remaining data will be considered as covariates, as shown in Figure 1.

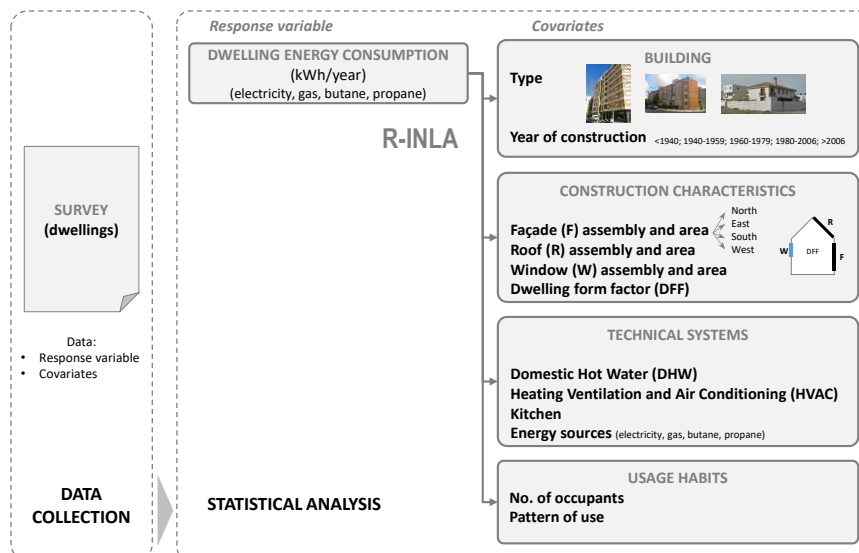


Figure 1. Methodological framework

A total number of 64 surveys were conducted in different dwellings in the city of Castelló (Spain), which corresponds to climate zone B3 according to CTE (2013). Subsequently, the collected data was statistically analyzed in order to identify the most significant covariates on energy consumption of dwellings, applying the Integrated Nested Laplace Approximation (INLA) methodology (Rue et al., 2009), which is based on Bayesian inference. INLA delivers an



integrated approach to make predictions and also allows conducting sensitivity analysis.

3. Results and conclusions

Fifteen INLA models were run, firstly combining the response variable with each covariate separately, and finally, another model integrating all covariates. The results showed that the inclusion of a higher number of covariates improves the model since DIC (deviance information criterion) and CPO (conditional predictive ordinate) become lower, the correlation coefficient between the predicted and observed values increase and the RMSE (root mean square error) decrease. The results of the best fit model are presented in Figure 2.

DIC: 1224.61
CPO: 56.4266
Correlation:
0.921655
RMSE:
1394.517

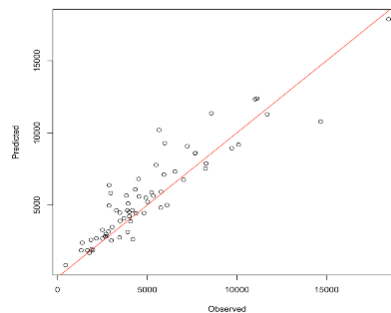


Figure 2. Results of the best fit model including all covariates

The INLA statistical analysis enabled us identifying that the most significant covariate on the final energy consumption is the number of dwelling's occupants, which demonstrates that usage habits play an important role on building energy performance assessments.

4. Acknowledgment

The authors are grateful to Universitat Jaume I, Convocatòria d'ajudes postdoctorals per a la incorporació a grups d'investigació de l'UJI (Spain). (Contract POSDOC-A/2017/17).

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CLIMATE CONTROL DEMAND ANALYSIS IN A DWELLING WITH PASSIVES STRATEGIES: ENERGY SIMULATION

Patricia Aguilera Benito, Sheila Varela Lujan

Keywords: *solar radiation; energy simulation; passive strategies; air conditioning demand; energy efficiency.*

1. Introduction

In Spain, the construction sector has a weight of 30% in final energy consumption, distributed in 18.5% in the residential building sector and 12.5% in non-residential buildings (Ministerio de Fomento, 2017). Due to this high percentage, it is interesting to reduce energy consumption and minimizing the carbon footprint. In addition, within the residential sector in the European Union, 24.1% of the population lives in semi-detached houses and 33.3% isolated homes, assuming a total of 57.4% of single-family homes, compared to 42, 6% of multi-family dwellings (Statistics Explained, 2017). In Spain the single-family dwelling is the second building typology built as the first residence (28.2%), considerably increasing its use as a second residence (46.9%) (Ministerio de Fomento, 2014).

In order to undertake measures aimed at optimizing the items with the highest consumption in the residential sector, especially in single-family homes, a detailed study of the different equipment is necessary. The air conditioning installations (heating and cooling) demand the most energy, both in Spain and in the European Union. This consumption in air conditioning is a variable depending on the climatology of the zone, from 43% in Spain, up to 65% in the whole of the European Union. It is also observed that the energy consumption by refrigeration in Spain, in relation to the average of the European Union, is 60% higher. Therefore, within the objectives of decreasing the demand for energy in the building sector, the aim is to reduce the loads for climate control in the residential sector.

2. Methods

In the detailed study of the building, it is very important to take into account the orientation.

In order to quantify the influence of passive strategies, we first look for a base model to work on and an energy simulation tool. Later, the model is analyzed with different passive strategies as the incorporation of passive elements, such as the installation of different types of glass and the installation of different lengths of cantilevers (Zalamea-León & García-Alvarado, 2018), taking into account the orientation of the dwelling.

3. Results and conclusions

In this section, the heating and cooling systems that must be installed in the different simulated models are evaluated.

- Incorporating simple glass with LCS in the East and South facades does not present a significant energy improvement in the heating demand in relation to the original model. In the refrigeration demand, the decrease of the system is of 7.3%. Incorporating double glazing in all orientations and comparing it with a double glass model with LCS in its East and South facades does not mean



a decrease in the demand of the heating system, however it is observed a great decrease in energy demand in the refrigeration equipment (30.7%).

- Replacing simple glass by double glazing supposes a decrease of the heating system of 28.3% and in the cooling system of 11.5%. In the same models, but both with LCS in their East and South facades, they have the same decrease in the design of the heating system (28.3%) but in refrigeration the equipment is reduced by 27.0%.

- Incorporating cantilevers in the East and South facades designed with a length of 6.60 m and 1.80 m, represent a decrease in the cooling system of 43.2% and 37.9% respectively. The difference is negligible for the heating system. Cantilever over 1.80 m on the east facade does not entail any significant energy difference in the cooling system (5.3%).

As a final conclusion, the results obtained in this research confirm again the importance of the detailed analysis of the geometry and orientation of the building in order to properly choose the glazing and the passive protections necessary for a building. A correct choice of them entails a decrease in the energy consumption necessary for the use of air conditioning inside the house.

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ENERGY SAVING POTENTIAL OF GREEN ROOFS IN SOUTH EUROPEAN CLIMATES

M. Porcaro, M. Ruiz de Adana, F. Comino, A. Peña, E. Martín Consuegra, T. Vanwalleghem

Keywords: *extensive green roofs; recycles substrates; energy saving*

1. Introduction

Green roofs are passive construction systems that allow to reduce the thermal loads of a building and decrease the temperature fluctuations of the roof assembly (Li, 2013). Green roofs also help to mitigate the urban heat island effect through evapotranspiration process, absorb CO₂ and retain meteoric water (Shafique, 2018). This work focuses on the study of extensive green roofs, which have a thickness of 60-200 mm and the plant species used require low maintenance (Besir, 2018).

The main objective of this study was to obtain experimentally the energy saving of three extensive green roofs with different substrates, compared to a traditional gravel ballasted roof, during the summer period, for the climatic conditions of Córdoba.

2. Materials and methods

The three plots with green roofs and a reference plot with gravel ballasted roof were installed in an office building located in the University of Córdoba. The substrates of the three green roofs were composed of commercial growing medium and recycled construction materials, each of them with a different percentage, see Figure 1. In each green roof, ten temperature probes were installed along the vertical profile of the parcel, five in the east side and five in the west side. Two heat flux probes and two water content probes were also installed, one in the middle of each side, see Figure 1. In the reference plot three temperature probes were installed in the middle of the parcel, along the vertical profile, and two heat flux probes, see Figure 1.

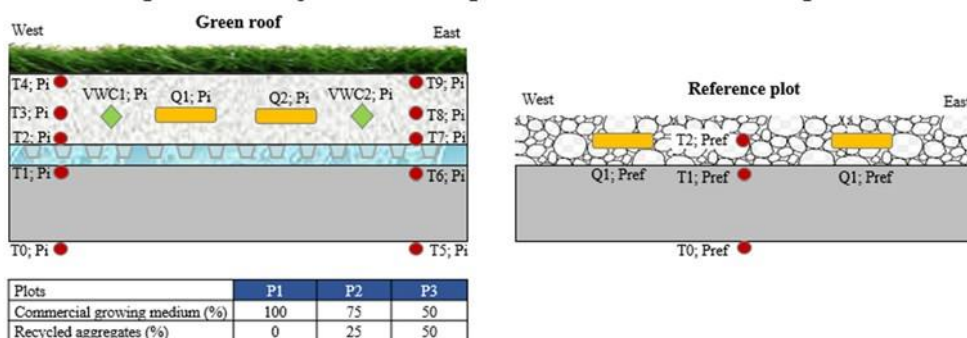


Figure 1. Plots layers and sensors of the green roofs and the reference plot.

Experimental data of heat flux were collected during the summer period of 2016, from June to September. The energy saving of each plot was calculated with Eq. 1, where q' is the heat flux [W/m^2] referred to the area of the parcel [m^2].



$$\text{Energy saving}(\%) = \frac{Q'_{ref} - Q'_{Pi}}{Q'_{Pi}} \times 100 \quad (1)$$

The results of energy saving of the three plots with green roofs, compared to the reference plot, are shown in Figure 2.

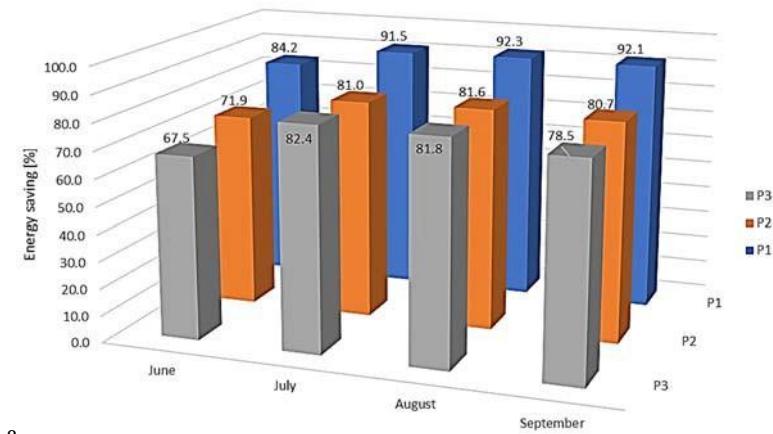


Figure 2. Energy saving of the three green roofs.

It can be observed that all plots with green roofs achieved energy saving greater than 67.5 %, with respect to the reference plot. The plot that achieved the best results was P1, with a mean value of energy saving of 90.0%. The greater reduction was obtained in August, with a value of 92.3%. This behavior is mainly due to the capacity of the substrate to retain water. The results suggested that all the green roofs allow a significant reduction of energy gains during the summer months. In conclusion, green roofs can be considered as an interesting passive construction system to achieve energy saving in buildings located in South European climates.

3. Acknowledgements

Weather data from the Agroclimatic Information Network of Andalusia which have been supplied by the Institute of Research and Agricultural and Fisheries Training of the CAPDR of the Andalucía Regional Administration, Junta de Andalucía. The authors would like to express appreciation for the financial support of the European Regional Development Fund (ERDF).

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EFFECT OF INTERNAL SKIN-PANELS METAL FRAMEWORK IN THE VENTILATED FAÇADES INSULATION

José Antonio Entrenas, José Ramón Jiménez

Keywords: Heat transfer, Thermal Bridge, Ventilated façade, Metal framework, Building simulation.

1. Introduction

To reduce buildings' energy demand, the façade is the architectural element that has received more attention in the building sector. Ventilated façades have significantly evolved in recent years for new construction and renovation of buildings. A ventilated double façade is a conventional single façade doubled by a second façade, either inside or outside. Each of these façades is commonly called a skin. A ventilated cavity is located between these two skins (Loncour et al., 2004). The external skin incorporates the exterior coating elements, which are generally glazed, although they can be metallic, ceramic or made from stone. The ventilation of the cavity can be natural, fan-supported or mechanical. The internal skin can be a conventional façade built with traditional masonry or new building materials, such as industrial panels.

The industrial panels used as internal skins are an advanced dry lining system formed by cement board outdoor panels and accessories for exterior finishing, a metal or timber framework, insulation materials, joint compounds and interior finishing options, such as gypsum boards. The use of these panels in ventilated façades allow builders to satisfy the growing demands of new technical codes to meet the sustainability criteria (Blázquez, 2012).

The goal of this study is to determine the effect of a metallic substructure supporting the internal skin-panels in the ventilated façades insulation by numerical simulation. The metallic profiles of the framework are the elements with higher thermal conductivity; therefore, these elements have a notably unfavorable influence on the equivalent thermal conductivity value of the façade. The spacings and thicknesses of the profiles depend on the actions on the façade; however, recommendations are given concerning the use of metallic profiles to save energy.

2. Materials and methods

A commercial ventilated façade system is used to simulate the thermal conductivity. Fig. 1 shows the analyzed model, where the boundary conditions and materials are represented by a color code.

The simulations were performed on two variations of panels with different insulation material thicknesses (60 mm and 80 mm), and two different profile spacings (400 mm and 600 mm) and thicknesses (1 mm and 2 mm) are used.

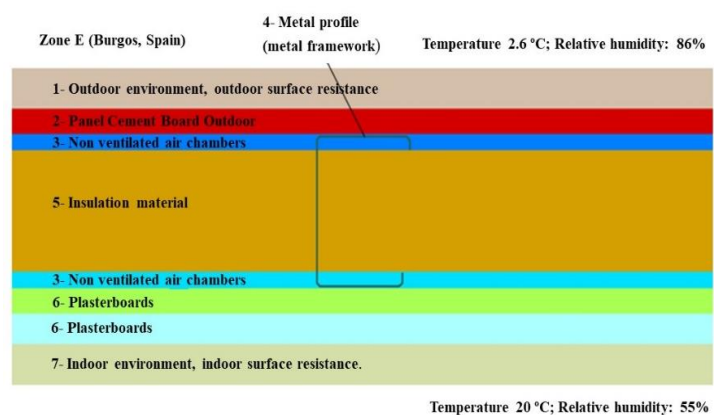


Fig. 1 Calculation model (Software BISCO)



3. Results and conclusions

Fig. 2 shows an example of the thermal flow lines analysis. Table 1 shows the values of the thermal equivalent transmittance (U_{eq}) for all variations tested.

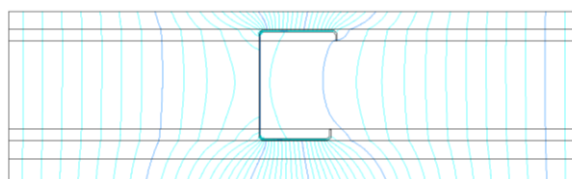


Fig. 2 Thermal flow lines

Table 2. Equivalent thermal transmittance (U_{eq}) in all alternatives studied

Alternative	Profile Spacing (mm)	Profile Thickness (mm)	Insulation Thickness (mm)	U_{eq} (W/m ² K)	Increase U_{eq} , in relation to reference values.
R1	-	-	60	0.426	-
V1	400	1	60	0.716	68.07 %
V2	400	2	60	0.776	82.16 %
V3	600	1	60	0.620	45.54 %
V4	600	2	60	0.660	54.93 %
R2	-	-	80	0.340	-
V5	400	1	80	0.637	87.35 %
V6	400	2	80	0.710	108.82 %
V7	600	1	80	0.538	58.23 %
V8	600	2	80	0.587	72.64 %

R1: Reference 1 (Cement board outdoor: 12.5 mm; Panel width: 75 mm; Plasterboards: 12.5 mm; Plasterboards with vapour barrier consisting of aluminium film: 15 mm).

R2: Reference 1 (Cement board outdoor: 12.5 mm; Panel width: 100 mm; Plasterboards: 15 mm; Plasterboards with vapour barrier consisting of aluminium film: 15 mm).

In reference cases without a metal framework, an increase of the thermal insulation thickness from 60 mm to 80 mm implies a decrease in the thermal transmittance of 20.18%.

The use of metal framework increases the equivalent thermal transmittance of the building envelope. It is preferable to increase the distance between metal profiles, even if it is at the expense of increasing the thickness of the metal profiles.

As a recommendation to save energy, when designing panels it is better to increase the distance between profiles than to use thinner profiles placed closer together, even if this approach involves increasing the profiles' thicknesses.

4. Acknowledgment

The authors thank the company Knauf GmbH Spain for funding a portion of this research.

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SELECTION OF CRITERIA FOR THE GREEN ROOF DECISION SUPPORT SYSTEM

Andrius Gulbinas, Daiva Makutėnienė, Airida Tylienė

Keywords: *Criteria for green roof selection, Green roof, Decision support system, expert systems*

1. Introduction

A green roof system is an extension of the roof which involves high quality water-proofing, root repellent system, drainage system, filter cloth, a lightweight growing medium, and plants. Roof is very important part of house and few ways are possible for renovation – to construct gable roofs with additional living space, recovering of constructions, and more possibilities – to make green roof. Because of green roof construction processes have many attributes, actors and criteria, Decision Support Systems (DSS) can be considered as one of the potential information technologies that can be applied to enhance the quality of design decisions.

2. Decision Support Systems for green roofing

The construction of green roof is complex. DSS can provide a list of well-proven construction companies, as well as contentious and problematic situations analysis, as well as construction drawings, costs etc. The goal of this article is to define the main criteria for the future DSS for green roofing.

The DSS also has the potential to be constructed as a system platform for implementing building information contained in BIM models, associated with other databases, analytical models, and expert knowledge. Green roof subject can have place in BIM, too. This article explores an opportunity to extend green roof design processes toward the decision support and artificial intelligence domains by applying the theories and principles of DSS. This research is the first step toward the development of web-based DSS for green roofing system selection.

Before examining the mechanism of the decision-making for green roofing system selection and defining main criteria, authors present briefly look at the typical assembly and generic classification of green roof systems. Contemporary vegetated roofing is frequently divided into two generic categories: extensive and intensive, based on virtue of the depth of its growing medium (Charoenvisal, 2013).

Defining the main criteria for upcoming DSS for green roofing is based on decision-making framework developed by Elizabeth J. Grant from her dissertation paper, *A Decision-Making Framework for Vegetated Roofing System Selection* (Grant, 2007). The framework was developed to help designers determine the most feasible green roof system for a particular project based on a summation of total importance of the advantages represented by each design alternative.

According to Suhr, the paramount advantage can be defined by the Defender-Challenger process (Suhr, 1999). The process starts with selecting one of the advantages as the initial defender and selecting another advantage as the initial challenger. After the paramount advantage is defined, the decision maker can begin to weigh the importance of each most important advantage, compared directly or indirectly with the paramount advantage based on the similar scale-of-importance, ranging from 0 to 100. After the crossover point is identified, the numeric scores of



importance of the advantage of a particular alternative can be estimated. It is interesting to note that this method allows the comparison results to be visually displayed.

As part of the article analysis, the criteria affecting green roof design was carefully defined and organized into six categories: storm water, energy, acoustics, structure, compliance, and cost. The framework by itself can be considered a navigable path through the decision-making process. From the perspective of DSS development, main criteria for green roofing defined by authors has considerable potential to be developed further in the form of computer-based DSS, especially in the category of Expert Systems (ES).

Theoretical analysis and defined criteria made by authors has considerable potential to be developed further in the form of an ES for solving green roof design problems, because it fulfills the four features of ES suggested by Turban et al. (Turban, Aronso, Liang, & Sharda, 2007) At the end of article the four features of ES that include expertise, symbolic reasoning, deep knowledge, and self-knowledge are analyzed.

3. Results and conclusions

Defining the main criteria for upcoming DSS for green roofing is based on a decision-making framework developed by Elizabeth J. Grant (2007).

The criteria affecting green roof design was carefully defined and organized into six categories: storm water, energy, acoustics, structure, compliance, and cost. The framework by itself can be considered a navigable path through the decision-making process.

From the perspective of DSS development, the main criteria for green roofing defined by authors has considerable potential to be further developed in the form of computer-based DSS, especially in the category of Expert Systems (ES).

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QUANTIFICATION OF NATURAL LIGHT USE IN FACADES

José Ramírez-Faz, Javier Gómez-Uceda, Rafael López-Luque

Keywords: *solar access in urban fabric; Solar Vision Factor*

1. Introduction

The incidence of natural light inside living spaces has a high impact on the health and psychological comfort of people and it also contributes to improving the indoor climate, at the same time it reduces the energy demand of the building (Márquez-García, 2013). Thus, the energy audit of buildings will require an in-depth analysis that allows each piece of the building to be known (Márquez-García). In the constructive phase, the knowledge of the degree of window exposure can determine the final design of the building (Gómez Muñoz, 2003). In addition, it allows us to choose the materials conforming the window, (transparent polymer, glass sheets and translucent polymer...) (Smith, 2004). This design method is increasingly needed in geographic areas where buildings require heating. In this sense, the Building Performance Simulation (BPS) tools compare from a theoretical point of view different models related to energy use and efficiency in buildings, providing quick and useful information to technicians [4]. However, in urban settings, this analysis can be complex, due to several existing interactions, including those with neighboring buildings or the effect of trees [7] and the fact that each neighbourhood must be studied independently [8].

2. Materials and methods

This paper presents a method for evaluating variables related to shading and solar access inside rooms. This method uses the LRTV (Light Ray Tracing and Visioning) device shown in figure 1. The reflection images of the spherical mirror must be treated by means of specific software to obtain the stereographic, polar, Lambert hemispherical projections. Its advantage is to avoid the need to characterize geometrically both the building under study and the adjacent buildings, as well as all possible obstructions.

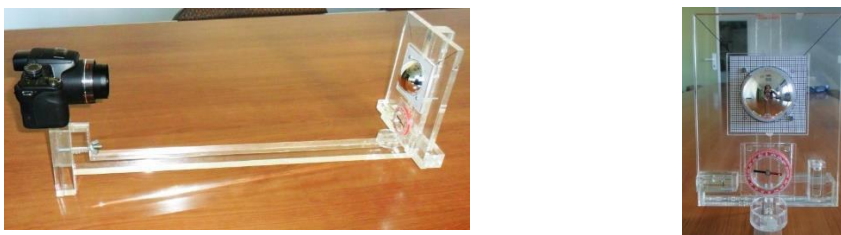


Figure 1. Arrangement of the LRTV device to take the photograph to characterize a vertical hole.

The application of an astronomical algorithm for every image in the same facade made it possible to represent the solar trajectories on the 15th of each month. This algorithm has been the basis of the results presented in figure 2. It shows the possibility of graphical representation incidence moments (red lines) during day hours (white sections). The precise knowledge of the instants in which solar incidence occurs enables us to determine the incidence schedules for the representative days of each month. Figure 2 shows these times, both in solar and GMT+1 time.

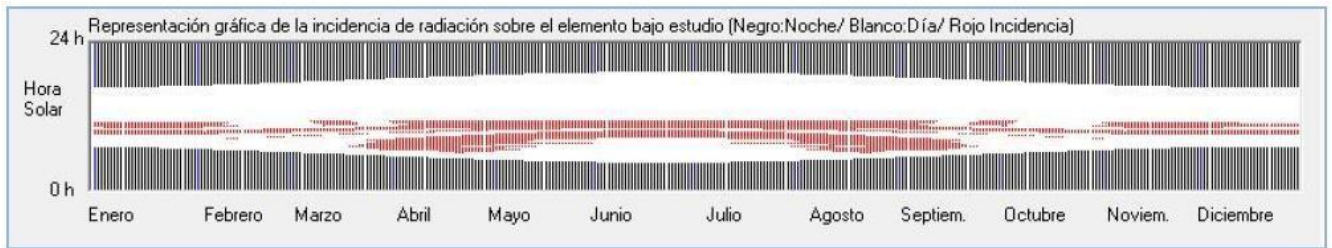


Figure 2. Graphical representation of light hours received in a window

A systematization when taking images in all the windows of a building, allows to map on the building facade the potential of solar incidence during the representative days of the year. Figure 3 shows the sunshine potential for the month of June on the west facade of Building C2 in Campus of Rabanales (University of Cordoba, Spain).

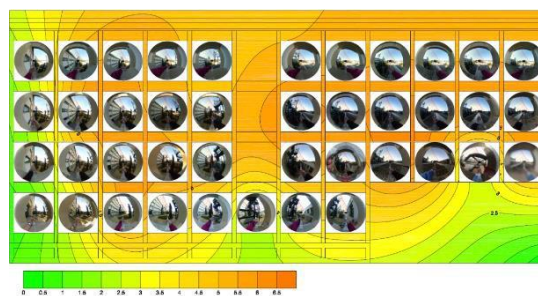


Figure 3. Graphic representation of the hours of light received in the West facade of the C2 building and stereographic view of the visual vaults from each window.

3. Results and conclusions

Obstruction angles, sunshine duration on any given day, vision factor can be measured by image interpretation algorithms. Graphical outputs obtained from the computer application allow to interpret numerical results. The SKY tool developed for this purpose is an aid element for the improvement of the built-space audit.

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DEVELOPMENT OF INSULATING MATERIALS FOR THE CONSTRUCTION BASED ON EXPANDED AGGREGATES IN A GEOPOLYMERIC MATRIX

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Keywords: *geopolymers, expanded aggregates, insulation materials, thermal conductivity, industrial by-products.*

1. Introduction.

The present paper will develop an insulation material for buildings with a high percentage of industrial by-products and with suitable resistance and durability properties. To this end, expanded aggregates will initially be formed starting from clay materials that will be, in different percentages of addition, the basis of the density decrease of the final material, and therefore, of the thermal conductivity.

The mortar employed for the manufacture of the insulation materials will be a geopolymer composed with the main by-product of the ceramic industry, named chamotte, which belongs to the ceramic products that, as consequence of their form and aesthetics, are rejected. In order to achieve the proper mechanical resistance, this material must be activated with compounds for such purpose, creating a resistant material with low CO₂ emissions in its manufacturing.

Subsequently, different percentages of expanded aggregates will be added, studying the physical properties of the materials obtained, its resistance and, obviously, its thermal conductivity.

2. Materials and methods.

The materials used in this project are mostly industrial by-products, creating a material that is sustainable with the environment and with low CO₂ emissions during its manufacturing; among the materials used to conform the geopolymer, the main one is the chamotte, which is produced by the ceramic industry, and the activator capable of producing appropriate mechanical properties of geopolymers. At the same time, as a way to improve the insulation, light aggregates will be developed through the expansion of clay and the addition of other by-products, with the purpose of reducing its density and, therefore, its thermal conductivity. The different percentages of addition of this material will create diverse insulation materials which will be subjected to the main tests of compressive strength, absorption coefficient and thermal conductivity, being able to determine the one with the best initial and service properties.

Therefore, once the materials and the relevant tests have been described, the methodology to be followed is more specifically detailed:

- Physical and chemical characterization of clay and the different by-products additives to conform the expansive aggregates.
- Study of the physical properties of the aggregates obtained and selection of the optimal conformation process.
- Physical and chemical characterization of the chamotte, the industrial by-product.



- Conformation of geopolymers with different water proportion and activator at low temperature.

Study of the mechanical properties of the different geopolymers conformed and selection of the optimal process which obtains the highest resistance.

- Conformation of the insulation material with the selected expanded aggregates and with the highest mechanical resistance geopolymer, for that purpose the expanded aggregates will be added to the chosen geopolymer until it reaches a limit of coherent workability.
- Study of the thermal conductivity, absorption coefficient and mechanical resistance of the different materials conformed to the different proportions of expanded aggregates, along with their physical properties.
- Obtaining of the optimal expanded aggregates addition to the geopolymer with proper physical, mechanical, insulation and durability characteristics.

3. Results and Discussion.

The monitoring of the detailed methodology, as well as the determinate study, have shown that the expanded aggregates obtained have good mechanical characteristics to be used as addition to the geopolymer, obtaining at the same time a relatively low density which will be essential to achieve the insulation of the final material. Furthermore, the geopolymer obtained from the activation of the ceramic industrial by-product has shown a proper resistance just as durability properties. In the combination of the materials previously mention a gradual and expected decrease of its density and conductivity with the increasing addition of expanded aggregates to the studied geopolymer has been observed. However, its mechanical resistance decreases with its addition. Therefore, and based on this, a practical limit has been set, in which the physical properties are not sacrificed and a low conductivity is obtained along with suitable physical characteristics; creating an insulation material with low CO₂ emissions during its process and with the use of a high percentage of low cost industrial by-products.

4. Acknowledgments.

The group TEP 222 Materials and Mine Engineering appreciates the assistance provided by the Superior Polytechnic School of Linares, University of Jaen.

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STUDY OF TWO VARIABLES ASSOCIATED WITH THE RADIATIVE EXCHANGE OF WINDOWS AND THE DEGREE OF VISUAL COMFORT

Marta M. Varo-Martínez, José Ramírez-Faz, Rafael López-Luque, Luis M. Fernández-Ahumada

Keywords: *Daylight and solar access; Sky Vision Factor ; Sky Opening Index*

1. Introduction

In order to develop the energy audit of existing buildings, effective devices and procedures are required to evaluate the potential for solar accessibility of openings and windows. Window insolation is related to solar gain, the potential for natural lighting or the need for sun protection. The *Sky View Factor* (SVF) index or radiative exchange factor between the window and the open sky is used for its characterization. As an indicative parameter of psychological comfort, the *Sky Open Index* (SOI) is used, or solid angle with which an observer can appreciate the sky being in the center of a window. Published methods to characterize these indices require extensive geometric characterization of solar obstructions (Alzoubi and Alshboul, 2010; Compagnon, 2004; Gómez-Muñoz, 2010). In this work it is shown, by the means of a practical case, the suitability of use of the device LRTV, to determine them and to be able to interrelate them.

2. Methodology

The Light Ray Tracing and Visioning (LRTV) device consists of a flat platform with a hemispherical mirror. An arm, which is perpendicular to the platform, enables to hold a conventional camera by placing its optical axis perpendicular to the platform and coinciding with the center of the mirror. In order to enable the correct levelling and alignment of the lens plane with vertical (windows) or horizontal (skylights) faces, three levels of bubbles are arranged in this section. Figure 1(a) shows a photograph device. This device has a disadvantage, that is, in a hemispheric photography the camera and the device arm will appear, however, a correct interpretation of the image allows to obtain useful images in all cases.



Figure 1. (a)LRTV device; (b)Window imaging

3. Results of the building of the Faculty of Philosophy and Psychology of the University of Seville (Seville, Spain)

The results will be presented for the building shown in figure 2. There are S-W facing walls with azimuth 19.8° S-W and N-E facing walls with azimuth 109.8° N-E, highlighted in red in figure 2.



Figure 2. S-W and N-E orientation faces (Google-Earth source)

The methodology presented in the work, allows to automate how to obtain SOI and SVF. In order to understand its interdependence, the pairs of values associated with each window have been represented in figure 3. Different dot marks have been chosen according to the orientation of the openings and windows.

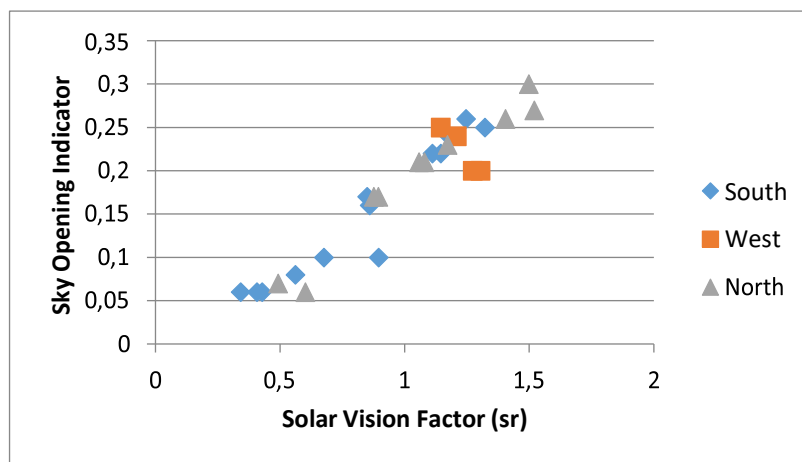


Figure 3. Relationship between the variables indicating the opening of the sky in windows of different faces

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ASSESSMENT OF EARLY DEGRADATION OF GLAZING SYSTEMS WITH DAMAGED SOLAR CONTROL FILMS

Júlia Pereira, Henriqueta Teixeira, Maria da Glória Gomes, António Moret Rodrigues

Keywords: *solar control film, early degradation, glazing system*

1. Introduction

Solar control films (SCF) are an innovative and efficient solution for glazing refurbishment in buildings. These materials, when correctly applied on the glass surface, can increase the thermal and energy performance of indoor environments by altering the thermal and optical properties of the glass (Moretti, 2015). According to EN 15755-1, these films change the solar factor of the glass by modifying parameters, such as the solar transmission, reflection, absorption and transmission of ultraviolet and visible light.

The present study intends to identify the current state and conditions of solar control films applied on the external surface of the glazing system of a building of the case study that suffered an early degradation. For this, several inspections were made in order to evaluate the main problems associated with the current glazing system.

2. Materials and methods

The building of the case study is located near the Tagus estuary in Lisbon, Portugal, and mainly consists of offices and conference rooms. The building presents a high window-to-wall ratio and, due to several problems associated with high solar gains through the glazing system, a solar control film (SCF) with a high reflective coefficient was installed. However, the film suffered an early degradation and shows several problems regarding its integrity. Several exploratory visits were made in order to assess all the pathologies existing in the glazing system of the case study.

3. Results and conclusions

Figure 1 shows some of the existing pathologies representative of the actual SCF degradation conditions that consist essentially on tears (Figure 1 a), cracks (Figure 1 b), blistering (Figure 1 c), lack of transparency (Figure 1 d), detachment (Figure 1 e) and deterioration of the external layers of the film (Figure 1 f).

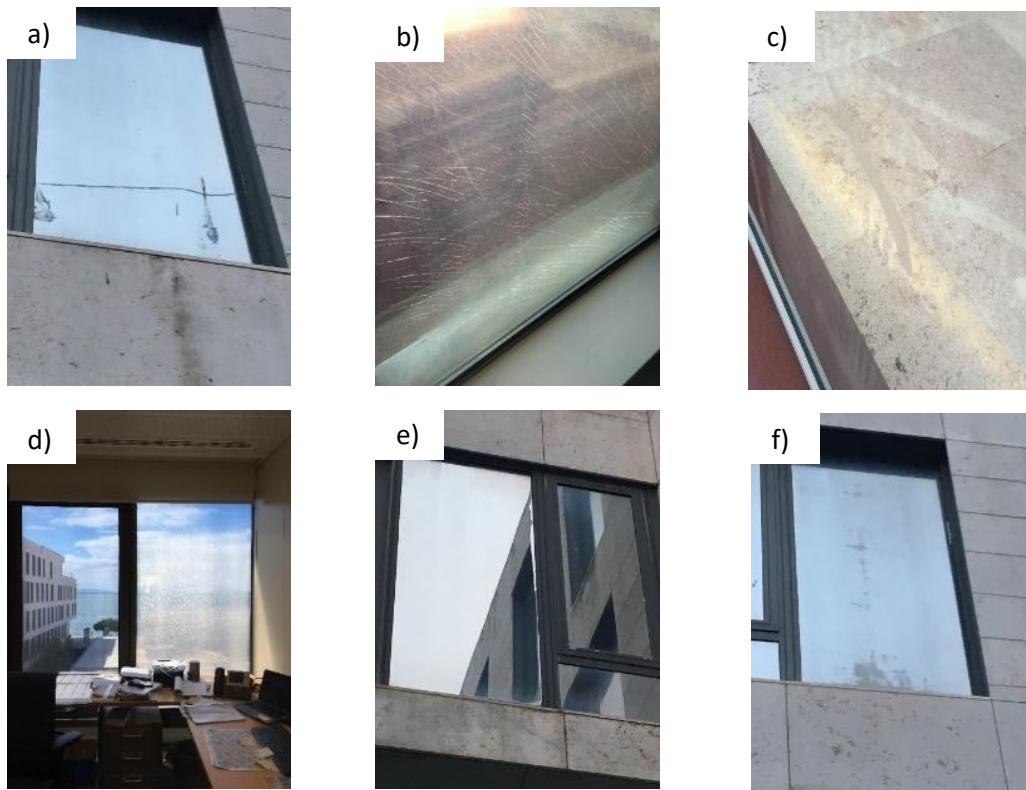


Figure 1. Existing solar control films pathologies: a) tears; b) cracks; c) blistering; d) lack of transparency; e) detachment; f) deterioration of the external layers of the film

The physical conditions of the existing SCF demonstrate that the optical and thermal properties of the film are not homogeneous throughout the glass area and can vary from office to office, depending on the level of deterioration of each film. These conditions decrease the external visibility through the glazing system and create luminous and thermal asymmetries in the indoor space, reducing the building's energy efficiency, indoor thermal and luminous environment and the occupants' satisfaction with the workspace comfort conditions.

4. Acknowledgment

The author wishes to acknowledge the support of FCT (Foundation for Science and Technology) PhD Grant FCT PD/BD/127848/2016.

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NUMERICAL SIMULATION OF THE PERFORMANCE OF GLAZING SYSTEMS WITH SOLAR CONTROL WINDOW FILMS

Henriqueta Teixeira, Júlia Pereira, Maria da Glória Gomes, António Moret Rodrigues

Keywords: *Solar control window film, Numerical simulation, Energy consumption, Thermal and optical performance,*

1. Introduction

The rapid rise of the world's population and its lifestyle quality have led to a global increase in energy needs. Today's energy systems are dominated by fossil fuels which are responsible for the emission of greenhouse gases, primarily CO₂, acting as drivers of global climate change. Therefore, a transition to a more efficient use of energy is needed. Globally, in 2015, the building sector consumed 30% of the final energy. Buildings with large window areas tend to have more heat transferred between the interior and exterior through the glazing systems, causing an increase on the cooling and heating loads. Applying solar control window films (SCWF) on existing glazing systems can reduce the heat gain, the annual energy consumption and peak demand load (Yin, Xu, & Shen, 2012). In the present study, an evaluation of the thermal, optical and energy performance of different types of SCWF applied on the glazing system of a non-residential building, in Lisbon, is made. The evaluated results were obtained from EnergyPlus building energy simulations, calibrated with experimental results.

2. Materials and methods

Three adjacent offices located in the first floor of the Mecânica III building (Figure 1) of Instituto Superior Técnico, in Lisbon, were used as case study: with an exterior film (RHE20SIERHPR), one with an interior film (R35SISRHPR) and another without SCWF. An experimental campaign was conducted in the offices during heating and cooling seasons (Lourenço, 2016). Before building the EnergyPlus simulation model, the window software Optics6 and Window 7.6 were used to estimate the thermal and optical properties of the glazing system without and with the SCWFs (a list including the two films used during the experimental campaign and 10 new ones with different properties). With SketchUp, a 3D model of the offices was generated (Figure 2). The outputs obtained from the abovementioned programs were used as input parameters in the EnergyPlus simulation model and the typical meteorological year climate data of Lisbon was associated. The EnergyPlus model was first calibrated using the experimental data from Lourenço (2016) and then used to perform the simulation of the remaining glazing systems.

3. Results and conclusions

Due to SCWF RHE20SIERHPR's low visible transmittance ($\tau_v=16\%$) and low solar heat gain coefficient ($g=0.2$), a comfortable temperature range (18°-25°C) was achieved during 41% of working hours, when installed on the glazing system. Considering the same film, in 43% of working hours the glare comfortable zone (DGI of 18-22) is achieved. From the considered SCWFs, the one referred to above has the highest thermal and optical performance. Comparing with the glazing system without SCWF, the installation of film PR70EXT ($\tau_v=70\%$; $g=0.48$) has



the highest energy performance, enabling to achieve the highest reduction (38%) of the annual electricity consumption (Figure 3), annual electric peak demand load and annual CO₂ emissions. When considering the different exterior façade orientations of the building, the highest energy performance was obtained with the film PR70EXT installed on a West oriented window.



Figure 1 – Office’s glazing systems identified on the exterior façade (Southeast) of the building.

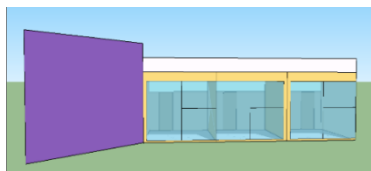


Figure 2 – 3D Simulation model of the case study’s offices, using SketchUp.

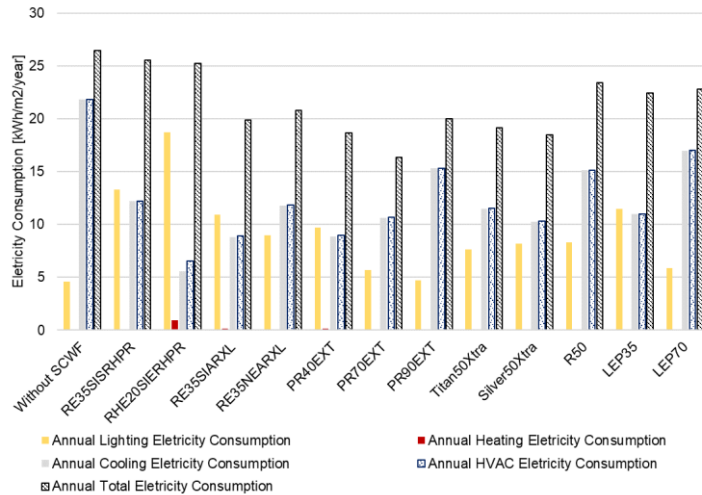


Figure 3 – Annual electricity consumption for considered glazing systems.

4. Acknowledgment

The authors would like to thank the office rooms’ occupants and Impersol company for the collaboration in the present study. The second author wishes to acknowledge the support of FCT (Foundation for Science and Technology) PhD Grant FCT PD/BD/127848/2016.

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THERMODYNAMIC BEHAVIOR OF TRANSITIONAL SPACES IN ARCHITECTURE. REVIEWING THE MAIN THERMAL TEMPERING PARAMETERS

Carlos Rivera-Gómez, Carmen Galán-Marín Carmen, Eduardo M. Diz-Mellado, Victoria López-Cabeza

Keywords: *Climate change; Courtyards monitoring; Aspect ratio; Diurnal Temperature Range; Maximum outdoor temperature;*

1. Introduction:

Due to the ongoing global warming, heat mitigation strategies are becoming more and more important. Furthermore, the growth of the cities influences the urban climate and may lead to a localized increase of air temperature. Elevated air temperatures, especially during the summer season, may have major implications for building energy demand, local air quality, and outdoor thermal comfort.

Courtyards have been traditional popular architectural resources, common in warm- climate Mediterranean cities. Thermal regulation provided by passive strategies such as t h e courtyard design can lead to considerable energy savings. There are many possible strategies to improve the thermal tempering efficiency inside the courtyard. Especially in hot and dry climate (Zamani, 2018), the geometry of the courtyard form affects considerably the shadows produced on the building envelope, and, consequently, the received solar radiation and the cooling and heating loads of the building (Taleghani, 2018). Therefore, heating and cooling loads for different courtyard shapes should be evaluated. Courtyard shape can be defined by basing on the aspect ratio (AR). AR is the ratio of courtyard width (W) to courtyard length (L) (Al-Masri , 2012).

2. Materials and methods

The possible feedback between the courtyard geometry and its effectiveness as a thermal regulator depending on the outdoor temperature has been investigated. Accordingly, several studies done through field measurement regarding the thermal behavior of a number of courtyards in different Spanish cities are described. Specifically, we explored the diversity of microclimatic conditions in and around a number of geometrically different courtyards.

The results show the importance of the specific geometry of a courtyard in view of the courtyards' microclimate.

3. Results and conclusions

The evaluation of the courtyard performance in a complete daily cycle through the DTR analysis supports the tendency detected for the maximum outdoor temperature, according to which a greater thermal range shows greater effectiveness of courtyard thermal tempering. It is also possible to establish a correlation between the courtyard aspect ratio and the diurnal thermal range gap between the outdoor and courtyard. Furthermore, analyzing the courtyard diurnal thermal range percentage within the proposed adaptive thermal comfort range, it can be verified that for the bigger aspect ratio the courtyard is 100% within an adequate thermal comfort zone.

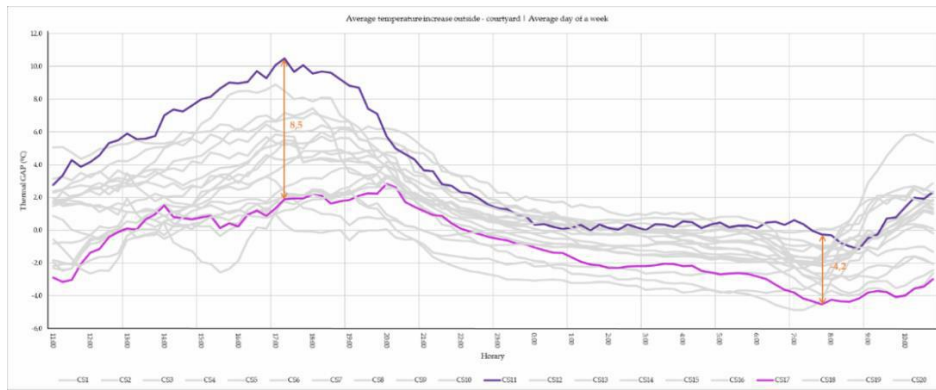


Figure 1: Thermal gap representation contrasting all the courtyards temperatures versus the outdoor ones.

4. Acknowledgment:

This work has been supported by the National Government of Spain Research Project MTM2015-64577-C2-2-R, Ministerio de Economía y Competitividad. The authors also want to thank AEMET (Agencia Estatal de Meteorología - State Meteorological Agency, Spanish Government) for the data supplied.

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IMPACT OF HEIGHT/WIDTH PROPORTIONS ON THE THERMAL COMFORT OF COURTYARD TYPOLOGY FOR SPANISH CLIMATE ZONES

Eduardo M. Diz-Mellado, Eduardo , Carmen Galán-Marín,
Carlos Rivera-Gómez

Keywords: *passive cooling systems; Courtyards; Aspect ratio; Thermal comfort; Adaptive thermal comfort.*

1. Introduction.

Currently, international organizations such as UN admonish countries to adopt measures facing climate change effects. In the Paris Agreement (Nations, 2015) on climate change, global warming was limited up to 2°C. From the last climate change summit, held in Katowice (Poland) on December 3rd, 2018, the rules for a correct implementation of the Paris Agreement for 2020 were detailed. It is in this context of collective will to reduce the climate change effects, where courtyard acquires a singular meaning, especially in warm climates as the Spanish one.

2. Materials and methods.

Thermal behavior inside the courtyards is determined by different variables (Zamani, Heidari, & Hanachi, 2018). Not all these variables, and not in all cases the same variables, determine the same degree of courtyard internal microclimate modification. Some of them stand out with respect to others due to the relevance of different aspects in the courtyard thermal regulation ability and, as a result, in the reduction of the climate change effects. Characteristic aspects such as geometry, orientation and location in a climatic environment, are the most studied so far; but there are others, such as the use of shading elements (Soflaei, Shokouhian, Abraveshdar, & Alipour, 2017) and property (Wilmers, 1990), or albedo characteristics, which are also fundamental and influence the temperature of buildings. The aim of the present research is to assess the influence of the thermal variables and the distinctive parameters of the courtyard thermoregulatory performance as a positive tool against climate change aftermaths.

3. Results and conclusions.

Therefore, a set of courtyards with different characteristics and geographic locations were compared to analyze their thermal behavior. The results of the monitored case studies corroborate (Figure 1) the initial hypothesis, according to which when daytime temperatures begin to rise, the outdoor-versus-courtyard thermal gap is positively emphasized, while, when night temperatures are significantly lower, this thermal gap is negative. This tempering effect is positive for the courtyard's adjacent locals passive cooling, reducing the overall energy demand of the building and favoring, at the same time, a mean courtyard temperature within the thermal comfort range.

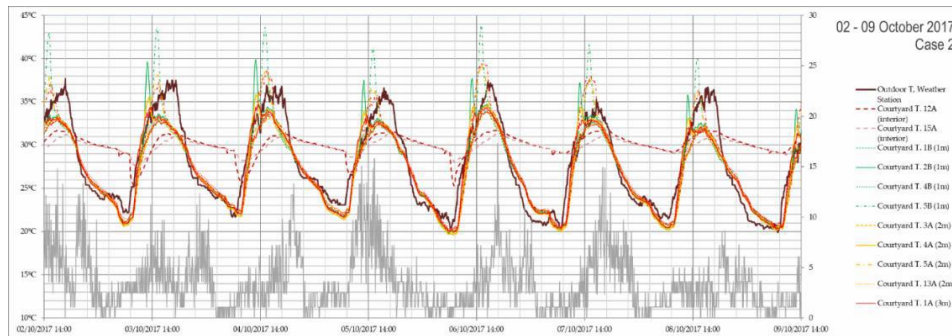


Figure 1: Example of the courtyard monitoring results graph.

4. Acknowledgment

This work has been supported by the National Government of Spain Research Project MTM2015-64577-C2-2-R, Ministerio de Economía y Competitividad. The authors also want to thank AEMET (Agencia Estatal de Meteorología - State Meteorological Agency, Spanish Government) for the data supplied.

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THERMAL PERFORMANCE EVALUATION IN HIGH SCHOOL BUILDINGS: METHODOLOGY CALIBRATION AND CASE STUDY ANALYSIS

**José Antonio Romero-Odero,, Carmen Galán-Marín,
Carlos Rivera-Gómez**

Keywords: *Outdoor and indoor air temperature; Atrium monitoring; Adaptive thermal comfort; Building energy savings; Free running buildings.*

1. Introduction.

The process of climate change has increased the planet's temperature, especially in locations with warm climates, an example of which can be found in the abnormal temperatures in the cities of Córdoba and Seville in July 2018 reaching 44.3°C. In this scenario, the educational centers in Andalusia, mostly built during the 20th century, are unable to reach the thermal comfort situation inside alongside the year without resorting to mechanical air conditioning procedures. In some of these buildings it is possible to reach very high temperatures inside the classrooms in the hottest months of the year.

2. Materials and methods.

This paper proposes the indoor, outdoor and transitional spaces simultaneous monitoring of a case study to verify the effectiveness of the passive cooling systems and the thermal envelope effectiveness of the building. Field monitoring campaigns are proposed in three periods, according to three main thermal ranges: winter, summer and intermediate seasons.

In addition, the study proposes the users' thermal comfort perception analysis, considering the adaptive comfort methodology. For this purpose, surveys have been conducted, and their results have been compared with the thermal monitoring data in order to establish the refurbishment recommendations regarding the current design and the potential building improvement proposals.

3. Results and conclusions.

The selected case study is "IES Murillo" (Seville). At this moment, the winter monitoring campaign has been done, and it is possible to observe the building thermal performance with medium / cold temperatures. The Atrium space turns out to be energy accumulators that help to regulate the temperature during the course of the day, inside the building. So, the tempering function of these transitional spaces is demonstrated.

On the other hand, this study can prove that the classroom inside temperature are influenced by the orientation and their opening direction (to atrium or to outside). Finally, the last floor classrooms happen to be the ones with higher temperature increase.

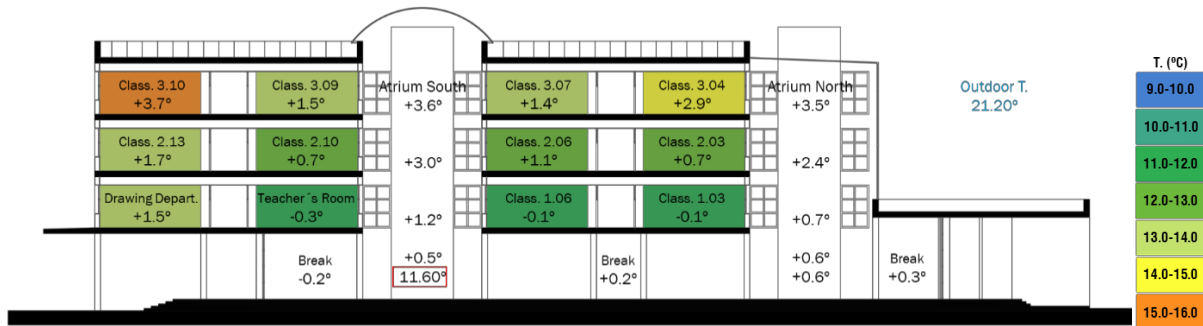


Figure 1: Example of the case study section. Temperature record [I 6/01/19 - 16:00h].

4. Acknowledgment

This work has been supported by the National Government of Spain Research Project MTM2015-64577-C2-2-R, Ministerio de Economía y Competitividad. The authors also want to thank AEMET (Agencia Estatal de Meteorología - State Meteorological Agency, Spanish Government) for the data supplied.

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BIBLIOGRAPHIC ANALYSIS OF CLIMATIC CLASSIFICATIONS AND THEIR APPLICABILITY IN BUILDING

Juan Jesús de la Torre Bayo' Carmen Díaz-López, Emilio Martínez Ibarra, Emilio Molero Melgarejo' Montserrat Zamorano

Keywords: *Climate classification, green construction, island heat effect, H2100.*

1. Introduction

Climate change is possibly the biggest environmental challenge to face in this century, due to its global dimension, and its profound social and economic implications. One of the main actors of the acceleration of climate change and the exhaustion of natural resources is the construction industry, being responsible for 40-50% of everything the use of energy in the earth, increasing the anthropogenic emissions of greenhouse gases greenhouse (Hamdy, 2017).

Consequently, the construction can have a direct impact on the atmospheric conditions of the place. In this context, it is essential to study the regional climates to foresee the adverse effects of the building and take the appropriate measures to avoid or minimize the damages that can be caused in the medium and long term (Macías, 2010).

It is of vital importance to reach a balance between the climatic zones assigned to a region and the construction that is going to be carried out in the place, prioritizing the sustainable building model that adapts to the climatic conditions of the area, mitigates the adverse effects of climate change and offers the potential to adapt to possible climate alterations.

2. Materials and methodology

This is a bibliographic review in which, first of all, the most important climatic classifications worldwide and at the state level in Spain have been collected, analyzing the climatic variables, types of classification, methodology and applicability.

The second part of the investigation corresponds to the relation between climate and building, in which classifications have been studied, generally bioclimatic, which have been developed in several countries of the globe. In Spain, the classification has been analyzed, climate exposed in the Technical Building Code (CTE), along with other publications at the regional level that aim to zoning the territory in the search of a better efficiency in the construction sector.

3. Results and conclusions

The proposed guidelines to obtain a potential classification should serve as a starting point for the bioclimatic design of buildings, including the impact of the heat island effect and adaptable to the H2100 trends (Sánchez, 2008).

- Unlike the current CTE (Código Técnico de la Edificación) classification, the interpolation of climate variable data for municipalities without registries should be done regarding



differences of latitude and longitude, besides altitude, given the importance of these factors in the climatic conditions, and consequently in the building.

- To combat the heat island effect through building, it is considered viable to develop the bioclimatic charts in the main cities of Spain to identify the possibilities of urban microclimates and to be able to combine these results with those obtained by climatic severities.
- In order to adapt the climate classifications to the H2100, the proposal is to apply this methodology with the prediction data that the IPCC marks, having as a goal the development of zoning that adapts to the climatic conditions.

4. Acknowledgment

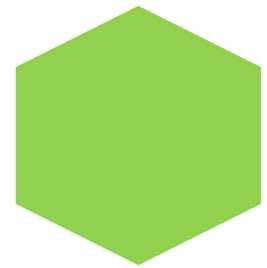
This project has the support of the Biodiversity Foundation, the Ministry for the Ecological Transition and the research group TEP-968 Technologies for the circular economy.

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ENERGY SOURCE AND RENEWABLE ENERGY





PUMP-AS-TURBINES FOR ENERGY RECOVERY: AN ATTRACTIVE SOLUTION FOR AUTO CONSUMPTION IN AGRICULTURAL FARMS

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Jorge García Morillo

Keywords: *Pump as turbine; Energy recovery; Irrigation networks; GHG emission savings; Auto consumption*

1. Introduction

Agriculture is one of the largest energy consumers in the European Union (EU), accounting for around 2.2% of the total energy consumed in 2016 (European Commission, 2019). In some regions where agriculture is an intensive activity, this consumption is even more significant. In the case of Spain, agriculture was reported to consume 3% of the total energy in 2016, which constitutes an increase of 43% since 1990 (IDAE, 2019), being responsible for important greenhouse gases (GHG) emissions and climate change contributions.

This research aims to study the potential benefits of pump as turbine (PAT) installations for energy recovery and auto consumption of this energy at farm level in pressurised irrigation networks, recovering energy from the existing excess pressure that is currently dissipated. The design and potential savings of a micro hydropower plant, which aimed to replace a diesel generator for a PAT in a farm located in Southern Spain, is discussed in this research.

2. Materials and methods

The research has been carried out in a farm located at the left bank of the Genil river irrigation district (GMI), in Southern Spain. The irrigated farm has a surface of 163 ha, with walnut as the sole crop. The hydraulic infrastructure feeding the farm is part of an on-demand irrigation network, where water is available 24 hours per day. Different devices on the farm require electrical energy during irrigation activity, with a maximum power of 3.6 kW. The pressure at the hydrant of the farm varies along the irrigation season, always having at least an excess pressure of 20m that is dissipated using a pressure reducing valve (PRV). The water demand also varies between zero, where no power is required, and 190 l s^{-1} along the irrigation season from April 1 to September 30, depending on the crop water requirements.

The plant proposed in this research consists on the installation of a 4 kW PAT installed in a by-pass, which will recover energy from the existing excess pressure. However, large flow fluctuations make the anticipation of its performance and design complex (Lydon, 2017). To select the PAT, analyze its performance during the irrigation season and assess its economic viability, the methodology proposed by Crespo Chacon et al. (2019) was applied. The selected PAT was tested in a hydraulic model, to ensure no impacts on network performance along the season were produced. The environmental impact of the installation was also assessed.

3. Results and conclusions

The minimum flow to be turbined to have a constant production of 4 kW was 37 l s^{-1} . Its cumulative occurrence probability was 84% along the irrigation season. However, the minimum



theoretical flow demanded was 65 l s^{-1} , excluding zero, ensuring its operation when the farmer irrigates. The number of working hours estimated was over 3,000, always working under best efficiency conditions, and generating more than 12 MWh. The diesel generator emissions, considering $2,6 \text{ kg eCO}_2 \text{ l}^{-1}$ (MITECO, 2018) of diesel, amount to 9.6 t eCO_2 that will be completely avoided using the proposed solution. The payback period estimated was five years. The construction of this plant will take place during March and April of the current year.

MHP is a potentially viable solution for improving the energy efficiency on the irrigation sector. Its usage at farm level to replace diesel generators seems to be a technically and economically effective way to, partially or completely, avoid GHG and air pollution emissions without interrupting irrigation activity. Future research will use the results of this experimental plant to investigate the long-term performance of MHP technology in this setting.

4. Acknowledgment

This research is partially funded by the European Regional Development Fund (ERDF) through the Interreg Atlantic Area Programme 2014–2020, as part of the REDAWN project (Reducing the Energy Dependency in the Atlantic Area from Water Networks) and the AGL2017-82927-C3-1-R Project (funded by the Spanish Ministry of Economy and Competitiveness).

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TESTING OVERHEATING IN AN UNGLAZED TRANSPIRED COLLECTOR IN THE SUMMER SEASON

F. Peci, F. Comino, F. Taboas, M. Ruiz de Adana

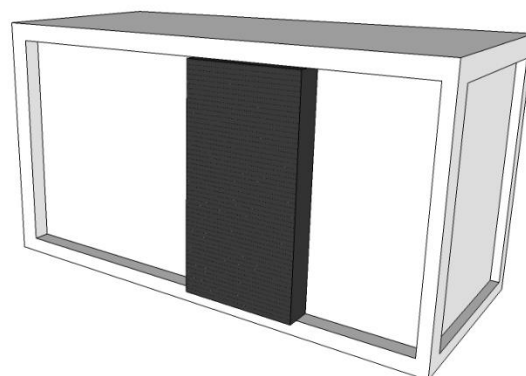
Keywords: *unglazed transpired facades, solar façade, solar collector*

1. Introduction

Nowadays, the utilization of renewable energy sources in buildings is required to minimize the total energy consumption and gas emissions. Solar energy is the main source of energy available and it is used in different ways, solar façades being one of them. However, not every climate could be suitable for using this system. Solar facades provide heating during the winter season, but in the hot season overheating could be a problem, as it increases the thermal loads of the building (Yu et al. 2017). This study shows a comparison of the heat transfer rate between façades with and without an unglazed solar collector (UTC) façade under hot summer climatic conditions.

2. Materials and methods

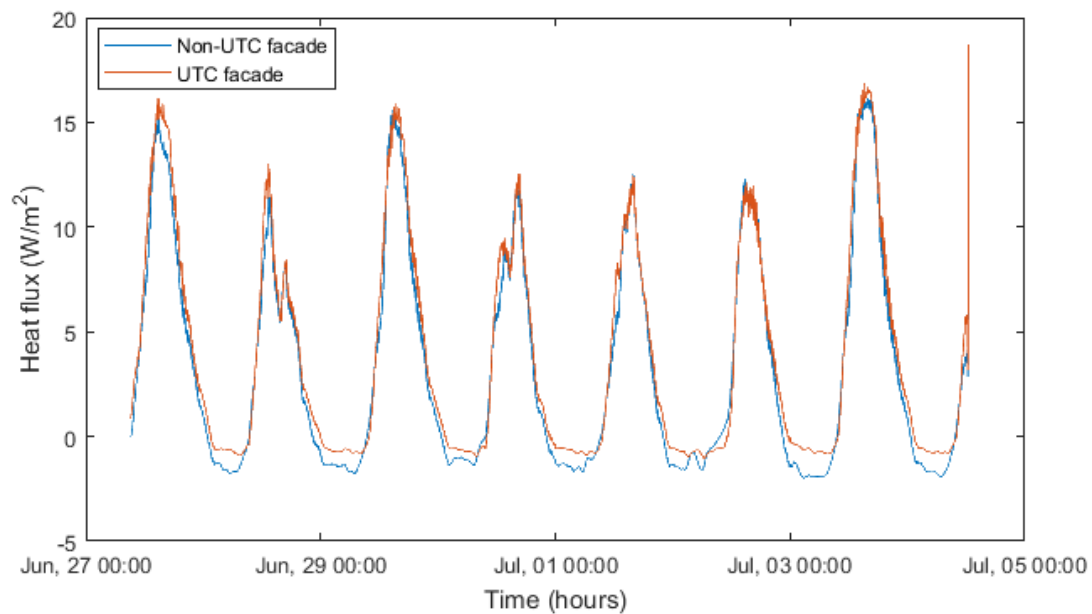
A test cell with an experimental module of UTC was set outdoors under real weather conditions, see figure below. The heat transfer through the insulation panels was measured using two heat flux probes installed in the section of the façade with UTC and in the section without solar façade. The measurements were taken for seven days in the summer season in Cordoba, Spain. The weather during the test was very hot and dry, reaching temperatures above 40 °C. The UTC façade ventilation was on, and the heated air was exhausted.





3. Results and conclusions

The results showed that installing an UTC façade did not significantly increase the heat flux through the insulation layer and, therefore, the benefits of using an UTC façade as a heating system in the winter season are not counteracted by overheating in the summer.



4. Acknowledgment

This study was possible with the financing of the University of Cordoba Galileo III program.

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COVERAGE OF ELECTRICITY DEMAND THROUGH PHOTOVOLTAIC PRODUCTION IN THREE TYPES OF BUILDINGS IN THE CITY OF CORDOBA (SPAIN)

Isabel Santiago, Emilio J. Palacios-Garcia, Isabel M. Moreno-Garcia, Rafael J. Real-Calvo, Víctor Pallarés-López

Keywords: *Photovoltaic, electricity demand simulation, self-consumption.*

1. Introduction

The energy consumption in the residential sector represents 30% of global consumption and it is rising, due to the growing number of residential housing units and the increasing quality of life. One of the objectives to reduce its impact would be to attain a greater integration of renewable energy generation in the buildings and to balance consumption with production. Moreover, the advantages of self-consumption would be to reduce losses occurring in the current system of transmission and distribution of electricity, estimated around 14% of the energy produced, and to reduce the need to invest in new grids. In addition, the widespread deployment of self-consumption would help to achieve the objectives set by the global challenges and guidelines related to the electricity production, by means of renewable sources.

In this context, the main objective of this work has been to carry out an analysis over a full year of the electricity demand coverage degree through photovoltaic (PV) installations on the rooftop of typical buildings in the city of Cordoba. Three types of buildings have been considered, depending on their economic level, which have been classified as low, medium and high level of incomes.

2. Materials and methods

In order to carry out this study, the types of buildings typical of neighborhoods in the city of Cordoba were first analyzed. For the electricity demand a previously developed model (Palacios-García, 2017) was used. The percentage of household appliances installed in the dwellings, according to their economic level was taken into account from data of the Statistics Institute of Andalusia for the province of Cordoba. The meteorological conditions registered in the city were also considered. For the generation of electricity, the production data monitored in a PV installation located on the rooftop of a building in the city of Cordoba was used. These data were extrapolated to the different types of buildings, taking into account the available surface on their roofs. With this information the values of the Demand Cover Factor (DCF), which is defined as the ratio to which the energy demanded by the installation is covered by the local PV production, and the named Supply Cover Factor (SCF), defined as the ratio to which the local PV supply is covered by the energy demand, were obtained. The first parameter would have a value of 100 % when all the energy consumed was simultaneously generated in a renewable way through the PV installation. The second would have a value of 100 % when all the locally generated PV energy was simultaneously consumed.

3. Results and conclusions



Figure 1 shows the average monthly values of the DCF index, obtained for each of the typical buildings. It is observed how, throughout the year, the highest value of the DCF index takes place in the buildings catalogued with the lowest economic level, with values of 54.77% in June, which indicates that in this month, more than half of the electrical demand of this type of housing is covered with the energy produced in the PV installation. The minimum value of this coverage index in this type of buildings takes place in the month of January, with a value of 27.73 %, so that only this small percentage of the demand is covered with the production of renewable energy present in the building, the rest of the energy consumed must be taken from the grid. The value of the DCF index in middle and higher-income dwellings is reduced on average by 3.19% and 9.38% respectively, this trend being maintained throughout the year. Current regulations can be decisive for consumers to decide to invest massively in this type of installations, especially when about half of the overall PV capacity is likely to be deployed on buildings. Only in this way will it be possible to achieve the proposed energy saving and environmental objectives.

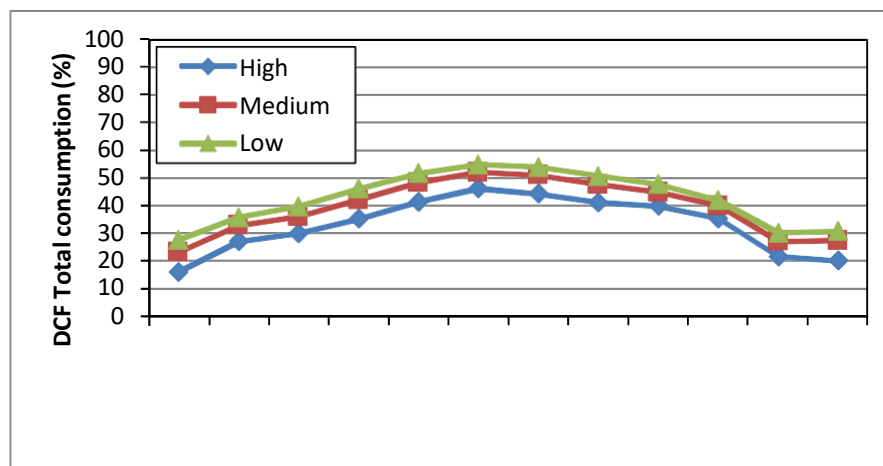


Figure 1. Monthly average values of the DCF coefficient for the three types of buildings according to the economic level

4. Acknowledgment

This work is supported by the Spanish Ministry of Economy and Competitiveness under Research Project SCEMS TEC2013-47316-C3-1-P. It is also supported by an agreement with Solar del Valle SL company.

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CALIBRATION AND PERFORMANCE OF TWO PYRANOMETERS PLACED ON TWO-AXIS SOLAR TRACKERS OF A PHOTOVOLTAIC PLANT

Isabel M. Moreno-Garcia, Rafael López-Luque, Marta Varo-Martínez, Víctor Pallares-López, Isabel Santiago

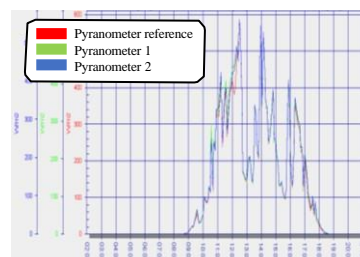
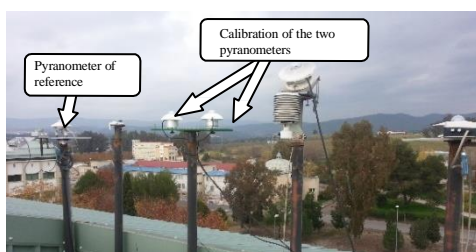
Keywords: *Renewable energy, photovoltaic, irradiance, pyranometer*

1. Introduction

A photovoltaic (PV) system connected to the grid is mainly characterized for providing electrical energy in adequate conditions to be injected into the conventional distribution network. In these systems, the energy produced during the hours of sunshine is channeled directly (on-line) to the electrical grid. For a PV installation of this type to be dispatchable, one requirement is to have the entirely characterized, having always a precise knowledge of the state of operation of all the components that integrate it, such as photovoltaic modules or inverters (Santiago, 2017). In general, the operation of the different components of a PV installation is carried out by monitoring its operating parameters. Specifically, to analyze the behavior of photovoltaic generators, it is essential to monitor the irradiance (Woyte, 2014). The total irradiance in the plane of the PV field is defined as the radiant power, both direct and diffuse, affecting the unit of area of an inclined surface. The calibration of two pyranometers for succeeding installation in a PV plant with two-axis solar trackers is presented, as well as the performance of both when they were operational into the facility.

2. Materials and methods

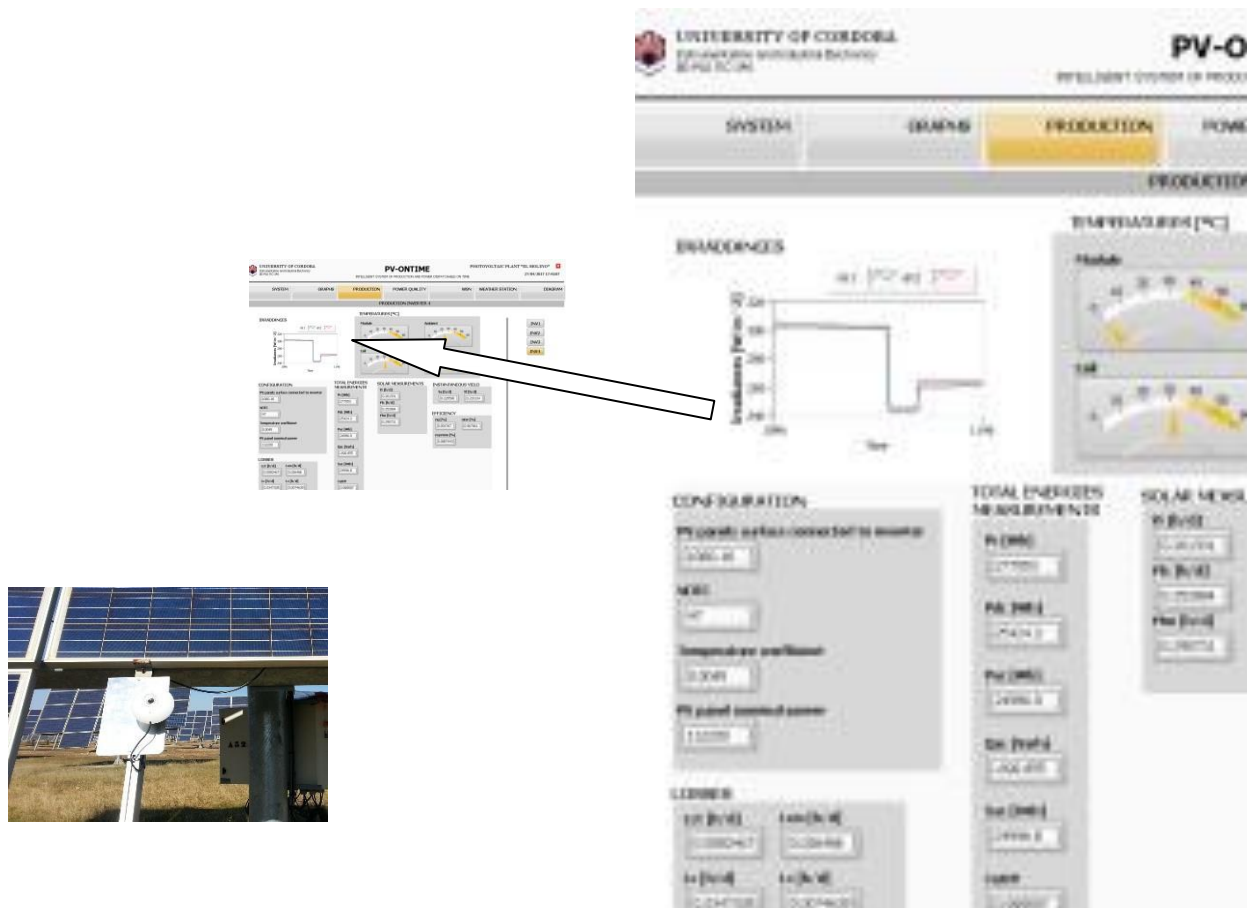
The main advantages of having two irradiance measurements are the possibility of analyzing the effect of clouds in the production, and to ensure that the irradiance is always measured. For this end, two pyranometers were firstly calibrated and tested. For the calibration process, the two pyranometers were installed on the roof of the Department of Applied Physics of the University of Cordoba. A radiometric station that measures instantaneous irradiance from several pyranometers is available, storing data every 5 minutes. The pyranometers were mounted on a high pole to avoid shading. With the first measures the good operation of both devices could be verified: the two measured the same and their values were practically equal to the rest of the installed sensors.



Once calibrated, the pyranometers were placed with the same inclination and orientation as the PV panels of the installation, Figure 2(a). In this section, a snapshot of the monitoring system used for providing the state of the plant's operation in real time is shown too, Figure 2(b). This



monitoring tool displays instantaneous and calculated data in real time through interactive dashboards. Figure 2(b) shows the production tab, where the production parameters of a determinate inverter are shown, such as energy produced, yields or efficiency. These output data calculated based on the pyranometers irradiance data. The arrangement of these measures, therefore, is very useful for installations occupying a large area, where it might be advisable to have several records of irradiance recorded by the installation, either to compare the data or to have this information available if one of the sensors fails



3. Acknowledgment

This research is partially supported by CLARA Project, which has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement No 730482.

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Woyte, A.; Ritcher, M.; Moser, D.; Reich, N.; Green, M.; Mau, S.; Garrad Hassan, G.; Beyer, H. (2014), *Analytical Monitoring of Grid-Connected Photovoltaic Systems. Good Practices for Monitoring and Performance Analysis*. Available online: <http://iea-pvps.org/index.php?id=276>



SUPPORTING THE SMALL HYDROPOWER SYSTEMS MANAGEMENT THROUGH SEASONAL FORECAST OF RIVER STREAMFLOW

Eva Contreras Javier Herrero, Cristina Aguilar, María José Polo

Keywords: *seasonal forecast, climate service, small hydropower plant, streamflow*

1. Introduction

Hydroelectric power is one of the cheapest, reliable, sustainable, and renewable sources of energy (Yildiz, 2019). Small hydropower plants located in mountainous areas, with no dam or water storage, despite being one of the most cost-effective (with relatively low operational and maintenance costs) and environmentally benign energy technologies (Paish, 2002), has the disadvantage that the production is not constant and is subjected to the run-of-river flow, which is also depending on a high variability in precipitation and snow cover. When inflow drops below the minimum technical inflow of the turbines, the hydropower station does not have enough water to remain operational. Another drawback of these systems is that when inflows are extremely high, water will have to be “spilled”, which represents a lost opportunity for generation (IRENA, 2012). The management has to accomplish with some particular operation conditions of the plant but also some environmental flow requirements. The aim of this work is to propose and develop a climate service targeted at end-users, able to support small hydropower systems management to foresee the water availability for the energy production in the most efficient way, and to make it profitable.

2. Materials and methods

The pilot application of the climate service proposed consists in the assessment of a three small hydropower plants system located in Poqueira River (Southern Spain), with a generating capacity between 10 and 12 megawatts and managed by a leading company in the Spanish energy sector which normally takes decisions based on historical information of the inflows. The annual precipitation regime is highly variable, ranging from 200 to 1000 mm in dry and wet years, respectively (Pérez-Palazón et al., 2015). The mean annual fractional snow cover area for the period 2000-2013 was $0.21 \text{ m}^2 \cdot \text{m}^{-2}$, ranging from 0.9 to $0.16 \text{ m}^2 \cdot \text{m}^{-2}$ in wet/cold and dry/warm years, respectively (Pimentel et al., 2017), which results in a very heterogeneous spatial distribution over the years,

In this regards, a new technological pilot tool was developed following a co-generation process involving data providers, service purveyors and end-users. Seasonal (6 months) forecast of daily river flow and precipitation were provided by the Swedish Meteorological and Hydrological Institute. These data were combined with historical and real time local data provided by the Andalusian Environmental Information Network to make the downscaling generation of local impact indicators (river flow in the uptake points, as an indicator of available water to generate electricity) to the point of interest. Then, a set of local specifications, such as indicator thresholds, turbine performance curve, specific consumption and environmental flow rules were defined by end-users. Finally, the on-line implementation of a data model and a web interface were carried out.

3. Results and conclusions



The result is an innovative technological tool, SHYMAT (Small Hydropower Management Assessment Tool) with a core system responsible for bringing the automatically updated information all together, executing the necessary operations with the appropriate models, and providing the results to a Web-based user interface. The user interacts with the application with utilities to display some alerts, show graphical outputs, export data, generate formatted reports and validate predictions previously made by incorporating actual measured flow data. This friendly tool is targeted at end-users, providing forecast of river streamflow, turbinable water (taking into account ecological flow restrictions and the capacity of the hydropower plant), the energy production and the number of days of operability expected for the next 6 months according to the forecast provided.

This tool will allow managers to anticipate the real risk of drought/scarcity scenarios, but also the water excess discharges coming from snowmelt to quickly tune up the machines in order to increase the capacity of the plant when possible. Thus, users can take advantage of forecasting climate data in order to: 1) anticipate if the hydropower plant could or not be operative in order to schedule the operation for medium-long term investments; 2) avoid losses of turbinable water flow by having the turbines ready to start operation tasks, and 3) predict the energy production of the facility for market issues. SHYMAT has been designed to be easily applied in other hydropower plants for planning and management of operation tasks.

4. Acknowledgment

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PHOTOVOLTAIC TECHNOLOGIES APPLIED TO WATER HEATING SYSTEMS

**José Ramírez-Faz, Marta M. Varo-Martínez, Francisco J. Casares,
Luis Cámara**

Keywords: *Photovoltaic, Water Heating, Sustainability*

1. Introduction

Problems related to the consumption of fossil or nuclear energy have made necessary to change the energy model. In this line, in recent years the use of renewable energy is being promoted. Thus, for example, research into photovoltaic (PV) technology for the harnessing of solar radiation has led to a greater conversion efficiency in cells. As a consequence, this technology, which allows efficient and clean direct generation of electric power, has reduced its costs, achieving in 2013 parity or cost equality with conventional supply.

Regarding the systems of water heating, the scheme of a conventional solar installation is based on the use of solar thermal collectors, frequently located on roofs, to which the heat transfer fluid (commonly water) is conducted in the central hours of the day. The plumbing installation that completes the system can be complex, depending on the geometry of the building and, the more complex the installation is, the greater the maintenance needs of the system. On the other hand, in summer, solar radiation is excessive, so traditional installations must be covered to avoid damage and breakdowns.

However, in the new scenario of photovoltaic costs, the traditional system, previously described, begins to compete at a disadvantage with new water heating systems, based on photovoltaic electricity. These devices are composed of the PV solar panels, the water tank, and the heater with resistance. Specifically, the heating of the water is performed by means of a resistance and an electronic control system.

Thus, the advantages of these PV water heating systems are:

- The installation with PV panels is less complex and cheaper than traditional solar thermal installations.
- The PV system would be easy to integrate into almost all the previous installations.
- Contrary to conventional thermal heater systems, the elements of the installation do not need maintenance.
- In this type of installations there would not be quite high temperatures that shorten the life of the installation.
- The surplus of PV electricity production in summer could be used in other needs of the buildings (such as air conditioning) or could be discharged to the electricity grid in those cases in which the legal framework of the country allows it.

For all these reasons, architects and technicians are beginning to reconsider the traditional solar



water heating systems towards the new systems based on photovoltaics (Herrando & Markides, 2016, Meyeres et al., 2018). However, information on these new systems is scarce and little contrasted in our climate, so it is necessary to deepen the knowledge of this technology. In this context, this work presents the design of a prototype of a PV installation for water heating with the aim of evaluating its behavior and contributing to the scientific advance of this new use of PV technology.

2. Materials and methods

This paper presents the preliminary results obtained from an experimental facility, built ex professo, in the Hydraulic Engineering laboratory of the University of Cordoba (Cordoba, Spain) consisting of a photovoltaic unit, an experimental electronic impedance adaptation system, a sanitary hot water tank and a monitoring and control system.

The photovoltaic system has five Munchen Solar 330 monocrystalline modules, inclined 25° and oriented to the South. The photovoltaic system operates at 1650 Wp, with 230.95 V open circuit voltage and a 9.11 A short-circuit current. This system will feed a 17 Ω heating resistor of 17 Ω located inside a 300L capacity insulated tank. In order to utilize the maximum available photovoltaic power and adapt the output impedance of the PV collectors to the resistance, a MPPT electronic circuit based on a 0.001 F capacitor and a MOSFET-n IRPF 250 have been designed. Power control is performed by means of an ESP 32 circuit that permanently monitors the voltage at the terminals of the capacitor to pilot the transistor gate as well as the electrical current supplied by the PV system. A recirculating pump has been installed to measure hot water production. This pump renews the water content in the tank every night and replaces it with cold water. The night-time control of the recirculating pump as well as the monitoring of the temperatures inside the tank is also implemented by means of an ESP 32-based electronic board. WIFI and BlueTooth connection of the proposed electronics makes the entire experimental device accessible from the cloud.

3. Results and conclusions

This work presents the study of the energy costs associated with this type of facilities as well as the comparison of theoretical values with experimental ones. Results demonstrate the existence of economic advantages associated with the heating of water for sanitary use by means of photovoltaic solar energy.

4. Acknowledgment

This study has been carried out thanks to the financing of the project PVACS-UCO SOCIAL INNOVA.

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MONITORING PHOTOVOLTAIC FACILITIES IN BUILDINGS BASED ON INTERNET OF THINGS AND COMMUNICATION USING LORAWAN TECHNOLOGY

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Keywords: *Monitorization, Photovoltaics, IoT, Free hardware, LoraWan*

1. Introduction

The use of non-fossil-based energy is a social, economic and technical imperative that has recently made spectacular progress around the world. Within clean energy, solar energy, and especially photovoltaics, has seen an enormous rise for a variety of reasons (Mousazadeh et al., 2009).

Increasing the efficiency of the modules comprising a photovoltaic facility is a key element when evaluating the competitiveness of this technology compared to other market options. The monitoring of PV installations is an essential tool in this objective and focuses on the significant variables of the modules (ambient air temperature, output voltage, output current...) (Raza et al., 2016).

In recent years, the development of ICTs has led to the rise of the Internet of Things (IoT) connecting any type of information associated with an object to the Internet. Once data to be shared have been identified, the chosen system (photovoltaic panel) must be equipped with the software, hardware and communications necessary for connecting to the Internet (Carballo et al., 2019)

IoT-based communication solutions designed to be located on the rooftops of buildings must comply with the following requirements: range, low cost and the possibility of connecting a large number of devices. The Low-Power Wide Area Networks (LPWAN) are wireless, allowing to operate with very high range (several km in urban environments) as well as low energy consumption and low cost.

2. Materials and methods

Figure 1 describes the system proposed to monitor the relevant variables of the photovoltaic module, so that the final user can interact with the module from an IoT platform (Thingspeak in our case). The Arduino MKRWAN 1300 board manages the reading of the module's control variables, as well as the sending of such variables, through the LoRaWan network, to The Things Network (TTN) platform. This network allows communication of IoT-based objects with low battery consumption, long range and low bandwidth. TTN is based on Gateways or concentrators receiving the information to be monitored. Node-Red, a software tool communicating hardware and IoT services in a fast and simple manner is employed.. For the proposed supervision, TTN is connected to ThingSpeak, Matlab® IoT platform. This is the platform where the application's end user can visualize, interact, store and control the information received.

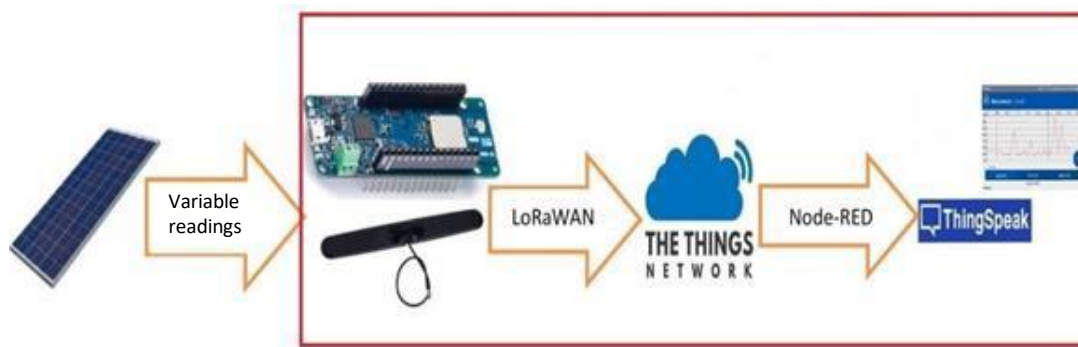


Figure 1. General diagram of the hardware and software solution

3. Results and conclusions

A prototype for the monitoring of a photovoltaic installation using LoRaWAN has been implemented achieving a high range, low energy consumption and low equipment cost. The solution allows data communication under the IoT paradigm. The global tool provides analysis for monitored data to estimate the performance of the photovoltaic system through IoT Thingspeak platform (fig. 2). The methodology employed to implement the project can be perfectly replicable in other fields of renewable energies.

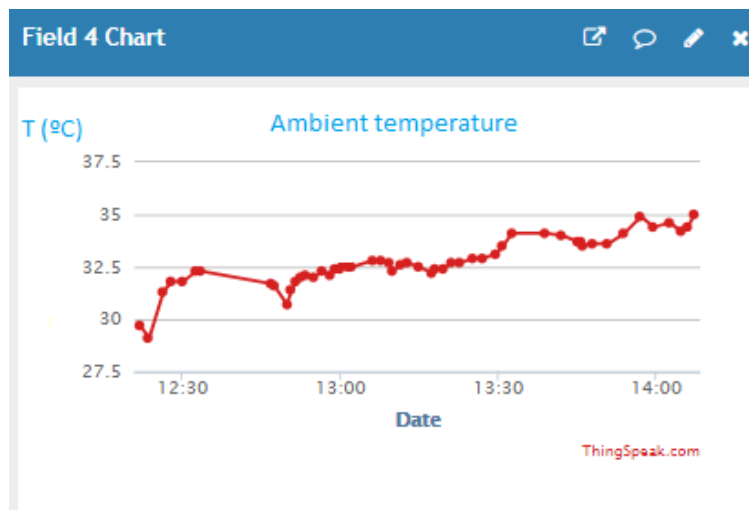


Figure 2. Ambient air visualization in Thingspeak app.

4. References

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REDUCTION STRATEGY OF THE ENVIRONMENTAL IMPACT IN TERTIARY SECTOR BUILDINGS THROUGH LIFE CYCLE ASSESSMENT

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Keywords: *Life Cycle Assessment, biomass, building, renewable energy, environmental impact*

1. Introduction

According to the data provided by the Institute for the Diversification and Saving of Energy (IDAE), the main part of the energy consumption produced in tertiary buildings is due to air conditioning. Thus, the energy consumption of heat production systems represents 60% of the total (IDAE, 2016).

Biomass, including urban solid waste, biomass, biogas, and biofuels, accounts for most of the primary consumption of renewable energy in Spain, although its contribution has decreased since the 1990s (IDAE, 2016). The use of biomass as combustible material has a series of advantages associated with the nature of the material, but the use of the mentioned fuel must be analyzed from a life cycle point of view. That is, its environmental impact must be analyzed throughout the life of the material.

This paper shows the application of the EPS 2000 life cycle analysis methodology using SimaPro software for the study of the environmental impact of a biomass boiler located in a tertiary building.

2. Materials and methods

For the present work a boiler of biomass of pellets of the DOMUSA brand, model BioClass HM model, composed of a main body, where the burner, the expansion vessel, the recirculation pump, an accumulator for hot water and a fuel storage silo are located.

To carry out the study, it is necessary to carry out an initial analysis stage that will allow us to obtain the appropriate information to be able to develop the analysis through SimaPro software and, finally, obtain the environmental impact analysis (Figure 1).

Initially, it is necessary to study the life cycle of the boiler, studying all the linked stages, from the processing of the raw material to the dismantling. Similarly, the life cycle of the fuel (pellets) is studied as it is a fundamental element of the system. Subsequently, an inventory is made describing and quantifying each of the individual components of the system: raw material, energy, transportation, garbage and emissions to the atmosphere. Additionally, it will be necessary to have an energy consumption estimate during the life cycle (estimated 10 years). By using the Regulation of Thermal Installations of Buildings (RITE, 1988), a consumption of 0.4167 TJ is estimated.

With the previous study it is possible to perform the life cycle assessment through the EPS 2000 methodology (Environmental Priority Strategies) (Steen B. 1999a, 1999b).

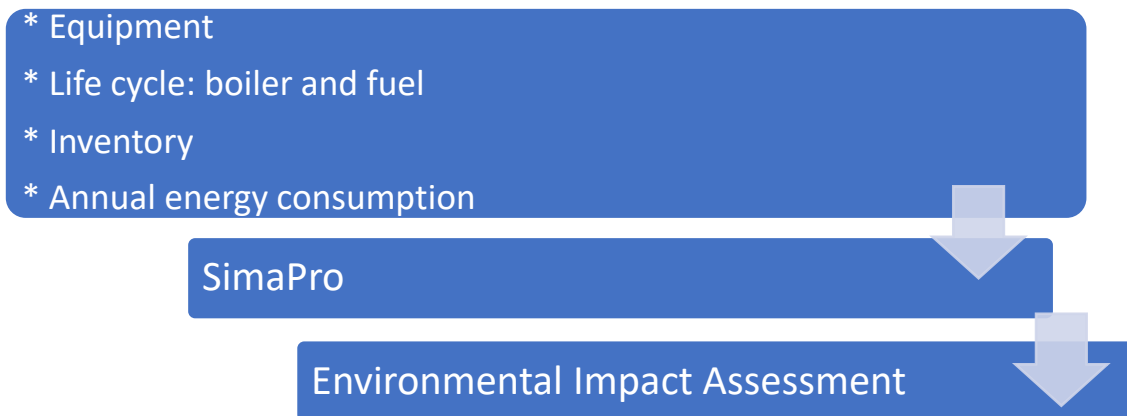


Figure 1: Methodology for Environmental Impact Analysis

3. Results and conclusions

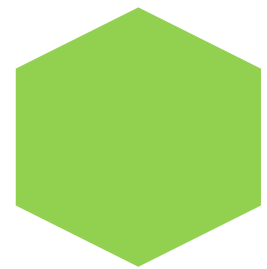
The program allows obtaining environmental impact data for the following categories: quality of the ecosystem, human health, natural resources and abiotic resources. The specific results of the EPS 2000 methodology for the pellet boiler establish that the depletion of resources represents 94% of the total contribution. It is also of interest that the impact on life expectancy (human health) turns out to be 4%. This impact is mainly produced by CO₂ emissions. The combined action of the other two categories represents only 2%. Thus, through the EPS 2000 methodology, it is possible to identify how the greatest environmental impact during the life cycle of the boiler is identified in the manufacturing process of the boiler. This knowledge would allow acting on the selection of materials with less impact for the manufacture of the boiler, in order to reduce the overall impact of the same.

4. Acknowledgment

The authors are grateful for the support of the Department of Mechanical and Mining Engineering of the University of Jaén.

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ADVANCED CONSTRUCTION MATERIALS AND TECHNOLOGIES





NEW NANOMATERIALS FOR SOIL STABILIZATION IN CIVIL ENGINEERING

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Keywords: *Soil stabilization, Expansive soil, Clay soil, Nanomaterials*

1. Introduction

The soil treatment techniques contribute to the competitiveness and sustainability of road engineering (Maestro and Ibañez, 2009). The material characteristics must satisfy the engineering functions that contribute to the durability and quality of the entire road structure (François and Jullien, 2009).

Extensive studies have been carried out regarding the treatment of expansive soils using various additives, such as lime, cement, fly ash, industrial waste products, potassium nitrate, calcium chloride and phosphoric acid (Croft, 1967; Sherwood 1993; Cabrera, 2018).

During the last years, there has been a great interest in nanoparticles due to the numerous technological applications that also tried to achieve an ecological and low cost. These useful features of the synthesized nanoparticles can benefit the engineering sectors (Kajbafvala et al., 2013).

This study presents the results of an investigation on the effects of the addition of nanomaterials in expansive soil in its plasticity limit, compaction characteristics, unconfined compressive strength and bearing capacity.

2. Materials

2.1 Expansive clay soil (ECS)

Expansive soils are those which show volumetric changes in response to changes in their moisture content. Such soils swell when the moisture content is increased and shrink when the moisture content is decreased. The expansive clay soil analysed comes from Villacarrillo (Jaen), Andalusia.

2.2 Quicklime (Q)

Hydrated lime is obtained when quicklime reacts chemically with water. Hydrated lime (calcium hydroxide) reacts with clay particles and permanently transforms them into a strong cementitious matrix.

2.3. Nanomaterials (N)

Liquid additive that, in combination with cementitious materials, is used to stabilize soils by increasing the mechanical properties of the soil.

3. Methods and results

The following parameters were measured to physically and mechanically characterize the samples: granulometric, absorption, density, Modified Proctor test, bearing capacity based on the CBR index, plasticity, compression strength test and fluorescence spectrometry.



Table 1: Summary of the main physical and chemical properties

		ECS	ECS+1.5%Q	ECS+1.5%Q+N
Plasticity (LL-PL)		22.79	N/P	N/P
Maximum dry density (gr/cm ³)		1.63	1.6	1.6
Optimal water content (%)		18.4	19.6	19.6
4-days soaked CBR		1.98	16.7	33.8
Expansion (µm)		152.5	46.5	30
Module (Mpa)		-	107	420
Compressive Strength (MPa) 14 days		-	0.21	0.25
Elemental content (%mass)	Si	12.9	12.9	12.3
	Ca	18.8	17.8	18.4
	K	1.10	1.21	1.14
	Mg	0.97	1.55	1.23
	Fe	1.84	2.13	2.13
	Al	4.09	4.69	4.65
	Na	0.11	0.17	0.13
	Ti	0.25	0.30	0.05

Comparing the values (Table 1), it is observed that ECS + 1.5%Q+N improved soil properties. The value (CBR) of ECS + 1.5%Q+N compared to ECS + 1.5%Q was increased by 102% and reduced expansion by 55%. The compressive strength and modules also improved with the use of the nanomaterial.

4. Conclusions

Based on the obtained results, the following conclusions are presented:

- The addition of Nanomaterial in the mixtures improved the bearing capacity. This result is better than those reported for the mix with 1.5% lime.
- Regarding the values of the strength, it can be considered high and enough to build any type of embankment, as well as sub-bases of roads and rural paths.
- It can be concluded that the use of nanomaterial reduces the expansion of expansive soils and improves physical-mechanical properties.

5. Acknowledgements

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USING GRAPHENE OXIDE AS MEANS OF IMPROVEMENT OF CONCRETE: A BRIEF REVIEW

Pedro Raposeiro da Silva, Luís Evangelista

Keywords: *Portland cement, concrete, graphene oxide, Mechanical property*

1. Introduction

Nowadays, the use of nanomaterials (NM) to improve the performance of cement and concrete matrixes constitutes a potential alternative to the exclusive use of Portland cement (PC). Similarly, there is currently no doubt in the construction industry (CI) about the pressing need to reduce the consumption of PC. The CI represents the world's third-largest industrial energy consumer, and the component related to the production of PC alone represents 7% of the carbon dioxide (CO₂) emissions globally (OECD, 2018). PC is undoubtedly the most used material in construction in terms of its relative volume. Raw materials for PC production are generally plentiful and they are also available throughout the world. It is possible to state that, at this moment, there is no other material with the same availability as the PC, which might be able to fulfil the construction's technical requirements as the concrete's main component. In this sense, it is imperative that the cement industry obtains viable technical solutions that allow the reduction of PC consumption. That reduction can be achieved either by its direct replacement with another material (e.g. using fly ash), or by improving the cement and concrete matrix performance with the addition of new materials, such as NM. This second option is quite interesting, since it allows us to maintain the cement and concrete matrix properties/characteristics, reducing PC consumption by adding a tiny amount of a NM.

2. Nanomaterials

The NM evolution has allowed the production of new cement-based nanocomposites with previously unimaginable properties. In general, NM can be grouped into three main types: the zero-dimensional (0D) nanoparticles, such as nanosilica; the one-dimensional (1D) nanofibres, such as carbon nanotubes and, lastly, the most recent two-dimensional (2D) nanosheet, i.e., graphene oxide (GO) (Chuah *et al.*, 2014). These materials, especially the 1D and 2D NM, have the ability to, in very small dosages, strengthen the cement and concrete matrix through the reinforcement and pore refinement. This allows conventional cement composites to achieve higher performance levels, or to maintain the same performance levels while decreasing PC consumption (Yang *et al.*, 2017).

3. Graphene oxide

In the particular case of GO, we are in the presence of one of the most recent advances in materials science, with enormous potential to be used as nano-sized additive for cementitious materials (Tong *et al.*, 2016). The GO shows a number of unusual properties, namely: super-high specific surface area, ultra-high strength and elastic modulus (Wang *et al.*, 2017); excellent thermal, electrical and optical conductivity (Wang *et al.*, 2017); since it easily forms composites with polymer and ceramic materials and contains a large concentration of hydroxyl, epoxide, carboxyl and carbonyl functional groups that are compatible with water and, for this reason, it is highly dispersible in polar liquids (Saafi *et al.*, 2015). Its introduction in the production of cement and concrete implies



a substantial improvement in the performance of these cementitious nanocomposites. There are reports which state that the 3 and 7 days compressive strengths of cementitious nanocomposites with 0.2 % of GO were increased by $\approx 36\%$ and $\approx 42\%$, respectively, when compared to the control mix (Yang *et al.*, 2017). Similarly, Tong *et al.* (2016) state, in their research, that the observed microstructure morphology shows that GO can significantly reshape the microstructure of the cement paste. However, the GO can cause a significant loss of the workability of the cement matrix, due essentially to the increase of its viscosity. This is mainly associated to its high specific surface area, (Wang *et al.*, 2017).

4. Closing remarks

The need for cement mixes with increasingly higher performances and, on the other hand, the need to reduce the impact of the CI, through cutting of PC consumption, require industry and researchers to look for new solutions and materials. The use of GO in the development of new types of cementitious matrixes can lead to a significant improvement in the performance of the mortars and concretes used in the CI.

5. Acknowledgment

The authors acknowledge the support of the *Instituto Politécnico de Lisboa* (ISEL - IPL) through the funding of the scientific research project “Performance evaluation of self-compacting mortars with nanomaterials” (IPL/2018/ Nanomortar /ISEL)”.

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ECO-CEMENT CLINKER DESIGN VALORIZING WASTES FROM DIFFERENT INDUSTRIES

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Keywords: *Eco-cement, Belite cement, Chamotte, Marble wastes, Aluminum industry*

1. Introduction

Cement is one of the main building materials in the world, among other reasons for its durability and compatibility with other elements that allow us to make composite materials with better properties. In this research, a new type of eco-cement was investigated, valorizing industrial wastes. The principal innovation is that the typical raw materials for cement production (clay and limestone) have been replaced by industrial wastes from different production processes.

The development of this new type of cement is based on the inversion of the Alite-Belite ratio, with a proportion of Alite (C3S) at 9 wt% and Belite (C2S) at 65wt%, as main components. Belite type cement reduces the CO₂ emissions by lower energy consumption, due to its lower clinkering temperature (1350-1400°C), in conjunction with a reduced content of limestone, compared to OPC. The energy demand is estimated at 15-20% less, for a LSF of 80-85% (Iacobescu et al., 2011; Uchikawa, (1994); Lawrence, (2003), Sharp et al., (1999)).

All these characteristics allow the belite-type cement to be framed within the circular economy concept. An effective use of natural resources it is intended, by manufacturing a new sustainable product through wastes from other industries that are currently disposed of in landfills.

2. Material and methods

The materials used in this study are chamotte residue (ceramic powder coming from ceramic fragments of defective pieces (bricks, tiles, etc.), manufactured at 950°C), sludge from cutting blocks and polished marble tables process and PAVAL (residue of aluminium oxide from the production of secondary aluminium, which is mainly composed of Al₂O₃).

The techniques used for the study of industrial wastes and the design of the belite-type cement were the following ones: X-ray Powder Diffraction (XRD), X-ray Fluorescence (XRF), Thermal Analysis (DSC/TG/DTG), Modified Bogue Equation and Quality Indices (LSF, AM, SM), Free lime content, Optical Microscopy and Scanning Electron Microscopy (SEM-EDX).

The design of the raw materials was based on the predictions of Bogue equations. A modified Microsoft's Excel® spreadsheet was built for the estimation of the mineralogical phases, formed according to Bogue equations, and the limits imposed by the indices, as lime saturation factor (LSF), silica modulus (SM) and aluminium modulus (AM) (Iacobescu et al, 2011).

3. Results and conclusions

According to the XRF analysis results of the chamotte, a high SiO₂ content is identified, as well as important CaO and Al₂O₃ contents. In the sludge from cutting blocks and polished marble tables



process almost the totality of CaO is observed, besides a loss on ignition very important, which corroborates the results of the essay of XRD. Finally, in the case of PAVAL, its content in Al₂O₃ mainly stands out y.

Textures were observed and recorded by reflected light microscope. Due to the fast cooling ,the belite polymorphism transitions are encouraged to take place successively, leading to the formation of complex microstructure, due to twinning or exsolution within the crystals. Belite is presented generally as round shaped, blue colored due to type of etching and crossed parallel striations (Iacobescu et al., 2011).

Belite type cements with industrial wastes were successfully produced at lower temperature (1350-1390°C), when compared to ordinary Portland cement (OPC), driving to less energy consumption. The need for a lower quantity of raw materials to be extracted from nature for the manufacture of cements and the use of industrial waste reduces the carbon footprint of the cement industry.

4. Acknolgements

S. Martínez-Martínez thanks the Ministry of Education, Culture and Sports for a University Professor Training Fellowship.

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INORGANIC GEOPOLYMERS SYNTHESIZED USING BLACK CLAY AS PRECURSORS BASED ON KAOLINITE SYSTEM

E. Bonet-Martínez, L. Pérez-Villarejo, D. Eliche-Quesada

Keywords: *Geopolymers, Alkali-activation, Black clay, mechanical properties*

1. Introduction

Inorganic polymers, or geopolymers, constitute a new class of materials synthesized from materials of aluminosilicate nature (clays and kaolin) and an alkaline activator. The geopolymers can be used in multiple applications, ranging from their use as a cementitious material (Sturm et al., 2016) to their use as a catalytic support (Azeer et al., 2016), and even as a reinforcing matrix for composite materials with fibers (Alshaaer et al., 2017).

Geopolymers are inorganic aluminosilicate polymers synthesized by alkali activation of Si- and Al-rich materials at near-ambient temperatures (Komnitsas et al., 2007).

For the synthesis of geopolymers, the chemical reaction between amorphous silica and alumina in combination with a highly alkaline environment at or slightly elevated temperature is used to form a three-dimensional polymer gel of Si-O-Al-O-Si (Hwang et al., 2015).

The objective of this research is to produce metakaolin and black clay-based geopolymeric materials for alkaline activation, using waterglass and sodium hydroxide.

2. Material and methods

The geopolymeric materials were prepared using metakaolin (MK), provided by the Caobar, S.A. located in Taracena (Guadalajara, Spain) and black clay (AN) obtained from clay quarries located in Bailén.

For alkaline activation, a mixture of hydrated sodium silicate (Panreac S.A.; 8,9 wt. % Na₂O, 29,2 wt. % SiO₂ and 61,9 wt. % H₂O) and NaOH (reactive grade, 98 wt. %, Panreac S.A) was used. The NaOH solution was prepared in distilled water (8 M).

The geopolymers were prepared with five different compositions: pure MK (100 % MK, Si/Al=1.63) and four other compositions, such as MK-25BC (75% MK, 25% BC with a ratio Si/Al = 1.90), MK-50BC (50% MK, 50% BC, Si/Al = 2.29), MK-75BC (25% MK, 75% BC, Si/Al = 2.91) and 100BC (0% MK, 100% BC, Si/Al = 4.06). The synthesis was carried out by mixing the raw materials for 10 minutes. Subsequently, the activating solution was added and stirred for 10 minutes and, then, the generated slurry was transferred to plastic molds. The samples were cured under controlled conditions (70 °C) for 24 h and curing for 7 days at room temperature.

Geopolymers were characterized by XRD, ATR-FTIR. Microstructural analysis and FTIR scanning were used to examine the progress of the geopolymer reaction during the curing stage.

The bulk density (kg/m³) was determined by Archimedes method. Water absorption capacity (wt.%) was determined according to the standard procedure UNE 772-21:2011 from weight



difference between the as-dry and water-saturated samples immersed in water for 24 h. The compressive strength for cured samples was measured according to the standard procedure UNE-EN 772-1:2011.

3. Results and conclusions

The addition of BC increased bulk density of geopolymers. The bulk density of the control geopolymers was 1270 kg / m^3 , increasing up to 1500 kg / m^3 with the incorporation of 25 wt.% of BC and up to 1670 kg / m^3 with the incorporation of 100 wt.% of BC. Water absorption of the control geopolymers was 30.9 %. The incorporation of BC produced a significant decrease in water absorption. This indicated a lower open porosity in geopolymers that contains black clay. The compressive strength of the reference samples (with 100 wt % Metakaolin) was 17.5 MPa. The addition of up to a 75 wt% of BC produced a slight decrease in compressive strength, decreasing up to 15.67 MPa. However, the addition of 100 wt % of waste produced a significant decline in compressive strength, up to 10.20 MPa.

The data indicated that it is possible to substitute 75 wt% of MK for BC by obtaining geopolymers with adequate physical and mechanical properties

4. Acknowledgment

This work has been funded by the Project “Development and characterization of new geopolymers composites based on waste from the olive industry. Towards sustainable construction” (MAT2017-88097-R), FEDER/Ministry of Science, Innovation and Universities, State Research Agency.

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ALKALI-ACTIVATED MATERIALS FORMULATED FROM OLIVE GROVE BIOMASS FLY ASH

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Keywords: *alkali-activate materials, biomass fly ash, olive grove, Circular Economy*

1. Introduction

Alkali-activated materials or geopolymers are a new family of materials with low environmental impact which constitute a promising alternative to ordinary Portland cements (OPC). The search for industrially viable alternatives to the high emissions of gases produced by OPC is urgent. An aluminosilicate source is needed for the manufacture of these geopolymers, which can come either from raw materials, such as common clays or kaolin or from by-products or industrial waste, such as those used in this work. Fly ash from a plant that uses potassium-rich olive and pine biomass to generate electricity was used as a raw material to obtain sustainable geopolymers.

Up to the present moment, many researches have employed fly ash to obtain these materials, but the vast majority of them use ash from coal (Rakhimova and Rakhimov, 2019). It is necessary to deepen the investigation of the effect that the usage of olive grove biomass ash has on the formation of the geopolymer. In addition, the use of these ashes with biomass origin can help to reduce even more the environmental impact, by reusing an industrial waste and promoting the Circular Economy.

2. Materials and methods

For the development of these materials, metakaolin (MK) was used, obtained after firing kaolin acquired from the company Caobar (Guadalajara, Spain) at 750°C for 4 hours and olive grove fly ash (OGFA) provided by the company Aldebarán Energía del Guadalquivir S.L. (Andújar, Spain). For alkaline activation, a mixture of aqueous sodium silicate was used (Panreac S.A) and NaOH (reactive grade, 98 wt %, Panreac S.A). A NaOH solution (8.0 M) was prepared by dissolving in distilled water. The liquid/solid ratio utilized was 0.85. MK, replaced by different amounts of OGFA (25-100 wt %). The Si/Al molar ratio varies from 1.6 to 5.3 from pure MK up to 100 wt % OGFA. The samples were cured under controlled conditions (60 °C and 99 % relative humidity) for 24 h. The specimens were then demolded and kept at ambient conditions for 7 days of curing.

Bulk density was determined by Archimedes method. Tests on compressive strength were performed according to UNE-EN 772-1 (UNE-EN 772-1, 2011) on a MTS 810 Material Testing Systems laboratory press. Prior to the breakage of the ceramic samples, the average surface of the two faces was calculated and the maximum load reached between the average surfaces was divided and expressed with an accuracy of 0.1 MPa. The open porosity was determined by calculating the weight difference between the samples saturated in water and dry, divided by the volume.

3. Results and conclusions

The compression strength results obtained for pure MK geopolymers was 17.54 MPa after 7 curing days. Compared with the geopolymers obtained with different olive grove fly ash substitutions at the same curing ages, for 25% by weight, the mechanical resistance increased by 11.3% to 19.52



MPa, but higher substitutions imply a decrease in mechanical strength: a 50 wt % substitution generates a value of 14.47 MPa, which means a fall of 17.5%.

The mechanical strength of these materials is closely related to the porosity generated during their aged and the amount of geopolymeric gel formed. It is observed that as the olive grow fly ash increases its percentage by weight more dense and, therefore, more compact materials are formed.

The replacement of olive grove fly ash by metakaolin generates a significant decrease in apparent porosity, 39.08% for pure MK geopolymers compared to 9.86% for a 25% OGFA wt% substitution, which represents a reduction of 74.77%, and 85.59% for geopolymers with 75% OGFA wt%. This reduction in porosity is also reflected in the reduction of water absorption: -79.32% and in the increase of bulk density values, +22% OGFA wt%. Subsequent increases of ash added causes the values of water absorption to decrease even more, so for a substitution of 75%, water absorption decreases by 88.31%, while the bulk density remains constant.

It can be established that up to 25 wt % of olive grove fly ash substitution by metakaolin generates denser materials, with less water absorption as a consequence of a lower porosity and, therefore, generates better mechanical benefits.

4. Acknowledgment

This work has been funded by the project Development and characterization of new geopolitical composites based on waste from the olive industry. Towards a sustainable construction (MAT2017-88097-R), FEDER/Ministry of Science, Innovation and Universities, State Research Agency.

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THE CHEMICAL TREATMENT OF NATURAL STONE INFLUENCES ON INFRARED SPECTRA

**Volodymyr Shamrai, Antonio Rodero, Jose Maria Fernandez,
José Ramon Jimenez, Valentyn Korobiychuk**

Keywords: *impregnating, natural stone color, natural facing stone, infrared spectroscopy of natural stone*

1. Introduction

The influence of wetness, microorganisms, temperature and chemicals contributes to the destruction of natural stone. These factors lead to the reduction of strength and decorative indicators of natural stone. Currently, there are chemical impregnating agents for the protection and improvement of decorative properties that are widely used in the stone industry. The great numbers of chemical agents change the color indicators of a natural facing stone. The quality criterion of transparent chemical impregnating agents is the consistency of color after processing by these means. However, practical experience shows that color indicators also change after treatment with transparent chemical impregnating agents. Therefore, it is necessary to investigate the mechanism of their interaction with the natural facing stone using methods of spectral analysis and digital imaging processing.

2. Material and methods

During the study 18 samples of Bukivskyi gabbro (Galant) and 4 chemical impregnation agents were used.

Infrared spectrometry (IR) was performed in order to determine the structure of chemical impregnation agents and natural stone samples with different treatments. The IR spectra of natural stone samples were measured by an FTIR Bruker Tensor 27 spectrometer, scanning from 4000 to 250 cm^{-1} using the KBr as a reference sample in transmission mode (for study of chemical impregnation agents) and drift mode (to study the changes of natural stone samples after chemical and mechanical treatment).

3. Results and conclusions

In order to investigate the nature of the change in color coordinates after the influence of chemical impregnating agents, the method of IR analysis of chemical agents and natural stone samples (processed by chemical and mechanical methods) was used.

To determine the mechanism of influence of chemical impregnation agents, an IR spectral analysis of natural stone samples between mechanical and chemical treatment was conducted.

The absorption spectra of natural stone shown in Figure 1 demonstrate clear changes of absorption between mechanical and chemical treatments. At the same time, the absorption rate of chemically treated samples is much lower. The change of average values of absorption spectra of natural stone samples of the corresponding peaks of wavelengths depends on the type of processing.

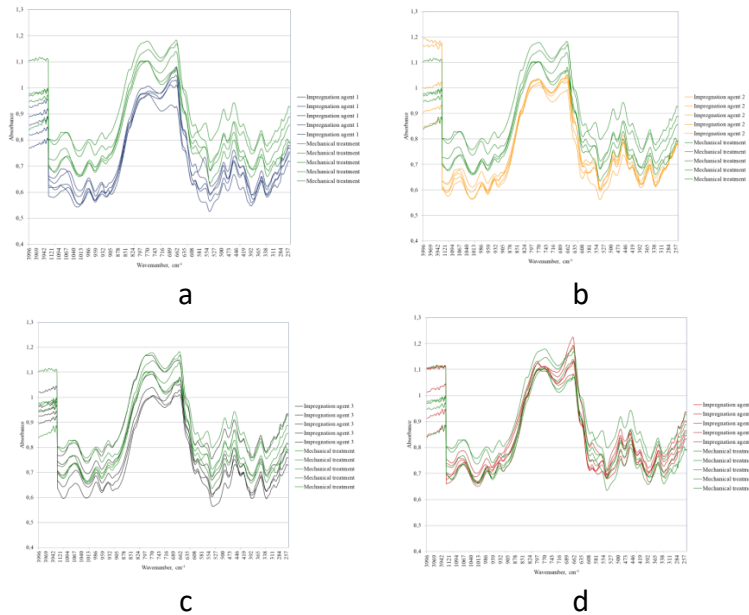


Figure 1. The changes in the spectrum of absorption of samples of Bukivskiy gabbro (Galant) between mechanical and chemical treatment: a – Impregnation agent 1 (pH = 5.36); b – Impregnation agent 2 (pH = 3.98); c – Impregnation agent 3 (pH = 9.12); d – Impregnation agent 4 (pH = 7.45)

According to fig. 2, the largest change in absorption of gabbro within the wavelengths of 1111 – 387 is observed for Impregnation agent 1 and 2. After Impregnation agent 3 and 4 treatment the changes of absorbance is not significant.

Main conclusions are:

1. The essence of chemical processing is the penetration of the means in the pores, microcracks and cavities of the stone and subsequent crystallization in them and the formation of the film, which is confirmed by infrared spectral analysis.
2. The change in the absorption of infrared radiation is due to the effect of cavities and the scattering of rays in connection with the transition, through a crystallized film, of chemical impregnation agents

4. Acknowledgment

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The changes of absorbance caused by change of reflection angle of infrared ray [1]:

1. The cavity effect. The effect of cavities depends on the quality of polishing the surface of the natural stone (surface roughness). If the IR ray enters to cavity, the absorption increases. The cavities are filled, using chemical impregnation agents with the absorption decreasing.
2. Volume scattering. The scattering is caused by the passage of IR ray through a transparent layer of chemical impregnation agents and a change in the angle of reflection.

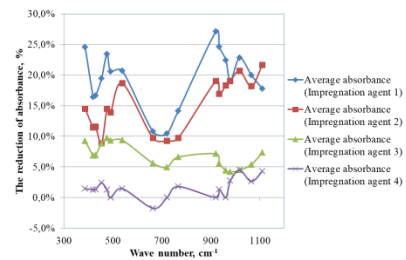


Figure 2. The reduction of absorbance of Bukivskiy gabbro (Galant) according to chemical treatment



COLLOIDAL NANOSILICA AS ADVANCED EXTERNAL REPAIR METHOD FOR CONCRETE STRUCTURES

Mercedes Sánchez, Fabiano Tavares, Ruben Beltrán

Keywords: *surface treatment, crack sealing, durability, colloidal nanosilica*

1. Introduction

External repair methods based on applying colloidal nanosilica on the hardened concrete surface are proposed for consolidating the existing cementitious matrix and improving the effectiveness and durability of the repair work. Nanosilica is able to penetrate through the concrete pores and to incorporate into the existing solid phases of the existing cementitious matrix (Sánchez, 2014). The compatibility of the nanosilica with the substrate will improve the durability of the treatment against the penetration of aggressive agents (Fajardo, 2015).

Different application methods have been proposed in the literature, such as soaking the sample into the nanosilica dispersion (Hou, 2015) or by migrating the colloidal nanosilica through the concrete pores under the action of an electric field (Sánchez, 2014). Colloidal nanosilica dispersions have been recently proposed also, for sealing cracks in hardened cementitious materials (Sánchez, 2018). The nanosilica dispersion is a liquid able to penetrate in depth through the crack, and after, the colloidal nanoparticles form a gel-like polymer based on silica, able to seal the crack.

In the present work different results related to the durability parameters of different mortar samples after external repair treatments based on colloidal nanosilica application are shown, both used as surface treatments and as crack sealing treatments. The resistance against water penetration of the treated sample is shown. SEM analysis confirming the presence of the nanosilica inside the cementitious matrix and/or filling the cracks are also included.

2. Materials and methods

Mortar samples prepared with OPC cement in a water/cement ratio of 0,5 have been used for the study. The commercial colloidal nanosilica dispersion Bindzil CC301 (Dp 7 nm, TS: 30%) has been used.

Two different situations have been considered: (a) Surface treatment based on applying the nanosilica dispersion on the sample surface, allowing the penetration through the concrete pores, (b) Injection of a crack with the nanosilica dispersion for sealing the crack.

Durability studies based on estimating the improving on the water absorption capillary penetration have been carried out. The presence of the nanosilica inside the cementitious matrix and inside the crack has been analyzed by SEM.

3. Results and conclusions.

In figure 1 the water capillary absorption tests for a mortar sample with a surface treatment by nanosilica application penetration (Figure 1-Left) and for a mortar sample with a crack sealed with nanosilica (Figure 1-Right) are shown. A clear decrease on the water capillary absorption



in the treated samples can be observed.

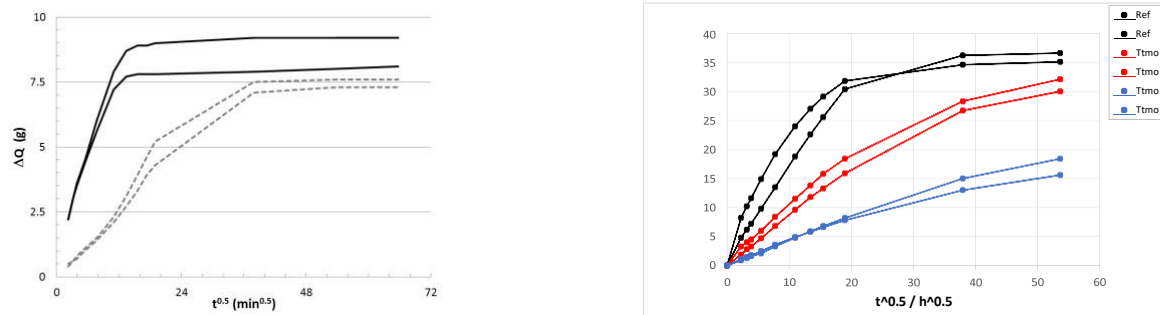


Figure 1. Left – surface treatment by applying nanosilica, solid lines (Ref.) and dot lines (treated sample). Right – crack sealed by nanosilica, black (Ref) and blue/red (treated samples)

4. Acknowledgment

RYC-2016-21422 Grant and COST Action CA15202.

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IMPROVING THE BIOCIDAL PROPERTIES OF THE RESTORATION MORTARS BY CARBENDAZIM ADSORBED ON INORGANIC SUBSTRATES

Adrián Pastor, Manuel Cruz-Yusta, Ivana Pavlovic, Luis Sánchez

Keywords: *biocide, mortar, layered double hydroxide, clay, carbendazim*

1. Introduction

The high microbial contamination of the stone materials present in the urban heritage provokes a negative effect on the aesthetics and durability of these materials, sometimes compromising the integrity of certain constructions (De Muynck, 2009). Currently, the most common prevention systems to avoid colonization are based on the use of biocides. However, the durability of the antimicrobial effect of the material is greatly reduced over time. In this sense, this research focuses on compounds that can protect biocides from external agents and thus improve the durability of stone material (Scarfato, 2016).

Layered Double Hydroxides (LDH) are materials similar to brucite. They are formed by positive sheets whose charge is balanced with the anions existing in the interlayer space. On the other hand, the clays have an antagonistic structure, in which the interlayer cations compensate the negative charge of the sheets.

In the present work, the adsorption of the biocide carbendazim (CBZ) in a layered double hydroxide and different clays has been studied. The adsorption complexes with the best biocidal activity were incorporated into a lime-based mortar.

2. Materials y methods

For the CBZ adsorption study, the adsorbent was added to a solution of CBZ. The mixtures were shaken to reach equilibrium and they were subsequently centrifuged. On the one hand, the CBZ concentration of the supernatant was measured by UV-HPLC. On the other hand, the solid (adsorption complex) was dried in an oven (70°C) and tested for biocidal activity. The commercial clays used as adsorbents were: SWy-1, Cloisite 10 (CL10) and Cloisite 20 (CL20). The LDH adsorbent was synthesized (LDH-DDS), the interlayer anion being dodecyl sulfate.

The biocidal activity of the samples was investigated. For this purpose, the adsorption complexes were placed in a Petri dish containing an inoculated strain of algae (*Stichococcus Bacillaris*) or fungus (*Aspergillus Niger*). At the end of the incubation period, the biocidal properties of the samples were visually analyzed by the presence or absence of microorganisms.

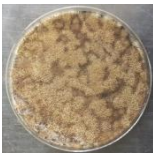
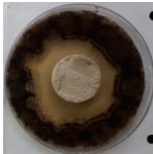

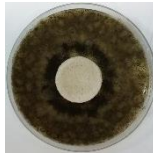
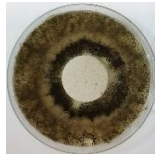
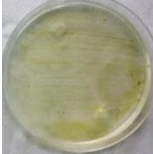




The adsorption complexes with the better biocidal properties were incorporated to the formulation of a hydraulic lime-based mortar. The mortar mix (mixing water = 19%) was placed in silicone molds (h = 5 mm). After a week, the samples were demolded and were left to cure for 21 days (20 ± 2 °C and 65 ± 5% relative humidity). Finally, the biocidal activity of the mortars was evaluated once, before and after, they were subjected to a standardized leaching test (EA NEN 7375: 2004).



3. Results and conclusions

The adsorption complexes with the highest amount of adsorbed CBZ (CL20-CBZ and LDH-DDS-CBZ) are those that showed good biocidal activity, both algaecide and fungicide. After including those complexes in the mortars, it was observed that the material achieved biocidal properties. In the case of the mortars subjected to the leaching test, it was found that the LDH-DDS-CBZ mortar was the one that best retained the fungicide and algaecide properties.

Table 3: Images of the Petri dishes after the incubation period of the microorganism.

Microorganism	Control	Before leaching		After leaching	
		CBZ	LDH-DDS-CBZ	CBZ	LDH-DDS-CBZ
<i>Aspergillus Niger</i>					
<i>Stichococcus bacillaris</i>					

4. Acknowledgments

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INFLUENCE OF HIGH TEMPERATURES ON PHYSICO-MECHANICAL AND DECORATIVE PROPERTIES OF LABRADORITE

Valentyn Korobiichuk, Oleksandr Sydorov, Iryna Leonets, Viktor Kravets, Stanislav Stovpnyk

1. Introduction

The ventilated facades that are decorated by natural stone are widespread. Although the natural stones are non-combustible materials, the effect of fire and heat can cause irreversible changes to their structure and physical-mechanical properties that influence the durability and static behavior of stone-made structures. Following a fire in buildings, there is an issue related to the renovation of these facilities. In this case, it is necessary to take into consideration the change in the physical-mechanical and decorative properties after exposure to high temperatures.

2. Material and methods

We studied the influence of heat treatment on the physical-mechanical properties of large-grain labradorite from Ukraine, which has a violet irisation of labrador grains. We experimentally examined samples from the four fields of labradorite, every deposit of labradorite was represented by 4 samples.

Samples of labradorite were heated in a furnace at a rate of 1 °C/min to the nominal temperature. A low rate of rise in temperature is used to maximize the temperature effect. The samples were heated in the electrical furnace to 200, 300, 400, 500, 600, 700, 800, 900 °C, followed by cooling to a temperature of 20 °C.

The front surface of labradorite samples was digitized using the Canon scanner CanoScan LiDE 700F. To determine the strength of natural stone and patterns in the development of cracks, we measured (in a stone sample) the velocity of surface ultrasonic wave propagation using the ultrasonic device UK-14MP, which is equipped with a surface sound sensor with a fixed base of 120 mm. We measured the propagation of ultrasonic waves along the diagonals of samples; the data acquired were averaged.

3. Results

Determining the surface area of the sample occupied by the oxidized metal at labradorite heating. The heating of labradorites led to the emergence of red spots at the polished surface of samples. This is explained by a phase transformation of crystals and the oxidation of Fe²⁺-elements in such minerals as pyroxene and magnetite to Fe³⁺. When computing the area of red spots relative to the total area of the sample, it was found that the area of red spots in the labradorite samples (Fig. 1) increased when heated to 300 °C. For example, for the Ocheretyansky labradorite, from 0.91 % to 4 %, for the Osnikivske labradorite, from 1 % to 3 %, and for other samples from deposits the growth amounted to 1 %. At a temperature of 400 °C, one observes an increase in red spots in labradorite samples from the Osnikivske deposit by 2.7 times, from 3 to 8 %. A sharp increase in red spots was observed in labradorite samples from the Ocheretyansky deposit at a temperature of 600 °C. At 900 °C, red spots cover the surface of the samples by 39 to 60 % of the area. The spots manifested themselves the least on labradorite samples from the Neviryvsky and Katerinovsky deposits, by 41 and 39 %, respectively. Red spots were most visible on labradorite samples from the Ocheretyansky and Osnikivske deposits by, respectively, 60 and 46 %, due to a higher content



of such minerals as ilmenite (FeTiO_3) and dusty magnetite ($\text{FeO} \cdot \text{Fe}_2\text{O}_3$).

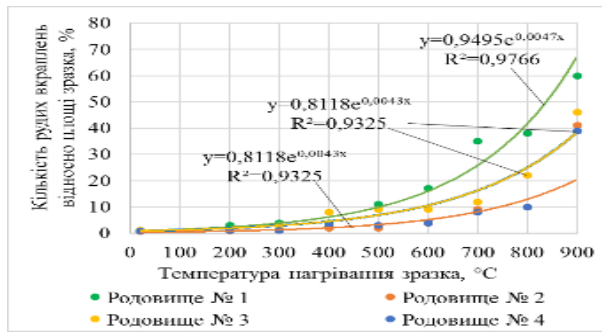


Fig. 1. Dependence of the area of red inclusions at the surface of labradorite samples on the temperature of heating

deposit No. 1 – Ocheretyansky; deposit No. 2 – Neviryvsky; deposit No. 3 – Osnikivske; deposit No. 4 – Katerinovskyy

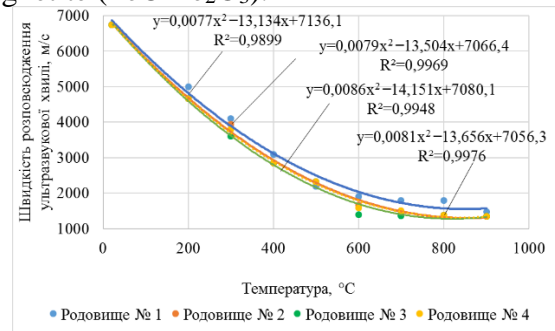


Fig. 2. Dependence of ultrasonic wave propagation velocity in labradorite samples on temperature, sample from

The results of this study provide an opportunity to compare labradorite deposits and evaluate the content of Fe^{2+} -elements in minerals. That would help selecting construction materials from labradorite for exterior cladding of buildings. Since at natural temperatures the oxidation of Fe^{2+} -elements occurs in labradorite over time under the influence of aggressive environments, red stains emerge at the surface.

Estimation of velocity of ultrasonic wave propagation in samples at labradorite heating. In the temperature range of 200–400 °C, labradorite demonstrates the disclosure of previously existing microcracks (Fig. 2). The most significant changes occur in a range from 500 to 600 °C, where there is an increase in pore openness. This is due to the formation of gaps between minerals, and merging the breaks with open pores. These phenomena are caused by the anisotropy of natural stone. The dependence of propagation velocity of ultrasonic wave on temperature is almost the same in labradorite samples. A decrease in the ultrasonic wave velocity by 80 % of the initial values occurs when heating the samples to a temperature of 900 °C. At a temperature of 700–900 °C, most labradorite samples demonstrate a decrease in the velocity of ultrasonic wave. This is explained by that the number of cracks in the studied samples reaches a threshold value. A change in the velocity of ultrasonic wave propagation in labradorite samples under the influence of temperature is nearly the same for all represented deposits.

4. Conclusions:

- Digital processing of images of labradorite samples has shown that the oxidation of minerals containing Fe^{2+} occurs permanently. At temperatures up to 600 °C, this process proceeds slowly in most labradorite samples. At a temperature above 600 °C, the oxidation of metals occurs more intensively. Red spots at the surface of samples is the result of oxidation of metal compounds Fe^{2+} , at various deposits of labradorite they cover a different area of the sample's surface of natural stone, which varies within 39–60 %.
- The dependence of ultrasonic wave propagation velocity in labradorite samples on temperature is almost the same. On average, there is a decrease in the ultrasonic wave velocity by 80 % of the initial values when samples are heated to a temperature of 900 °C. At a temperature of 700–900 °C, most labradorite samples demonstrate a decrease in the ultrasonic wave velocity. This is explained by that the number of cracks in the examined samples reaches a threshold value.



SENSORS FOR THE NON-DESTRUCTIVE CHARACTERIZATION OF CONCRETE DURABILITY

Fabiano Tavares' Rubén Beltrán' Mercedes Sánchez

Keywords: *Ad-hoc sensors , non-destructive, concrete, durability*

1. Introduction

The ongoing research presented in the present study deals with the remote monitoring of the durability parameters related to the reinforced concrete structures performance as a highly promising alternative for the non-destructive characterization of concrete (Barroca, 2013).

The general objective of the study is the design, development, fabrication and implementation of integrated wireless sensor systems to be embedded for the continuous monitoring of the concrete performance through the measurement of multiple variables in real-time: temperature, humidity content, resistivity, pH, presence of chloride ions, etc.

Different types of sensors are being developed, using the electrical resistivity as an indirect parameter for evaluating both the fresh state properties of concrete and the hardened concrete properties. The resistivity is used as the indirect parameter for evaluating the concrete moisture content (Cheng, 20068; Steinberg, 2016) and for detecting the penetration of aggressive agents from the concrete surface (chloride ions and/or carbonation depth, even adapting resistivity and RH/T probes in the same sensing module to obtain the simultaneous variation of the different variables). A remote data-acquisition system is also being implemented in the integrated sensor.

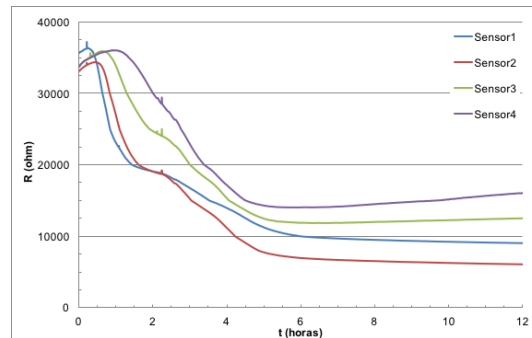
2. Material and methods

The ongoing research is on its very first stages and preliminary tests of two different types of sensors have been carried out:

- a) A miniaturized two-point sensor for evaluating the setting process of concrete mixes has been tested on laboratory conditions.
- b) An array of 5 sensors for assessing the water exchange through the concrete surface has been tested for both the uptake and the loss of water.

3. Results and conclusions

In the figure below, the results concerning the ability of the sensor array for detecting the water penetration through a dried concrete surface are included. It can be derived from the figure that the electrical resistance values decrease at different times depending on the depth of each sensor, with longer times of response for the deeper sensors.



Electrical resistance at the different levels of the sensor array embedded in a concrete sample.

The application of this study to the self-healing and external repair topic is highly promising from the perspective of a non-destructive and reliable characterization of the materials performance. The continuous monitoring of the electrical resistivity of self-healing materials will allow us to obtain the information in real time about the evolution of the cracks, from the formation to the healing process. It is interesting to note that the methodology is applicable, independently of the self-healing approach considered.

On the other hand, the array of sensor will be highly applicable for evaluating the effectiveness of the external repair methods, both concerning the penetrability of the treatment and related to the water-tightness and resistance against the aggressive agent penetration of the treated surface.

4. Acknowledgement

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PRODUCTION OF NANOSILICA, NANOALUMINA AND NANOTITANIA DISPERSIONS FOR EXTERNAL APPLICATION ON HARDENED MORTARS

Rubén Beltrán, Mercedes Sánchez, FabianoTavares

Keywords: *surface treatments, hardened concrete matrix, nanoparticle dispersions.*

1. Introduction

Cement-based materials are designed not only to provide mechanical performance to the structures but also to respond to durability demands and to maintain themselves for a certain useful life. Among the main factors that affect the durability of the structures is the presence of water in the concrete, since it is the vehicle through which most of the damage occurs to both the concrete (ice-thaw, attack by sulphates, ...) and to the rebar (corrosion by chlorides ...).

The proposed ongoing research deals with the development of more durable surface treatments, based on the penetration of nanomaterials dispersions through the pores of the concrete. This type of treatment aims to consolidate the cementitious matrix of the treated substrate with compatible products, such as nanosilica dispersions (Sánchez 2014, Franzoni 2014). And taking into account that other types of nanoparticles, such as nanotitania or nanoalumina, can also incorporate different properties to the existing substrate, such as photocatalytic capacity or fire resistance (Xiaoying 2017, part I and part II).

The proposal of the present work involves the production of ad hoc nanoparticle dispersions, to evaluate the influence of significant parameters, such as the size distribution of nanoparticles, the concentration of nanoparticles, the activity of nanoparticles ... and on the effectiveness for consolidating surface treatments and/or improving other properties, such as photocatalytic capacity or fire resistance. (Sánchez 2018)

2. Materials and methods

For this work, the first step was the synthesis of nanoparticles of Silica, Alumina and Titania by sol gel method. A commercial compound will also be used to compare the differences and the effectiveness of the powders. We made three different mechanical activations (Agate mortar, attritor mill and planetary mill) for obtain nano-size, in order to be able to penetrate inside the pores of the concrete.

Once the nanoparticles have been obtained and correctly characterized, different stable dispersions were prepared for the further application on the mortar-hardened surface. Different dispersions in water media with dispersant agent (ammonium polyacrilate) were made, using ammonium carbonate to obtain a pH near 8-9. This parameter is important because the stabilization of the dispersions depend directly on the pH.

Finally, the prepared dispersions were applied on the concrete samples to evaluate if they were effective and how they functionalize our structure.



3. Results and conclusions

In this first stage, the dispersions were prepared, choosing the best nanoparticles by composition and smallest diameter of particle. For the TiO_2 , nanotitania rich in Anatase phase with Planetary mill activation was selected; for the alumina, commercial alumina with attritor mill activation was used; and for the silica, powder calcined with attritor mill activation was synthesized.

Then, dispersions with different percentages of powder were prepared and the Z-potential test was carried out to make sure that the diameter of the particle were the correct and the dispersions were stable. The chosen dispersions are shown in the Table 1:

Material	d [nm]	ξ [mV]
AL ₂ O ₃ - 0,05 %	72,28 ± 11,1	-37,3
AL ₂ O ₃ - 0,1 %	42,84 ± 6,58	-29,5
TiO ₂ (S-4) - 0,01 %	111,4 - 63,5%	-54,2
	227 - 36,5 %	
TiO ₂ (S-4) - 0,1 %	109,4 - 63 %	-56,1
	241,9 - 37 %	
SiO ₂ - 0,05 %	261,6	-36,5
SiO ₂ - 0,1 %	245	-39
SiO ₂ - 0,05 % + D	280,5	-40,6
SiO ₂ - 0,1 % + D	238,5	-42,6

Table 1. Z-potential test and diameter of the particle in the dispersion.

The next step will be applying the dispersions on the concrete samples and evaluate their effectiveness and durability.

4. Acknowledgment

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RAW EARTH APPLIED TO MODERN MASONRY CONSTRUCTION SYSTEMS: PROPOSAL OF AN INNOVATIVE EXTERIOR ENCLOSURE

S. Mobili, C. Galán Marín, C. Rivera Gómez

Keywords: *raw earth; façade solutions; sandwich panel; sustainability; raw materials.*

1. Introduction

Nowadays, there is a growing need to use alternative technologies that allow to reduce construction waste and energy consumption during the life cycle of the building (in comparison with others) (Bragança & Mateus, 2006) (Vasconcelos et al., 2013). The development of raw earth construction is today one of the most important fields in the area of ecological materials. In fact, raw earth construction materials contain much less embodied energy and are, therefore, an alternative of great interest. The use of these materials in the construction of buildings can be an alternative in the path to be followed towards the building of nearly zero consumption (Arrigoni et al., 2017). This paper presents the results of an experimental campaign designed to develop an innovative proposal for an industrialized exterior enclosure that includes unfired clay as the principal material, and that responds to the mechanical, thermal and acoustic requirements necessary to ensure the comfort of space and reduce the demands of saving energy and resources.

2. Materials and methods

This work presents an innovative proposal for a construction system based on prefabricated insulated sandwich panels, as the prototype shown in the image, produced on the basis of a new eco-efficient composite material, with a raw stabilized clay base. (Galán-Marín, Rivera-Gómez, & Petric, 2010)

The proposed panel are sandwich type configuration with an intermediate insulating material and two exterior pieces, manufactured by an extrusion process. The composite material used in the production of these pieces is a raw earth stabilized with calcium alginate and natural fibers of animal origin.

The research proposes a series of approximate verifications of the thermal and mechanical behavior of the panel, as well as the analysis of constructive systems, such as patents that enabled us to highlight considerations that allowed the design and execution of the prototype.

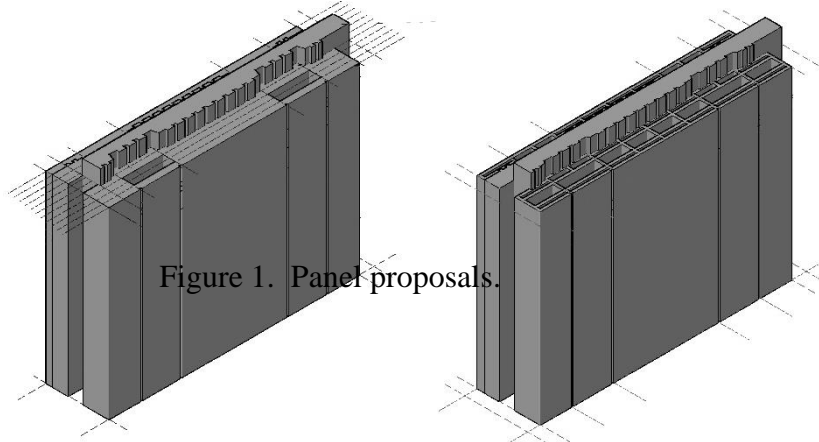


Figure 1. Panel proposals.

Their compliance with the values established by the Spanish building code has also been analyzed.



3. Results and conclusion

The first results confirm that the presented solution shows a better behavior than traditional constructive solutions. The system fulfils the necessary requirements to guarantee better thermal performance, above a great part of the traditionally used systems. It also guarantees the necessary structural stability. The whole process has been carried out to overcome the disadvantages of using the soil as a constructive element and to strengthen its value as a possible material for industrialized construction.

Also, the solution makes it possible to prioritize environmental aspects, considerably reduce the ecological impact generated during the manufacture of the piece, decreasing the energy consumption in this phase because it is not a fire element.

4. Acknowledgment

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NATURAL FIBERS FOR SUSTAINABLE CEMENT REINFORCEMENT

Lucia J Fernandez-Carrasco, Nourjmajal Gourgani

1. Introduction

Since Ordinary Portland cement is losing its hegemony in the field of research on cement-based materials to give way to the growing interest in the study and analysis of other more environmentally friendly cements, the number of studies on the properties and Aluminate Calcium cement applications in areas in which it had been discarded due to some technical problems in the past. Currently, it is therefore necessary to investigate new applications in which the CAC contributes with its good properties to the development of useful, sustainable and durable building systems.

The main raw materials used in the manufacture of CAC are limestone and bauxite. Once the fusion of raw material takes place, no material is added to the CAC clinker, the setting is controlled by its composition. The main reactive mineral in CAC is the monocalcium aluminate $\text{CaO} \cdot \text{Al}_2\text{O}_3$ (CA), the properties are determined by its hydration process and depends on the curing temperature. At low temperatures metastable hydrates are formed which converts into the thermodynamically stable ones [2]. The high early strength properties of this special cement made its main initial uses in the production of prestressed concrete units were no high temperature was needed opposite to Portland cement. But after a series of unfortunate collapses, the CAC ceased to be used in structural applications. The chemical resistance of CAC also dealt with non-structural uses.

The natural fiber reinforcement in concrete mortar and cement paste can enhance many engineering properties of these basic materials. It should be noted that the major attentions of recent investigations have been done is focused on Portland cement (OPC) concrete systems but the systems fabricated with PC and cellulose fibers have shown certain durability concerns.

The aqueous media of OPC composite systems represents a serious problem of durability for natural fibers due to the alkalinity of the porous solution caused by the dissolution of the portlandite. This ambient produces the deterioration of the fiber and therefore the flexural resistant effect contributed by the fiber. In such context, this paper presents alternative cements – as Calcium Aluminate Cement (CAC) as a possible solution of the durability disadvantages of OPC. CAC is a special type of hydraulic cement, it is differentiated from the normal PC with a high characteristic performance such as normal setting time but with a very fast hardening process, high chemical resistance, high corrosion resistance, high resistance against acidic materials. All these advantages of CAC lead this material to be used widely in the construction industry.

This research compares the results obtained for matrixes elaborated with CAC and natural vegetable fibers. The analysis of the study was supported by the determination of Mechanical strength, Water absorption and Porosity, X-Ray and Infrared spectroscopy in manufactured samples.

2. Material and methods

A calcium aluminate cement (Electro-land) from Ciments Molins Industrial S.L. was used as the cementing material in this study. The sand used for mixtures is a kind of silica sand, is a natural



sand, siliceous, with rounded grains, which silica content is at least 98%. The natural fiber used was a *Pinus insignis* in 2% of wt. referred to the cement content. The samples were analyzed at 7 days and 6 months.

3. Results and conclusions

Figure 1 presents the mechanical strength values of 4x4x16 cm measured mortars. The results show that the compressive and flexural strength values are significant important compared with a traditional OPC mortar. The flexural values present close to 10 MPa at 7 days and increasing to 12 MPa at 6 months. The compressive strength of the samples had close to 75MPa at 7 days and also increasing this value towards 85-90 MPa of strength, this is a very significative compressive strength compared with the OPC. The total porosity determined was 12%. The XRD mineralogical study shows the formation of hexagonal phases at this stage – CAH_{10} and C_2AH_8 phases.

4. Acknowledgment

We would like to gratefully acknowledge the Agència de Gestió d'Ajuts Universitaris i de Recerca (AGAUR) for their support through the project 2017 SGR 29.

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DOI: 10.3390/ma100202.1



CO₂ CAPTURE WITH HYDROTALCITES OF MGAL-CO₃ AND ORGANOHYDROTALCITES FOR APPLICATION AS SINK URBAN GREENHOUSE GAS

David Suescum-Morales, David Cantador-Fernández, José Ramón Jiménez, José María Fernández

Keywords: Capture CO₂, Hydrotalcite, Adsorption, Climate change.

1. Introduction

There is currently great concern at the international level regarding the emission of greenhouse gases (GHG) of anthropogenic origin and their environmental impact. The rate of growth of these emissions and the potential danger to which we expose ourselves has led society to consider how to address this problem. CO₂ emissions grew in 2017 by 460 million tons more than in the previous year, reaching a historical peak of 32.5 Gt. This growth in emissions has been the result of a growth in the economy, a drop in the price of fuels, and lower efforts in energy efficiency (IEA, 2017). According to the Kyoto Protocol, CO₂ is identified as the main responsible component of climate change and global warming (Montzka, Dlugokencky, & Butler, 2011). With this research we want to check the CO₂ capture capacity of two hydrotalcite families of MgAlCO₃ (one synthesized in the laboratory and another commercial); and of two types of organohydrotalcites (OHTs), one with anion dodecylsulfate (HT-DDS) interspersed and another with tetradecanodiató (HT-TDD), both prepared by the method of coprecipitation. The hydrotalcites, organohydrotalcites and those calcined at 500 ° C have been previously characterized.

2. Materials and methods

The physical and chemical characterization of both hydrotalcites and organohydrotalcites has been carried out by means of X-ray diffraction (XRD), thermogravimetric analysis (ATD-TG), particle size, transmission and scanning electron microscopy, as well as the realization of BET isotherms to study the Surface

To measure the CO₂ adsorption capacity of both hydrotalcites and organohydrotalcites, a "Sieverts type" adsorption analyzer has been used, making it possible to perform isotherms at different temperatures, using CO₂ as adsorbent (see figure 1).

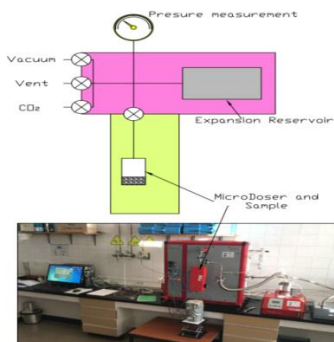


Figure 1. Diagram of equipment type Sieverts and PCTPro2000.



3. Results and conclusions

Isotherms have been made at 0, 20 and 35 °C for the hydrotalcites, and at 0 and 35 °C for the organohydrotalcites, calcined and without calcining in both cases. All these isotherms have been adjusted to the adsorption models defined by Freundlich, Langmuir, Temkin and Dubinin-Raduskevich.

The study shows that the applied heat treatment, such as the temperature at which the isotherm is made, is an important factor that affect the adsorption processes. The maximum adsorption capacity of the hydrotalcite MgAlCO₃-500 °C (synthesized) at a temperature of 0 °C is 140 mg / g. For organohydrotalcites, the maximum adsorption capacity is 170 mg / g, in the case of TDD-500 °C at a temperature of 0 °C.

4. Acknowledgment

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DETERMINATION OF THE REPEATABILITY AND REPRODUCIBILITY OF THE SOLUTIONS PROVIDED BY AN ACTIVE GEODETIC NETWORK: APPLICATIONS TO CONSTRUCTION

Enrique Cano Jódar; Francisco Javier Mesas Carrascosa.

Keywords: *GNSS, RTK, Repeatability, Reproducibility.*

1. Introduction.

Surveying plays a very important role in all the phases into which the construction of engineering projects is divided. It is responsible for ensuring that the project execution coincides with the geometric characteristics of the design. As a result, methods and instruments that allow the work to be dynamic and accurate enough are necessary, so it achieves the required quality. Although surveying has not undergone major changes from a general conceptual point of view, the development of instrumentation, together with the development of computer science and electronics in the 1970s, allowed the incorporation of distance meters that, used together with optical equipment, led to the use of semi-total and total stations, all in an effort to automatically collect data. Consequently, the use of distance measurement offered a substantial change in terms of how surveying methods were applied. Undoubtedly, the implementation of satellite navigation systems (GNSS) starting in the 1980s represented an authentic revolution in the field of surveying and geodesy, yielding different positioning techniques, from the development of differential correction methods (Hofmann-Wellenhof, B, 2001) to real-time data gathering techniques (RTK, Real Time Kinematik) (Remondi B, 1985). Depending on the spatial quality required by the user, GNSS systems can be applied to survey networks, surveys and stakeouts.

However, the application of these systems is not free from limitations in terms of performance and effective work. The emergence of Active Geodetic Networks starting in the 1990s (Fotopoulos et al, 2001, Rizos C, et al, 2002, Alves et al, 2006, Aponte et al, 2009) allowed us to overcome these limitations by increasing performance in survey work applied to construction. It is in this context that we consider the determination of the repeatability and reproducibility of the solutions provided by an Active Geodetic Network as applied to construction, by using the UNE 82009-2:1999 standard, equivalent to the ISO 5725-2:1994 international standard.

2. Methods and Materials.

The UNE 82009-2 standard (Accuracy (trueness and precision) of measurement methods and results, AENOR, 1999. Basic method for the determination of repeatability and reproducibility of a standard measurement method) was used to determine the repeatability and reproducibility of an active geodetic network. In planning this validation methodology, a number (p) of laboratories are set up in which a number of levels (q) are tested with the same number (n) of repetitions in each level, with identical repeatability conditions considered for each laboratory. The general term for designating the variability present between repeated measurements is precision. The standard considers repeatability and reproducibility as two types of precision for determining the variability of a measurement method, with two terms delimiting the precision: the repeatability characterizes the smallest variation, while the reproducibility the maximum variation.

In applying this standard to an active geodetic network, a set of three reference stations were considered as the laboratories. These stations will yield the position (x, y, z) of a general of six control points or levels, with a total of 90 measurements taken for each. The real-time correction method used in the position determination was the Master Auxiliary Concept (MAC) (Euler H.-J, 2001, N. Brown, 2005), a simple solution from the selected station. In this case, the selected station



matched the master station used by the MAC. The dual-frequency GNSS receiver used in this work was a Leica GG AX (Hexagon AB, Stockholm, Sweden), mounted on a pole and equipped with an internet-connected mobile phone to receive differential corrections from the selected station through the NTRIP (Networked Transport of RTCM via Internet Protocol) (Lenz, 2004). The Andalusian Positioning Network (RAP) of the Andalusian regional government was used as the active geodetic network.

3. Results and Conclusions.

The reproducibility and repeatability values of the system were determined using three reference antennas in the RAP network (Pozoblanco, Cazalla, Córdoba), applying the UNE 82009-2:1999 standard. Table 1 shows the repeatability and reproducibility values for the different levels tested, in both position and height.

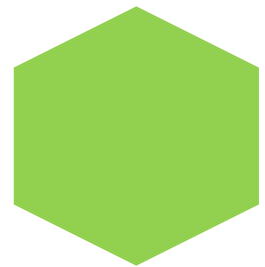
Table 1 - Repeatability and reproducibility values for the six levels tested.

Point	Repeatability		Reproducibility	
	Position	Height	Position	Height
1	0.005	0.012	0.014	0.031
2	0.006	0.017	0.007	0,038
3	0.005	0.016	0.007	0,036
4	0.006	0.009	0.014	0.045
5	0.006	0.010	0.011	0.023
6	0.006	0.013	0.013	0.029
Average	0.006	0.013	0.011	0.034

The average planimetry and altimetry results obtained, considering repeatability and reproducibility, allow us to state that the real-time services offered by the RAP network are suitable for use in construction works for engineering projects. In addition, since the base receiver is one of the antennas in the RAP network, this saves both time and money. Time-wise, this process eliminates the set-up period associated with the GNSS antenna that serves as the master. Moreover, since it is only necessary to acquire a single GNSS receiver, the financial costs associated with the work are further reduced.

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CLEAN ENVIRONMENT





APPLICATION OF COMPLEX NETWORKS TO THE DESCRIPTION OF OZONE DYNAMICS

Rafael Carmona-Cabezas, Eduardo Gutiérrez de Ravé,
Francisco J. Jiménez-Hornero

Keywords: *Ground-level ozone, air pollution, Visibility Graphs, complex networks, time series*

1. Introduction

Many studies have been performed about ground-level ozone over the last decades. The importance of ozone characterization and analysis lies on the fact that it is one of the main photochemical oxidants (due to its abundance). This irritant gas has serious repercussions for human health and harvests when its concentration is high (Doherty et al., 2009). The exposed damages have an economic impact, since every year they lead to losses of several billions of dollars (Miao et al., 2017). Ozone is a secondary pollutant, whose chemical formation and destruction mechanisms are known to be photochemical and nonlinear processes (Graedel and Crutzen, 1993). These mechanisms are highly dependant on meteorological variables, such as the temperature, wind direction and, mainly, solar radiation, and it depends as well on chemical precursors, such as nitrogen oxides (Sillman, 1999). As a matter of fact, all these factors make the analysis of the temporal evolution of ozone a very complex task.

2. Materials and methods

Here, authors propose the use of a recently created method to transform time series into complex networks, called Visibility Graph (VG) (Lacasa et al., 2008). After performing this transformation, it is possible to extract some properties from the signal (ozone concentration time series in this case) by analyzing the resulting network. This has been applied to ground-level ozone concentration time series corresponding to the pollution in the city of Córdoba, from 2013 to 2016.

In order to construct the visibility matrix which contains the information of all the nodes of the new system, it is necessary to establish a criterion to discern whether two points would be connected or not. This criterion reads as follows: two arbitrary data from the time series (t_a, y_a) and (t_b, y_b) have visibility (and would become two connected nodes in the graph) if any other data point (t_c, y_c) between them ($t_a < t_c < t_b$) fulfills:

$$y_c < y_a + (y_b - y_a) \frac{t_c - t_a}{t_b - t_a} \quad (1)$$

From it, the parameter that is mainly studied from the visibility graph is the so-called *degree* (k) (the number of nodes seen by each point) and its probability distribution $P(k)$. From its logarithmic regression, the γ coefficient can be obtained, which is known to be related to the fractal properties of the signal.

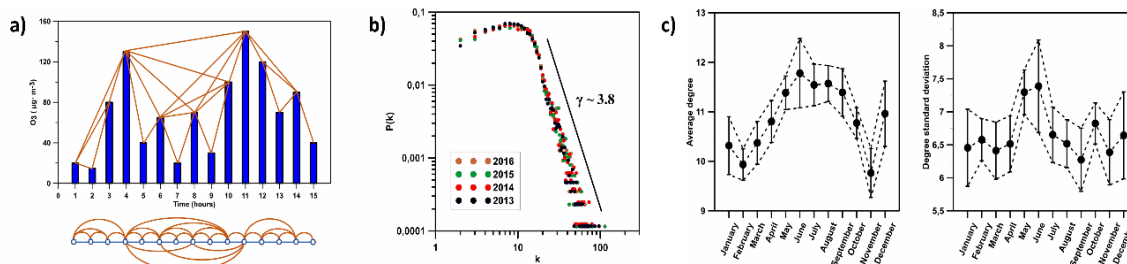
3. Results and conclusions

Results show that indeed, it is possible to describe the seasonal dynamics of the pollutant by checking the degree (average and standard deviation) of the resulting complex network. The



mean of this quantity has been discussed to be related to a higher number of hubs (nodes with the highest degree and therefore visibility), and the standard deviation, to the difference between day and night values of this ozone concentration (Carmona- Cabezas et al., 2019). Both were found to be maximum from May to September, when the conditions for ozone creation are more suitable. Also, the $P(k)$ was in accordance with other studies and constant through the different years studied.

Below, figures of an example VG (a), degree distributions (b) and main results (c) can be seen.



This can be regarded as a proof that this methodology is a suitable tool to describe the seasonal dynamics of this air pollutant. VGs have proven to have advantages such as: i) their topology inherits the features of the associated time series, which ends up resulting on supplementary information through the degree distribution; ii) and also, this novel connection between time series and complex networks opens a broad range of possibilities within the study of complex signals.

4. Acknowledgment

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VERY LOW ENERGY CONSUMPTION HVAC SYSTEMS FOR NZEB BUILDINGS. THE POTENTIAL OF INDIRECT EVAPORATIVE COOLERS IN SOUTH EUROPEAN CLIMATES

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Keywords: *indirect evaporative cooling, energy efficiency, NZEB buildings*

1. Introduction

Development of very low energy consumption HVAC (Heating, Ventilation and Air Conditioning) systems are required in the European frame of NZEB (Nearly Zero Energy Building). Evaporative cooling systems are an effective alternative to conventional technologies, due to their high efficiency and reduced primary energy consumption (Duan, 2012). There are two main types of evaporative coolers: the direct evaporative cooler (DEC), and the indirect evaporative cooler (IEC). DEC is based on direct contact between air and water, while IEC is based on heat and mass transfer between two streams of air, separated by a heat transfer surface with a dry side, where only air is cooling, and a wet side, where water is evaporated into air (Porumb, 2016). In addition, there are different types of IEC: conventional IEC, which supplies air between the dry bulb temperature, T_{sb} , and the wet bulb temperature, T_{wb} ; regenerative evaporative cooler (R-IEC), including single-stage counter-flow, and finally, Maisotenko-cycle (M-IEC), including multi-stage cross-flow. The last two supply air between the dry bulb temperature, T_{sb} , and the dew point temperature, T_{dp} . These types of evaporative cooler systems are shown in Table 1. This work focused on the study of R-IEC.

Table 1. Types of evaporative cooler systems (Porumb, 2016).

(a) DEC	(b) IEC	(c) R-IEC	(e) M-IEC
$T_{wb} < T < T_{sb}$	$T_{wb} < T < T_{sb}$	$T_{dp} < T < T_{sb}$	

The main objective of this study was to determine numerically the energy efficiency of a R- IEC air-cooling system for typical summer air conditions in Cordoba, Spain.

2. Materials and methods

The R-IEC study in this work is a self-contained device, mainly composed of a core heat and mass exchanger, a low energy consumption centrifugal fan, a water distributing system and an outer casing. The primary air of the device is cooled along the dry channels without moisture increase and, subsequently, discharged. Through the perforations located at the end of the channels, a portion of the primary air is diverted into the adjacent wet channels. Flowing in counter direction to the primary air in dry channels, the secondary air of wet channels is humidified,



heated and, finally, exhausted outside.

An analytical model was used to analyze the performance of R-IEC (Hasan, 2012). The size of this exchanger was: total length 0.86 m, total depth 1.1 m, total width 0.46 m, channel height 3 mm, channel width 45.8 mm and number of channels 320. The supply air volumetric flow rate was 1530 m³/h, and the secondary to intake air ratio was 0.44. A typical summer air conditions in Cordoba were selected: dry bulb temperature 37.78 °C and air humidity ratio 9.05 g/kg.

3. Results and conclusions

The air conditions of primary and secondary airflows are shown in Figure 1. It can be observed that the primary outlet air temperature was 21.5 °C, i.e. a temperature reduction of 16.28 °C. These results also showed that the cooling capacity was 8303 W, the fan power consumption was 394 W and the coefficient of performance, COP, was 21.

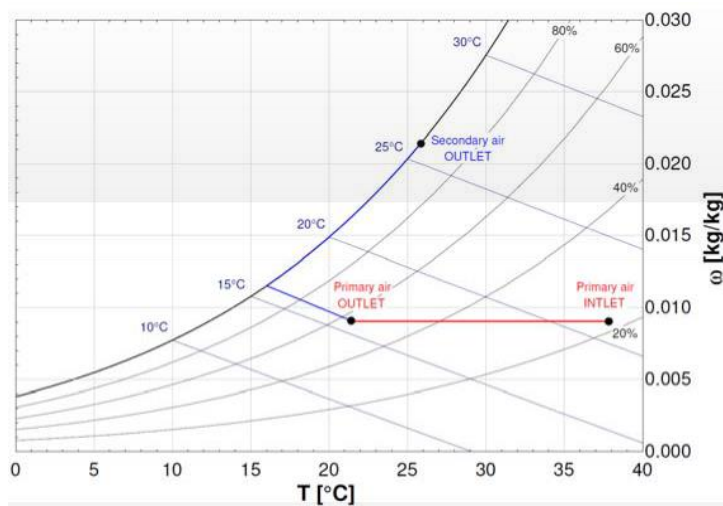


Figure 1. Psychrometric chart. Primary and secondary air processes.

In conclusion, these results suggested that R-IEC can be considered as a very low energy consumption HVAC system to cool air in hot and dry air conditions, such as in South European climatic conditions. Moreover, these systems would contribute to achieving the European objectives of NZEB.

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INDOOR AIR QUALITY IN BUILDINGS: MONITORING WITH LOW-COST DEVICES FOR RISK PREVENTION

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Keywords: *Monitoring of indoor air quality, Healthy homes, Air Pollution, INDOOR - prevention and control*

1. Introduction

The term "indoor air quality" has become particularly relevant over the last few years. It has been associated with the term "sick building syndrome", which encompasses a wide range of symptoms or illnesses that people who work or live in the building attribute to the building itself. According to the European Environment Agency's "Environment and Health" report, acute lower respiratory tract infections attributable to indoor air pollution account for 4.6% of all deaths and 3.1% of DALYs (disability adjusted life years) (EEA, 2005).

The main pollutants found in home indoor air, offices, leisure premises, etc. are: Carbon Monoxide (CO), Volatile Organic Compounds (VOC), Sulphur Dioxide (SO₂), Ozone (O₃), Biological Pollutants, Household Products, Nitrogen Oxides (NO_x), Environmental Tobacco Smoke (Fig. 1). Other important factors related to indoor air quality and health effects in the Mediterranean areas are high temperatures, humidity, air currents... (ISHT, 1990).

Experience indicates that traditional techniques used in industrial hygiene and in heating, ventilation and air-conditioning do not always provide satisfactory results in solving current indoor air quality problems. The solution must include pollutant continuous monitoring so that preventive measures can be taken to provide a rapid response to the possible risk. The guiding values, mechanisms involved according to current toxicological evidence and potential consequences on health can be seen in many publications (Viegi, 2004; WHO, 2010; WHO, 2012).

2. Materials and methods

Today, there are low cost sensors to measure the levels of CO, CO₂, O₃, NO_x, NH₃, CH₄, Volatile Organic Compounds, Temperature, Humidity, Noise,... In addition, a low-cost electronic board (approximately 6 €), based on ESP32 of ESPRESIF with WIFI connection and MQTT protocol is available. A distributed network of intelligent sensors is implemented, making data easily accessible and enabling a "mapping" of the monitored areas, where indoor air conditions can be observed.



APPROACH TO THE ANALYSIS OF THERMAL COMFORT IN EXISTING PUBLIC EDUCATIONAL BUILDINGS FOR THE IMPROVEMENT OF ENERGY EFFICIENCY: SMARTPOLITECH

Irene Amigo Gamero, Beatriz Montalbán Pozas

Keywords: *thermal comfort, smart building, public building, sensorization, energy efficiency, energy saving, user.*

1. Introduction

Energy efficiency in Spanish public buildings is a necessary challenge to address nowadays, on account of the obsolete real estate stock and the excessive energy consumption associated with its usage. Likewise, the hygrothermal conditions within them are very far from the stipulated values measuring interior comfort. User interaction with building emerges among the various factors that could influence both parameters. It seems necessary to analyse the interior comfort to determine the potential for improvement of energy efficiency in the use of buildings, and this interest increases in a possibly warmer scenario, as a result of climate change. The analysis is proposed from an adaptive model perspective, where users can interact with their environment to improve their comfort conditions, compared to some standards of approximation to comfort (Zomorodian, Tahsildoost and Hafezi, 2016). The sensorization infrastructure SmartPolitech, installed in the Polytechnic School of Caceres and distributed in buildings of the 90s with a high energy consumption and a high user population, allows the development of this comfort study.

2. Materials and methods

This study of thermal comfort is based on the methodological application of an objective survey and a subjective survey. These two approaches are proposed since it is proven that people with pro-environment attitude tend to be more permissive in accepting the interior environment of buildings (Yang, Yan and Lam, 2014). The objective survey is based on the constructive definition of buildings, inventory facilities, characterization of the conditions of occupancy and use, and operational conditions of facilities. In addition, real-time objective data on temperature and humidity are collected through the SmartPolitech sensor system. The system is based on the communication of the sensors with the database. The sensors can publish the data directly, or they can be consulted. The temperature and humidity sensors are RAY STH, wireless sensor with WiFi communication and battery powered, it has an accuracy of +/- 0.5 °C and +/- 3% RH. For the objective analysis of thermo-hygrometer comfort conditions, the Spanish regulatory ranges established by the Regulation of thermal installations in buildings (RITE) was employed.

The second part, the subjective survey, is based on knowing the user's perception of the temperature and humidity conditions of the interior spaces. To carry out the study surveys are conducted using the ASHRAE scale (American Society of Heating, 2010), referring to clothing level and metabolic rate, and characterizing the active user. The subjective survey is relevant because, according to some studies, the comfort range, in an adaptive environment, would be wider.



3. Results and conclusions

The building analysed is the Building Pavilion, whose construction system is traditional, the spaces are distributed on two floors with central corridor illuminated overhead, the facades have east and west orientation. There is a central heating system that supplies all the useful spaces and cooling systems only in the office spaces. The period analysed objectively covers from November 2016 to February 2019 and records were collected every hour. Table 1 shows that the objective thermo-hygrometer comfort conditions are only reached in a range between 7.24% and 21.17% of the hours, despite the existence of air conditioning systems, and these percentages are duplicated considering only temperature conditions.

Room	Floor	Orientation	Use	Records (N)	Comfort T-H (%)	Comfort T (%)
COM001	Ground	-	Corridor	18654	12.97	25.10
DES010	Ground	East	Office	18629	13.75	26.18
DES030	Ground	West	Office	17395	8.64	16.73
AUL011	First	East	Classroom	17983	17.82	30.63
AUL018	First	North-West	Classroom	18492	7.24	10.91
AUL020	First	West	Classroom	18949	17.34	27.98
DES009	First	East	Office	16057	21.17	31.61
DES023	First	West	Office	9576	18.14	23.81

Table 4. Objective analysis of thermal comfort in Building Pavilion Nov.2016-Feb.2019

The subjective survey was launched in February 2019 and it is still in process. Therefore, the results are still partial. Initial results suggest that the adaptive comfort range is higher than that established by RITE, with users in comfort at slightly lower and higher temperatures than those established in the objective analysis. It must be taken into account that users can interact with windows and blinds, that is, with ventilation and shading; In addition, clothing is adaptable to the operating conditions of the interior spaces for each user.

In conclusion, thermal sensation of comfort could be improved through the user's interaction with the building envelope, along with the selective use of the spaces according to the time of the year, the hours of the day, the orientation, and activity, among other factors.

4. Acknowledgment

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FROM THE QUALITY OF INTERIORS ENVIRONMENTS TO SUSTAINABLE DEVELOPMENTS

Milagros Lara de Williams

Keywords: *interior environment, air quality, sick building, sustainable development*

1. Introduction.

The environment dynamic has led to the emergence of new concepts to respond to the needs of the population, the preservation of the health and the environment itself, starting from the quality in interior environments, by making measurements of bio aerosols and parameters associated with comfort, temperature and relative humidity, to those related to the concept of Sick Building Syndrome (SBS), that not only contemplates the previously mentioned but also the characteristics of the building. The diagnosis of the SBS allows us to detect the presence of contaminants, correcting bad practices of maintenance, which can lead to excessive energy consumption, which in the end results in an inadequate use of natural resources, with the consequent reduction and even possible exhaustion of the same. This is when the concept of sustainable development emerges, defined as an advance that meets the needs of the present without endangering the ability of future generations to meet their own needs. This definition was used for the first time in 1987 in the World Commission on the Environment of the UN.

2. Materials and method.

Lara (2004) conducted a preliminary evaluation of the quality of indoor environments in day care centers and preschools, aimed at obtaining results that contribute to establishing recommended values or standards, adapted to the requirements and conditions of Venezuela. The parameters evaluated were: Bio aerosols (Fungi and bacteria), Relative Humidity, Temperature and Air Velocity For the measurement of biological agents or aerosols two techniques were used: gravitational, sedimentation in Petri dishes, qualitative and other volumetric, impaction, using an air sampler system, HIAIR, which allows obtaining quantitative results of the condition of the environment. The results were compared with the recommended levels according to the IAQA (acronym in English of the Association of Internal Air Quality of the United States), which indicates suggested limit values <300 CFU / m³ for fungi and <500 CFU / m³ for bacteria. With regard to Sick Building Syndrome (SEE), (Hernández and Landaeta, 2007), they evaluated in a preliminary way the factors that affected the appearance of the symptoms of the SEE, in the facilities of a university building.

They characterized the type of symptoms inherent to the SEE, estimated its magnitude, quantified the manifestations of the state of the facilities on the health of the teaching, administrative and student staff, and formulated corrective measures in order to minimize its effects. Within the framework of the project called "UCV Sustainable Campus", numerous works have been carried out, including that of Jiménez and Montozzi (2018), who evaluated the sustainability of a building of the Faculty of Engineering of the University City of Caracas through the international certification systems BREEAM, LEED, HQE and DGNB, using a research model based on the direct data collection of the study site and the application, as possible, of the different parameters established in each system, comparing the results obtained and proposing recommendations that could contribute to the sustainable aspects of the building, a survey was also applied in order to



compare its results with the similar aspects considered in the systems used and the perception of the SBS.

3. Results and conclusions

From the work of (Lara, 2004), it is clear that institutes 1 and 3, presented higher values than those suggested by the IAQA, both in bacteria and fungi. The highest concentration of bio aerosols was presented by Institute 1, which is located in a mountainous area. Regarding the relative humidity, the three institutes presented values higher than the range recommended by the ASHRAE, of 30-60%, and the dry temperature in all the institutes, remained in the comfort range (20-26 ° C) recommended by this same organism.

Among the results obtained from the work of (Hernández and Landaeta, 2007), the persistence of symptoms associated with the ESS was 55.4%, so the building is considered affected by the ESS, exceeding the stipulated by the WHO (20%). Regarding the magnitude of the symptoms, the discomforts that occur with a higher percentage are: headache (47.6%), sneezing in a row (42.3%), difficulty in concentration (34.8%), cough (30.7%) and nasal congestion (30.7%), which could be associated with relative humidity and temperature, whose values exceed those recommended by the ASHRAE; Directly coinciding the headache with poor lighting and few units of light bulbs, like nasal congestion and cough with ventilation problems. The areas with the highest average density of bacteria and fungi were the air handling units (UMA) of the ground floor and the first floor.

From the work of (Montozzi and Jiménez, 2018) for the BREEAM system, the building obtained the classification of 'Approved' according to the Manuals of Asset Performance and Building Management, and the classification of 'Acceptable' in the Management Manual of the Occupant, through the LEED system the building did not obtain any certification; by the HQE system, it obtained the classification of 'Good', and by the DGNB system, the building obtained the classification 'Bronze'. On the other hand, 70% of the users present some symptom associated with the SBS

4. Acknowledgment

To all the teaching and student staff, who over the years have participated in the studies carried out, especially Prof. Geovanni Siem, one of the pioneers of the UCV Sustainable Campus project.

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AN ARGON NON-THERMAL MICROWAVE PLASMA FOR TREATMENT OF BETX CONTAMINATED WATER VIA OH RADICAL OXIDATION

Enrique Casado, M. Carmen García, Dorota A. Krawczyk and Antonio Rodero

Keywords: *OH radicals, CG-MS, Plasma, Fluorimetry, OES.*

1. Introduction

In the last years, the use and design of plasma reactors capable to produce reactive oxygen and nitrogen species has become a main task in the development of both environmental and bio-medical applications. In this work, a non-thermal microwave argon jet has been used for water treatment, with a small xylene layer on the surface of the water which is oxidized via OH radicals. OH radicals play an important role in the degradation of aromatics. Products resulting from the plasma-xylene interaction were identified and quantified using Gas Chromatography – Mass Spectrometry (CG-MS) analysis under different plasma conditions: microwave power, argon flow rate, treatment time and geometry.

Rate production of OH using fluorimetry and plasma characterization using Optical Emission Spectroscopy (OES) have also been performed under different conditions.

2. Materials and method

The generation of the argon plasma was performed using a surfatron microwave power coupling device [Moisan, 1992]. In the present case, a T-shaped quartz tube (1.5 and 4mm of inner and outer diameter) with one of its ends opened to the air was used (Fig. 1). With this configuration the plasma column goes down and approach the water. All the liquid samples were placed in cylinder shaped glass containers (2 cm diameter and 4 cm high) containing 4 ml of miliQ water and 1 ml of Xylene.

Solutions of toluene treated with this plasma reactor were analyzed using CG-MS (Thermo Finnigan, Thermo-Quest Trace CG/MS-Trace DSQ) in order to see the oxidation products from Xylene and OH radicals.

OH radicals generation rate was measured from the fluorometric method proposed by Newton and Milligan [Newton, 2006] based on the use of 3-Coumarin Carboxylic acid dissolved in water. A PTI, Quanta Master 40 UC/VIS Steady State Spectrofluorometer was used.

3. Results and conclusions

Products resulting from the plasma-xylene interaction (oxidation of Xylene) were identified and quantified using CG-MS analysis. In this case, Benzyl radicals Tolualdehyde, 2,6-Xylenol and 2,3-Xylenol were identified in the chromatograms. These products came from xylene oxidation and have been previously studied [Zhao, 2005]. Fig. 2 shows relative changes in these products content for different microwave powers (30, 50, 70 and 90 W), Ar gas flows (0.9, 1.1, 1.4, 1.7 and 2 L/min), treatment times (1, 1.5, 2 and 2.5 min) and distance of sample to plasma (from 0.5 to 4.5 cm). For the three first parameters, a linear dependence was found. This means that it is



Fig. 1: Photo of plasma and sample



possible to increase the oxidation and water treatment capacity of plasma with increasing values of these parameters: power, gas flow and treatment time. Different behavior was found for the dependence on the distance between sample and plasma. In this case, an optimum distance has been found around 2.5 cm, where highest concentration of oxidation products is found.

The xylene oxidation is due to the generation of OH radicals. Presence of this radical in post discharge has been confirmed by fluorometric measurements of 7-Hydroxycoumarin Carboxylic acid produced from plasma treatment of a solution 0.003M 3-Coumarin Carboxylic acid in miliQ water.

In conclusion, this work shows that a non-thermal microwave plasma is a useful medium to the treatment of water contaminated with xylene, due to the oxidation produced by OH radicals from the plasma activation. The study of dependence of this oxidation on experimental conditions allows us to have a best knowledge of its future application to industrial scale..

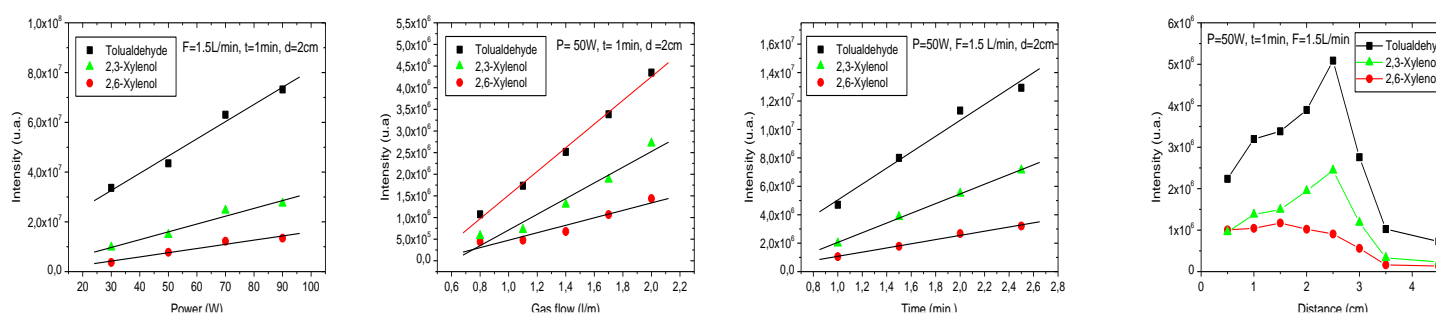


Fig. 2: Dependence of intensity of chromatographic peaks on microwave power, argon gas flow, treatment time and distance plasma-sample.

4. Acknowledgements

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SOCIAL INMOTIC TO IMPROVE ENERGY EFFICIENCY IN PUBLIC BUILDINGS: EFIPUBLIC PROJECT

Beatriz Montalbán Pozas, Irene Amigo Gamero, Agustín Sánchez Domínguez

Keywords: *sensorization, smart building, social inmotic, public building, energy efficiency, usage habits*

1. Introduction

Energy inefficiency of many public buildings is a worrying reality. Among other consequences, there is currently a waste of energy resources, situations of great discomfort, inefficiency of HVAC systems, wasted space, or inappropriate uses and habits, (D'Agostino, Cuniberti and Bertoldi, 2017). On the other hand, the advance in recent years of TICs, smart management and control systems, or the information in real time, is allowing us to address actions to improve buildings that could get positive results (Semprini et al., 2016), (Allab et al., 2017). It should also be mentioned that the study of the influence of user behaviour is decisive in the final results (Pisello et al., 2016), (OrbEEt, 2017). The in-depth study of a large teaching building: School of Technology in Cáceres (Extremadura University), through Efipublic project (Social Inmotic for the improvement of public buildings 2017-2020), is enabling the design and placement of sensorization and control devices, as well as the open and public data monitoring and its subsequent actions and users' participation.

2. Materials and methods

In this study a methodology to improve energy efficiency, currently under experimentation in a university public building, is developed. The method is developed in four stages: first of all, a building static data characterization is developed: typology and construction systems, equipment and HVAC, as well as consumption ratios through invoices and theoretical occupation. Then, a dynamic data characterization with low cost sensors has been carried out (Bamodu, Xia and Tang, 2017), data storage and visualization systems of water, electricity, and gas consumption, air quality, thermal comfort, real occupation, schedules facilities, etc. Thirdly, data tracking from previous characterizations is developed to detect deficiencies and propose improvement actions, and strategies according to climate period. Fourthly and finally, a smart control system with several levels of access will be developed to deliver to users (Sun and Hong, 2017), (Staddon *et al.*, 2016).

3. Results and conclusions

Some temporary results are: it has been defined as a set of actions in the use of thermal and electrical energy, and water consumption (sometimes with alarms), it also has been developed summer and winter strategies with usage guidelines bases in the annual period: window opening, shading, natural ventilation, etc., or information screens about hygrotermic and comfort conditions has been created and can be visualized with public monitoring. Results allowed us to design and expand the sensorization with new displays and parameters to measure. In addition, a typical user profile has been created to adjust the communication channels, so the monitored information will be effective:

- to managers and maintainers, with direct action in the programming of the systems, replacement of energy consuming equipment, etc.



- to cleaning staff, with access to key hours that can open and close windows, or lower or raise blinds, at the first or last hour of the day.

- to administration and service staff: workers with responsibility for the shutdown and use of the systems.

- to general users of public services: teaching staff, students and teachers, through sensorization campaigns.

In this way Efixpublic project is allowing us to improve efficiency energy with the collaboration of the users and through the use in real time of TICs. Working together with the users, the continuity of the progress made over time will be guaranteed.

4. Acknowledgment

This communication has been financed by Efixpublic project, IB16128, belonging to Call for Research Projects in Public R & D Centers financed by the Ministry of Economy and Infrastructure of Junta de Extremadura and European Regional Development Fund of EU.

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HUMIDITY, TEMPERATURE AND NOISE IN CONFERENCE ROOMS

Katarzyna Gładyszewska-Fiedoruk

Keywords: *Humidity, Temperature, Noise, Conference rooms*

1. Introduction

Relative humidity is the amount of water vapor present in air expressed as a percentage of the amount needed for saturation at the same temperature. During air parameters tests relative humidity is always used. The level of humidity inside the room is determined by the emission of water vapor connected with human metabolism, the humidity transported with the ventilation air stream, the diffusion, its accumulation in materials or processes in the rooms etc. The relative humidity in most rooms, like conference rooms should be in the range between 40 and 60% (PN-EN 13779).

Room temperature can be defined as the normal temperature of a room like a conference room in which people live. Room temperature is defined as a comfortable indoor temperature typically 20 to 23°C; neither heated nor chilled (PN-EN 13779; ASHRAE Standard 62-1989; WHO 2000). An example of room temperature is the temperature of a cup of water that has been sitting in a room for an hour.

The noise is the loud, confused, or senseless shouting or outcry the noise of the rioters, any sound that is undesired or interferes with one's hearing of something. Noise causes irritability, fatigue and fatigue of the whole body, especially hearing (Ayr et al., 2001). The noise has a negative effect on the human condition and the human health. The most commonly used measure of noise is the sound level expressed in dB (Jachimowicz & Gładyszewska-Fiedoruk; 2017). The noise in a conference room in Polish and European standards is 40 dB (PN-87/B-02151/02; PN-B-02151-4:2015-06).

2. Materials and methods

The research was conducted in a conference room located in Białystok, North-Eastern Poland. Research was devoted to issues related to the air parameters and noise in a conference room during the proceedings. The research included the relative humidity, the temperature and the noise.

In the analyzed conference room (fig. 1), only central heating appliances were installed from HVAC systems. The HVAC system is controlled by thermostatic valves. The meters are placed at a height of about 90 cm from the floor. It was assumed that this is the height on which the head of the participant is located. The meters are located at a distance from people (about 2 m) to avoid reflection or absorption. The measurements were performed using a Testo 435-4 equipped with an IAQ probe and for measurement of sound were using Testo 815 0563 8155.



Figure 1. Analyzed conference room

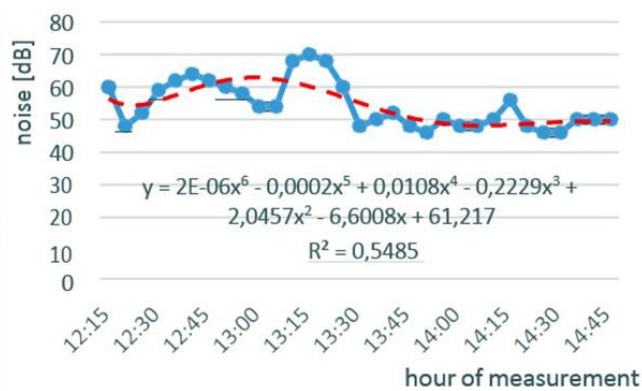


Figure 2. Noise in analyzed conference room

3. Results and conclusions

In the conference room, indoor air temperature was recorded in the range from 19.1°C to 20.9°C. Relative humidity was in range 39.9% to 44.3%. Noise level was even 70 dB (fig. 2).

During the deliberations in the room the temperature was too low. Relative humidity was in accordance with guidelines (PN-EN 13779).

Proper noise level is very important because noise also has a very negative impact on the people's health and fitness.

4. Acknowledgment

This scientific project was financed within the project VIPSKILLS (Virtual and Intensive Course Developing Practical Skills of Future Engineers) program of Erasmus+ (KA203).

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PRELIMINARY STUDY ON INDOOR AIR QUALITY IN THE ANTENATAL CLASSES

Paulina Zielinko, Dorota Anna Krawczyk

Keywords: *Indoor Air Quality, maternity, surveys, temperature, humidity*

1. Introduction

A proper indoor air quality (IAQ) is very important for the health of people who spend a significant share of their lives in indoor environment. Many researches were conducted in public buildings, meant to be a work place or a place for additional activities. One of specific places are gyms. As shown by Ramos, Wolterbeek and Almeida (2014), based on a monitoring program undertaken in 11 fitness centers in Lisbon/Portugal, the pollutants CO₂, VOC and CH₂O presented high concentrations, exceeding the national limits and were raised significantly during classes. Authors noted the necessity to optimize the HVAC systems, in order to reduce the exposure to air pollutants and provide real benefits of sport activities.

This paper shows results of one series of measurements and survey studies conducted during the Antenatal classes, as an example of rooms where IAQ parameters should be set at recommended level, to guarantee healthy conditions for pregnant women.

2. Materials and methods

The study was conducted in Poland during Antenatal classes. It was composed of two parts: experimental measurement and survey. The whole study covered several tests that differed in number of participants or parameters of the HVAC system, whereas the results of one of the selected series are presented in this paper.

Measurements were conducted using the IAQ instrument TSI 9565, with temperature, relative humidity, carbon dioxide concentration and VOCs probes. Precision of measurements was shown in table 1.

Table 1. Precision of the equipment.

Parameter	Precision
Temperature	± 0.1 °C
Carbon dioxide	± 50 ppm (± 3%)
Humidity	± 3%
Pressure	± 1 hPa
VOCs	± 10 ppm

Moreover, pregnant women took part in a survey, answering questions regarding their opinion about air quality, any discomfort if it appears and sensible temperature.

3. Results and conclusions



Indoor air temperature was recorded as the average 20.5°C, while relative humidity 35%. Figures 1 shows percentage of interviewees glad and not glad of indoor air quality.

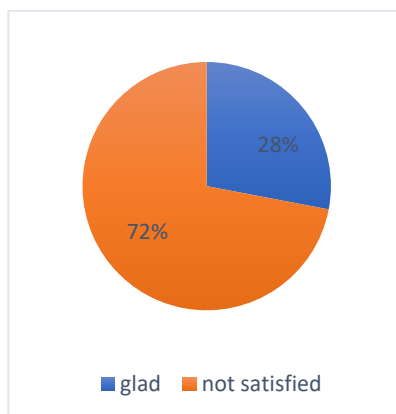


Fig.1. Results of survey on IAQ

Despite the fact that indoor air temperature was at acceptable level, 60% of women assessed it as lower (19-20°C) and complained about the air conditioning system work and indicated too high speed of air flow as a source of the problem.

Also, too low relative humidity was noted by interviewees. This fact is consistent with recorded values with the average RH=35%.

4. Acknowledgment

This scientific project was realized within the framework Project VIPSKILLS (Virtual and Intensive Course Developing Practical Skills of Future Engineers) Erasmus+ 2016-1-PL01-KA203-026152 and S/WBIS funds at Bialystok University of Technology from HE Ministry grant.

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