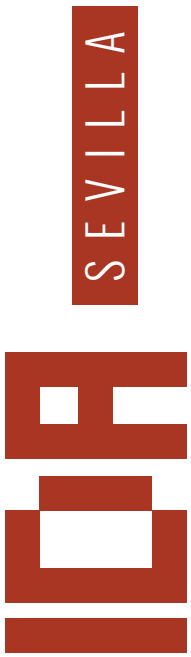
SEVILLA

IDA: ADVANCED DOCTORAL RESEARCH IN ARCHITECTURE



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FORMATO

Mesas temáticas
Las mesas temáticas son lugares de presentación de las metodologías y las experiencias de jóvenes doctores y de estudiantes de doctorado procedentes de las diferentes universidades. Son gestionadas por los propios estudiantes de doctorado que generan unas conclusiones para ser debatidas y reelaboradas en la sesión plenaria final. Las sesiones se desarrollan de manera simultánea con la presentación de los *papers* seleccionados en la *call*, organizados en cuatro áreas o líneas temáticas:

1. Tecnologías de la Arquitectura
2. Vivienda, Ciudad y Territorio
3. Patrimonio y Rehabilitación
4. Análisis y Proyectos Avanzados

Taller
El workshop del Congreso se orienta hacia el análisis de los problemas y las necesidades de gestión de los Programas de Doctorado con el fin de extraer conclusiones que pueden ser útiles a las Universidades implicadas. En el workshop participan los coordinadores de los programas de Doctorado en Arquitectura y los representantes de los doctorandos. Son temas de debate: las líneas de investigación, las metodologías, las necesidades organizativas de los programas de doctorado, el Doctorado Internacional y el Doctorado Industrial, y el futuro de la investigación doctoral.

Sesiones Plenarias
Las sesiones plenarias se realizan al inicio y al final del Congreso. En la primera sesión de bienvenida e introducción al Congreso se invita a participar a expertos investigadores del panorama nacional e internacional y a los coordinadores de los programas de doctorado. En la segunda sesión plenaria se propone un debate abierto para la reelaboración de las propuestas extraídas del taller y de las mesas temáticas. Sirve también de clausura con la presentación de las conclusiones finales del Congreso IDA_Sevilla 2017.

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FOREWORD

The Instituto Universitario de Arquitectura y Ciencias de la Construcción (IUACC), in collaboration with the Escuela Técnica Superior de Arquitectura (ETSAS) and the Escuela Internacional de Doctorado (EIDUS) of the University of Seville are pleased to welcome the heads of research from both Spanish and overseas universities, consolidated researchers and young doctoral researchers to the First International Congress of Doctorates in Architecture IDA Sevilla, from 27th to 28th November 2017.

The **IDA_Sevilla 2017** Congress offers a general perspective of doctoral studies in the field of Architecture and its related disciplines: urban planning, heritage, landscape, construction technologies and sustainability. In the new context generated after the elimination of the doctoral programs prior to RD 99/2011, it is necessary to carry out an analysis of the complex panorama that the former programs and the new doctoral programs have drawn up, in order to know in detail both what has been achieved so far, as well as the challenges of the future of advanced doctoral research in Spain, in the European and international context.

The startling changes that are taking place in our society call for a vision of research that is not compartmentalised into traditional disciplines or areas of knowledge. Doctoral research in Architecture must adapt to changes in society and to the sustainable productive needs of territory.

The congress will take place at the Escuela Técnica Superior de Arquitectura de Sevilla, organised in four simultaneous thematic tables, a workshop on the administration of doctoral programs and two plenary sessions.

The **thematic tables** are aimed at young doctors and doctoral students of the different participating universities who will present their experiences and methods of their research - in development or recently concluded. The participation in the thematic tables is carried out through the selection procedure with blind peer review established in the call for papers and through express invitations to the debate. The almost 70 communications have been structured in four thematic areas representative of the PhD programs in Architecture.

The **open workshop** will be held in two sessions with the participation of the coordinators of each of the collaborating programs of the Congress, and professors with extensive doctoral experience. Its objectives are multiple: to discuss the experiences undertaken in the different universities, exchange ideas about the approaches and models applied, address the challenges of internationalization and management, launch the new Industrial Doctorate with companies and public agencies, and so on.

There are two **plenary sessions**: one, a plenary session of introduction to the congress, with the participation of coordinators of national and foreign doctoral programs; and a closing plenary session, with an open debate for the going-over of the conclusions drawn from the thematic tables and the workshop, and the presentation of final conclusions.

We thank the Escuela Internacional de Doctorado of the University of Seville, and the Escuela Técnica Superior de Arquitectura de Sevilla for the support they have provided for the holding of this meeting, which contributes so much to the clarification of the future of doctoral studies in Spanish universities in the face of the great challenge of internationalization and the continuous improvement of the quality of research in Architecture. We also thank those responsible for the participating Doctoral Programs, the Architecture library of the US and all the participants and attendees.

Antonio Tejedor Cabrera
Marta Molina Huelva

Conference Chairpersons IDA_Sevilla 2017
Instituto Universitario de Arquitectura y Ciencias de la Construcción IUACC

PRÓLOGO

El Instituto Universitario de Arquitectura y Ciencias de la Construcción (IUACC), con la colaboración de la Escuela Técnica Superior de Arquitectura (ETSAS) y la Escuela Internacional de Doctorado (EIDUS) de la Universidad de Sevilla, se complacen en recibir a los responsables de investigación de universidades españolas y extranjeras, a los investigadores consolidados y a los jóvenes investigadores de doctorado en el I CONGRESO INTERNACIONAL DE DOCTORADOS EN ARQUITECTURA IDA_Sevilla, del 27 al 28 de noviembre de 2017.

El congreso **IDA_Sevilla 2017** ofrece una perspectiva general de los estudios de doctorado en el campo de la Arquitectura y sus disciplinas afines: urbanística, patrimonio, paisaje, tecnologías de la construcción y sostenibilidad. En el nuevo contexto generado tras la extinción de los programas doctorales anteriores al RD 99/2011 es necesario realizar un análisis del complejo panorama que han construido los programas extintos y los nuevos programas de doctorado, con el objeto de conocer con detalle tanto lo conseguido hasta ahora como los retos que depara el futuro de la investigación doctoral avanzada en España, en el contexto europeo e internacional.

Los vertiginosos cambios que se están produciendo en nuestra sociedad reclaman una visión de la investigación no compartimentada en disciplinas o áreas de conocimiento tradicionales. La investigación doctoral en Arquitectura debe adaptarse a los cambios de la sociedad y a las necesidades productivas sostenibles en el territorio.

El congreso se celebra en la Escuela Técnica Superior de Arquitectura de Sevilla organizado en cuatro mesas temáticas simultáneas, un taller sobre la gestión de los programas de doctorado y dos sesiones plenarias.

Las **mesas temáticas** están dirigidas a los jóvenes doctores y a estudiantes de doctorado de las diferentes universidades participantes que exponen sus experiencias y métodos sobre las investigaciones en desarrollo o recientemente concluidas. La participación en las mesas temáticas se realiza por el procedimiento de selección con revisión por pares ciegos establecido en la *call for papers* y por medio de invitaciones expresas al debate. Las casi 70 comunicaciones se han estructurado en cuatro áreas temáticas representativas de los programas de doctorado en Arquitectura.

El **taller** de puesta en común se realiza en dos sesiones con la participación de los coordinadores de cada uno de los programas colaboradores del Congreso y de profesores con amplia experiencia doctoral. Sus objetivos son múltiples: debatir sobre las experiencias desarrolladas en las distintas universidades, intercambiar ideas sobre los enfoques y los modelos aplicados, abordar los retos de internacionalización y de gestión, poner en marcha el nuevo Doctorado Industrial con empresas y agencias públicas, etc.

Las **sesiones plenarias** son dos: una sesión plenaria de introducción al congreso, con la intervención de coordinadores de programas de doctorado nacionales y extranjeros; y una sesión plenaria de clausura, con un debate abierto para la reelaboración de las conclusiones extraídas de las mesas temáticas y del workshop y la presentación de las conclusiones finales.

Agradecemos a la Escuela Internacional de Doctorado de la Universidad de Sevilla y a la Escuela Técnica Superior de Arquitectura de Sevilla el apoyo que han proporcionado para la realización de este encuentro que tanto contribuye a clarificar el futuro de los estudios doctorales en las universidades españolas ante el gran reto de la internacionalización y la continua mejora de la calidad de la investigación en Arquitectura. Damos los gracias también a los responsables de los Programas de Doctorado participantes, a la Biblioteca de Arquitectura de la US y a todos los participantes y asistentes.

Antonio Tejedor Cabrera
Marta Molina Huelva

Directores Congreso IDA_Sevilla 2017
Instituto Universitario de Arquitectura y Ciencias de la Construcción IUACC

OBJECTIVES

1. Analyze the research lines of the various programs and build a map of doctoral research in Spain with the support of coordinators, tutors / thesis supervisors, doctoral students and young doctors in the disciplines related to Architecture and their related areas.

2. To know the status of doctoral theses in progress or defended in the last three years, selected by means of a call with blind peer evaluation of the doctoral programs participating in the congress.

3. Discuss the structure and university management of doctoral programs in relation to employment challenges, collaboration with the productive sector and national research programs.

4. Exchange experiences with other international doctoral research programs on international mobility management, theses with international mention, co-supervised theses, theses with industrial mentions, etc.

5. No less important, consolidate a national and international network of Doctoral Programs related to Architecture, Urban Planning, Heritage, Landscape, Technologies and related disciplines.

IDA ADVANCED DOCTORAL RESEARCH SEVILLA 2020

LT 1 ARCHITECTURE TECHNOLOGIES

LT 2 HOUSING, CITY AND TERRITORY

LT 3 HERITAGE AND REHABILITATION

LT 4 ANALYSIS AND ADVANCED PROJECTS

FORMAT

Thematic tables
The thematic tables are places to present the methodologies and experiences of young doctors and doctoral students from different universities. They are managed by the doctorate students themselves, who generate conclusions to be debated and reworked in the final plenary session. The sessions are developed simultaneously with the presentation of the papers selected in the call, organized in four areas or thematic lines:

1. Architectural technologies
2. Housing, city and territory
3. Heritage and Rehabilitation
4. Analysis and advanced projects

Workshop
The workshop of the Congress is oriented towards the analysis of the problems and management needs of the Doctorate Programs, with the objective of arriving at conclusions that may be useful to the Universities involved. The coordinators of the Doctorate in Architecture programs and the doctoral students' representatives will participate in the workshop. The following are topics for debate: lines of research, methodologies, organizational needs of the doctoral programs, the International Doctorate and the Industrial Doctorate, and the future of doctoral research.

Plenary Sessions
The plenary sessions are held at the beginning and end of the Congress. In the first session of welcome and introduction to the Congress, researchers from the national and international scene and the coordinators of the doctorate programs are invited to participate. In the second plenary session an open debate is proposed for the going over of the proposals drawn from the workshop and the thematic tables. It also serves as a closing ceremony with the presentation of the final conclusions of the 2017 IDA_Sevilla Congress.

Beams were tested in bending, according to UNE-EN 408 (2011) (Fig.6), and the effects of GFRP reinforcements in the MOE, ultimate strength (MOR) and improvement in the dispersion of results were measured and analyzed. The failure modes of each beam were also observed.

Fig. 6 Duo beams test according to UNE EN-408.

The results of these tests on reinforced Populus beams are shown in Figure 7, with a significant improvement with increments in the moduli of elasticity of 10% for GFRP reinforcements of 1200 gr / m2 and of around 15% for GFRP reinforcements of 2400 gr / m2.

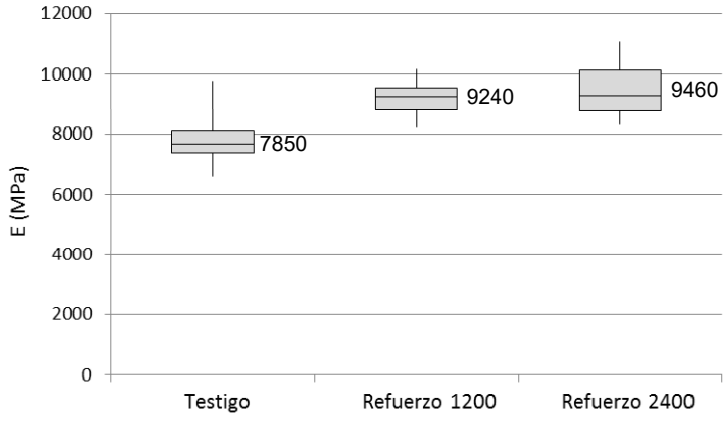

Fig. 7 Box and whiskers graph with the modulus of elasticity of poplar duo beams.

At the present time only the previous data analyzes of the poplar duo beams are available, and the bending test of the Pinaster beams is scheduled for close dates.

3.3. Creep tests

In order to study the long-term behavior of the reinforced duo beams, in relation to unreinforced ones, a long-term test has been set up, according to UNE-EN 380 (1998), with a total load of 10 kN, which represents approximately 50% of ultimate load of the beams. The ambient conditions of the laboratory remain nominally constant, 20 ± 2ºC; 65 ± 5% humidity in air, corresponding to a hygroscopic balance of 12% HR in the wood (Kollman 1959).

The load is applied by means of the filling and filling of individual tanks (Figure 8), single wall polyethylene (PE), with a useful capacity of 1000 liters and dimensions of approximately 1650x720x1260 mm, with upper filling nozzles and lower emptying device, with locking key. The support of the tanks on the beams is made with an intermediate resistant platform, which allows to apply the load on the beams on two points, following the support distances proposed by UNE-EN 408 (2011).

OBJETIVOS

1. Analizar las líneas de investigación de los diversos programas y construir el mapa de la investigación doctoral en España con el apoyo de los coordinadores, los tutores/directores de tesis, los doctorandos y los jóvenes doctores en las disciplinas relacionadas con la Arquitectura y sus áreas afines.

2. Conocer el estado de las tesis doctorales en marcha o defendidas en los últimos tres años, seleccionadas por medio de una *call* con evaluadores por pares ciegos de los programas de doctorado participantes en el congreso.

3. Debatir sobre la estructura y la gestión universitaria de los programas de doctorado en relación con los retos de empleo, colaboración con el sector productivo y los programas nacionales de investigación.

4. Intercambiar experiencias con otros programas de investigación doctoral a escala internacional sobre gestión de la movilidad internacional, tesis con mención internacional, tesis en cotutela, tesis con mención industrial, etc.

5. No menos importante, consolidar una red nacional e internacional de Programas de Doctorado relacionados con la Arquitectura, la Urbanística, el Patrimonio, el Paisaje, las Tecnologías y sus disciplinas afines.

IDA INVESTIGACIÓN DOCTORAL AVANZADA

LT 1 TECNOLOGÍAS DE LA ARQUITECTURA

LT 2 VIVIENDA, CIUDAD Y TERRITORIO

LT 3 PATRIMONIO Y REHABILITACIÓN

LT 4 ANÁLISIS Y PROYECTOS AVANZADOS


IDA
SEVILLA

LT 1

TECNOLOGÍAS DE LA ARQUITECTURA

ARCHITECTURE TECHNOLOGIES / TECNOLOGÍAS DE LA ARQUITECTURA

COMPLEMENTARY TECHNIQUES FOR THE CHARACTERIZATION OF NEW CONSTRUCTION MATERIALS: ANALYSIS AND REVIEW

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Abstract: Progress in the development of new construction materials has led to employ new testing techniques that have been used by other branches of knowledge. This work tries to make a tour on different investigations that have used some of these techniques to complete the characterization of the new materials studied, observing in each case the scope and usefulness of the use of these methods in the construction field. A detailed study of some of these techniques is performed by analysing the research in which they are used, observing the purpose of their use and the results obtained with the method. For this congress, a selection of five of these complementary techniques (chosen for their greater influence and utilization), which are X-rays computed tomography, ultrasounds, infrared thermography, X-rays Diffraction and Scanning Electron Microscopy, is made.

Keywords: X-rays Computed Tomography (XCT), Ultrasounds (UT), Infrared Thermography (IRT), X-rays Diffraction (XRD), Scanning Electron Microscopy (SEM).

1. Introduction

Many researchers are studying the creation of new construction materials or improving the properties of other products of the market. In this sense, one of the major challenges they face is to obtain an exhaustive and truthful characterization of them, using different techniques.

Last years, innovation and the development of techniques for the characterization of materials has undergone a great advance incorporating technologies that, to date, were used in other branches of science and knowledge. The main objective is to complete the characterization process of materials contributing and/or complementing the information obtained through the experimental trials.

Within these new techniques of inspection, Non Destructive Evaluation (NDE) methods stand out. They are trials that, without altering the original attributes or damaging the tested object, evaluate and inspect the different materials and composites for their characterization or to locate defects which are negliable with other techniques. As for the detection of faults, both superficial and internal, X-ray computed tomography is a non-destructive technique that allows to know with precision the internal structural organization of the materials, providing information about their porosity, among others (Wang and Dai, 2017). On the other hand, the ultrasonic analysis is a non-destructive method that provides information by measures that are used to estimate some resistant parameters, such as the dynamic and static elasticity modulus (Haach et al., 2015), as well as to locate some defects in the element (Huete-Fuertes et al., 1993). Finally, one of the most used in recent years non-destructive inspection method is infrared thermography, which provides images in which it is possible to detect defects in the materials (Rodríguez-Liñán et al., 2012).

In addition to NDE methods, there are other tests that are currently being used in the characterization process of new materials. The X-ray diffraction technique allows to know the composition and the crystalline phases that are generated in the materials (Jiménez et al., 2013) and scanning electron microscopy that allows to know its microstructure, impurities, the detection and identification of salts and their microcracking, among others (Ge et al., 2015).

In order to know the scope and viability of the use of these new techniques for the characterization of new developed materials, this work studies its applicability, analysing and limiting the usefulness of the data provided by its use in each case.

2. Objectives and Methodology

The present work analyses part of the existing bibliography with the objective of studying some of the characterization techniques applied to the field of construction and, in particular, the analysis of new

materials. The work concludes by relating the properties and/or characteristics of the materials with the most appropriate technique for analysis and/or quantification. Scientific papers published in journals and/or congresses are analysed by examining the limitations of the use of each technique, the authors' objective for its use, the achievement of those objectives and the results obtained.
The selection of papers is done by analysing the researches included in the WoS database (Web of Science, 2017), which is considered the main information platform in natural sciences, social sciences, art and the humanities. For the search we used keywords for each technique, filtering the results in the following categories: materials science multidisciplinary, materials science ceramics, materials science composites, materials science biomaterials, engineering mechanical, engineering environmental, materials science characterization testing and construction building technology.
Table 1 lists the keywords used for each technique as well as the results obtained for each year.

Table 1. Keywords and results per year (Web of Science, 2017).

Technique	Keyword	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008
X-ray Computed Tomography	XCT X-ray Computed Tomography	264	348	273	227	205	167	115	125	73	75
Ultrasounds	UT Ultrasounds	596	943	853	806	793	759	621	584	465	461
Infrared Thermography	IRT Infrared Thermography	188	267	233	216	190	193	144	158	110	114
Scanning Electron Microscopy	SEM Analysis	2403	3330	3009	3051	3063	2935	2818	2243	2101	1885
X-Ray Diffraction	XRD X-Ray Diffraction	9526	13239	13328	13715	13021	12141	11568	10016	9602	8849

3. Results and Discussion

For the analysis and description of the techniques, they are previously classified as Non Destructive Techniques and Destructive Techniques. A description of each method (Gholizadeh, 2016) is made to later review the publications in which they are used.

3.1. *Non-Destructive Techniques*

Non-Destructive Techniques (NDT) allow the evaluation of the characteristics of the materials and the location of defects without causing damage to the studied elements. X-ray Computed Tomography (XCT), Ultrasound (UT) and Infrared Thermography (IRT) are included as Non-Destructive Techniques.

3.1.1. *X-ray Computed Tomography (XCT)*

X-ray Computed Tomography (XCT) is one of the most used non-destructive tests to know the internal structure of the materials. With this test it is possible to evaluate defects which were originated during the manufacturing and/or service phases. As it defines the surface and internal structure of the composite, this technique also allows to carry out metrological and reverse engineering studies.
The XCT technique is based on the use of a computer with a large computational capacity that favours the correct generation and reconstruction of the information obtained from the test. The XCT technique is based on irradiating an object with a conical X-ray beam, at the same time a detector accumulates the radiation passing through the piece. Throughout this process a complete sweep of the piece is made by a controlled rotation of the piece taking images in different angular positions. The transversal sections obtained allow a very comprehensive three-dimensional reconstruction of the material/product.

Kim et al. (2012) use this technique to expose the limitations of the two-dimensional characterization in cement-based composites in the detection of air vacuum parameters presented in the samples tested. The results obtained by the three-dimensional reconstruction reveal that, when the number of sections analysed is greater than 10, representative values of air presence are obtained in the samples, with a variation range lower than 10%.
Huang and Li (2013) obtain a method that uses the captures obtained from the Tomography test to characterize, from a microstructural point of view, the heterogeneous materials to introduce and analysis them with a finite element calculation program. In this way, it is possible to reconstruct microstructurally with great precision the analysed models using image processing techniques (Fig. 1).

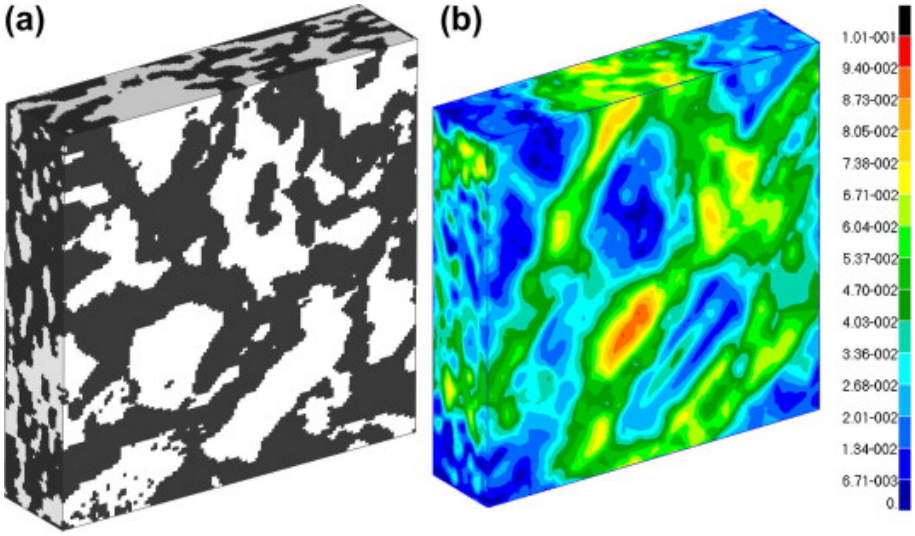

Fig. 1 Virtual model of the material by using the images obtained from the XCT test. (a) Reconstructed 3D model and (b) Characteristic deformation of the non-deformed composite in mm. (Huang and Li 2013)

Qi et al. (2017) use the XCT technique to know the possible alteration of the microstructure of the concrete made with recycled aggregate after subjecting it to sulfates attacks and wetting and drying cycles. The images obtained clearly show the damage suffered by the material and the change in the internal structure of pores of the samples while observing the existence of microcracks, not only on the outer face of the sample, but also inside.
Finally, among other works, Wang and Dai (2017) use X-ray computed tomography for the characterization and simulation of cement mortars. In particular, they analyse the porosity of the material without using destructive experimental tests to know the parameters of permeability and diffusivity of the mortars.

3.1.2. *Ultrasounds (UT)*

The ultrasound technique is used mainly for the characterization and/or localization of defects, being especially important its use on composite materials. It has one or two piezoelectric transducers that function as emitter and receiver, generating an ultrasonic pulse that propagates through the material. In its course, this pulse produces a reflection at all points where it finds a discontinuity (cavities, cracks, test face of the piece, etc.). The presence of such discontinuities is evidenced by the analysis of the time between the input pulse and the arrival pulse since there is a decrease in the propagation speed.
In 1993, Huete-Fuertes et al. (1993) analyse the application of ultrasounds for the verification of construction materials such as concrete, stone, ceramic products, plastic and wood. They say that, in concrete, propagation speed is key to analyse the quality, uniformity, time alterations and presence of cracks in the material.
Rubio-de Hita (1997) evaluated the state of wood in building structures. Thus, in 2004 Rodríguez-Liñán et al. (2004) use ultrasounds for the evaluation of wood slabs in rehabilitation works, mainly in historic buildings and use this technique for a prior diagnosis in sustainable rehabilitations (Morales-Conde et al., 2014).
Sena and Pazini (2003) apply this technique for the inspection of concrete. Their objective is to relate the static elastic modulus of the concrete with the ultrasonic speed. To verify this procedure, they analyse different types of concrete by varying the water/cement ratio, using different curing methods

and/or different types of aggregates. This work verifies the suitability of this technique to obtain, non-destructively, the static elasticity modulus. The results are compared with conventional tests, existing a minimal variation between both of them.
Rosell and Cantalapiedra (2011) use this technique to obtain the dynamic modulus of cement and lime mortars. In this case, the measurement of the ultrasonic pulse is linked to an excitation of the sample by impact. They state that, after comparing the results obtained with conventional techniques of breaking of specimens, the method is valid for the determination of the deformability under load of the standardized mortar specimens (Fig. 2).

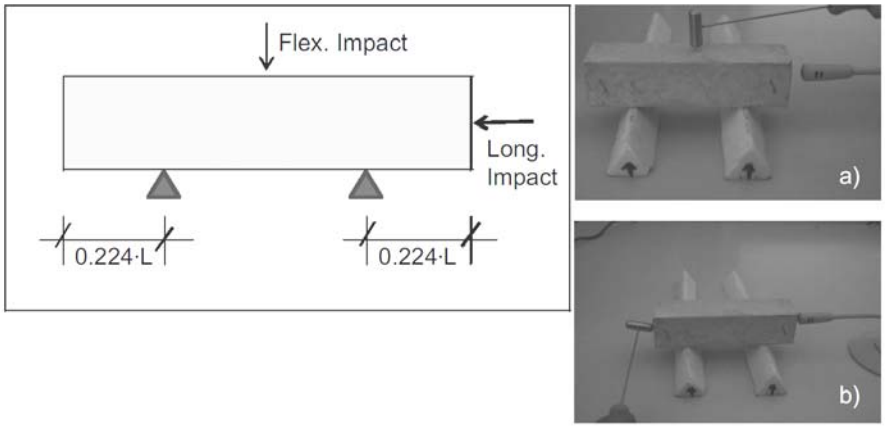

Fig. 2 Description of the test used by Rosell and Cantalapiedra (2011). (a) Long. Impact. (b) Flex. Impact.

Recently, other researchers have used the ultrasonic technique to identify different types of aggregates in concretes and cementitious composites (Cosmes-López et al., 2017). To do this, during the hydration process of the concrete, they identify specific frequencies related to different types of aggregates, distinguishing the types of aggregate by the domain of the frequency used. This research obtains better results in concretes. They have to improve the inspection technique for its use in cement pastes.

3.1.3. *Infrared Thermography (IRT)*

Infrared Thermography (IRT) is a non-destructive and non-contact test that facilitates the localization of defects, both superficial and internal, and that can be used in many materials. It allows to quickly inspect large surfaces, which facilitates their use for the evaluation of façades and the location of thermal bridges. Another advantage is the ease of handling and transportation of the instrumentation needed.
Rodríguez-Liñán et al. (2012) determine the feasibility to detect internal defects in wood structures, while analysing the influence of wood density on the thermograms.
Meola and Carlomagno (2014) use thermography for the detection of manufacturing defects as well as damages caused by impacts on different types of composite materials (Fig. 3) such as glass fiber reinforced plastics (GFRP) (Meola and Carlomagno, 2010) or carbon fiber reinforced composites (Meola et al., 2015).

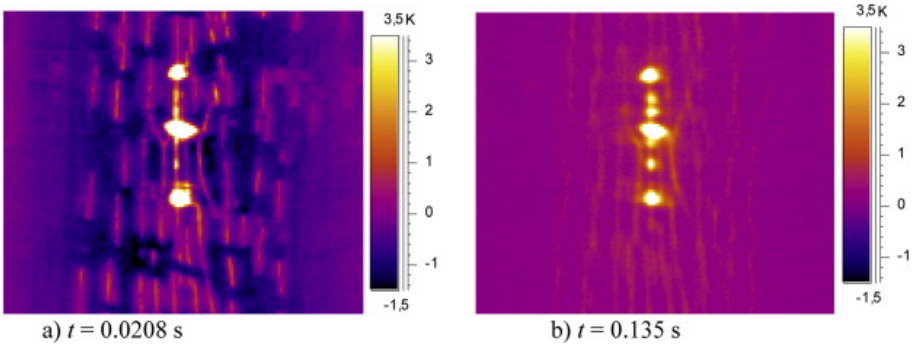

Fig. 3 Thermographic images obtained from the GFRP test specimen (Meola y Carlomagno, 2014). (a) t=0.0208 s. (b) t=0.135 s.

3.2. *Destructive and Semi-Destructive Techniques*

Scanning electron microscopy (SEM) and X-ray diffraction (XRD) are techniques that, despite being destructive or semi-destructive testing techniques, are widely used for the characterization of new materials.

3.2.1. *Scanning Electron Microscopy (SEM)*

Scanning electron microscopy is a semi-destructive test method that uses a fragment of the sample for its analysis. To do that, it is necessary that the samples are conductive, reason why, generally, they are covered with a thin layer of gold. Once the sample is prepared, it is swept with accelerated electrons traveling through a barrel obtaining high resolution images by electron-matter interactions. The amount and intensity of the electrons which is returned by the sample, is collected by a detector formed by electromagnet-based lenses that offers three-dimensional figures as high-quality digital images. In this way, it is possible to know the internal structure of the material and its properties can be argued.
Among the existing researches, Alejandre and Villegas (2009) study the differential alteration of two types of bricks of the Santa María de Jesús church in Seville, analysing the influence of two types of treatments for their restoration. In this case, microscopy is used to confirm the uniformity of the surface film treatments applied to the bricks and to assert that there are no differences between both types of bricks with respect to the film formed by the treatments used.
San Antonio-González et al. (2015) use the technique in the characterization of gypsum composites lightened with XPS wastes. In this case, the use of the technique demonstrates that, despite the internal structure of the XPS, the surface cohesion between the gypsum and the plastic waste is acceptable for this type of composite (Fig. 4).

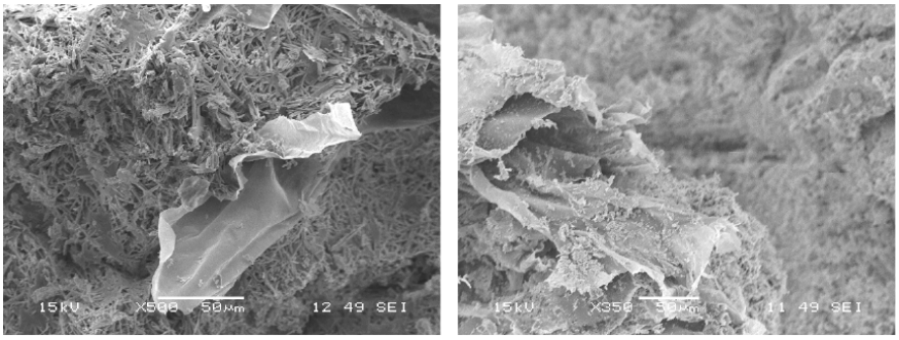

Fig. 4 SEM analysis of gypsum composites with XPS waste (San Antonio-González et al., 2015).

Ge et al. (2015) analyse the properties of cement mortar with ceramic brick and polyethylene (PET) waste. In this work, they use the SEM technique to justify the low water absorption by capillarity and the high durability presented on the new composites, which is due to the interaction of the ceramic waste with the polyethylene.
Kang et al. (2017) employ this technique to justify the increase in mechanical strength in cement composites by incorporating graphene oxide into the blend. It is observed that the incorporation of graphene oxide functions as a "bonding bridge" in the mixture, generating strong covalent bonds with C-H-S.
In concrete, Sharma et al. (2017) use scanning electron microscopy to try to justify some of the experimental results obtained in the characterization of concrete properties with granite waste as a substitute for coarse aggregate. Their images show the existence of a weak union between the cement and the polished surface of the granite which justifies the low strength capacities of the concrete when incorporating this type of waste.

3.2.2. *X-ray Diffraction (DRX)*

The X-ray diffraction technique is used for the study and analysis of crystalline solid materials. It is classified as a semi-destructive test because it is common to perform grinding of the analysis material, although it could be applied directly on samples of certain dimensions. The X-rays are diffracted by the electrons surrounding the atoms of the sample because they have a wavelength of the same order of magnitude as the atomic radius used. In this way, information about the position and type of atom that

the X-ray finds in its path is obtained. The periodic structure of the crystals causes the dispersion and amplification of the X-ray beams in certain directions, resulting in a diffraction pattern. Thus, through the use of mathematics, it can be obtained a correct representation at atomic scale of the atoms and molecules of the material.
Many researches use this procedure for the characterization of materials. Jiménez et al. (2013) characterize different mixtures, analysing the influence of the partial substitution of sand for recycled ceramic aggregates for the design of cement mortars. They contrast, as shown in Fig. 5, the diffractograms of three different composites thus viewing the phase differences in them.

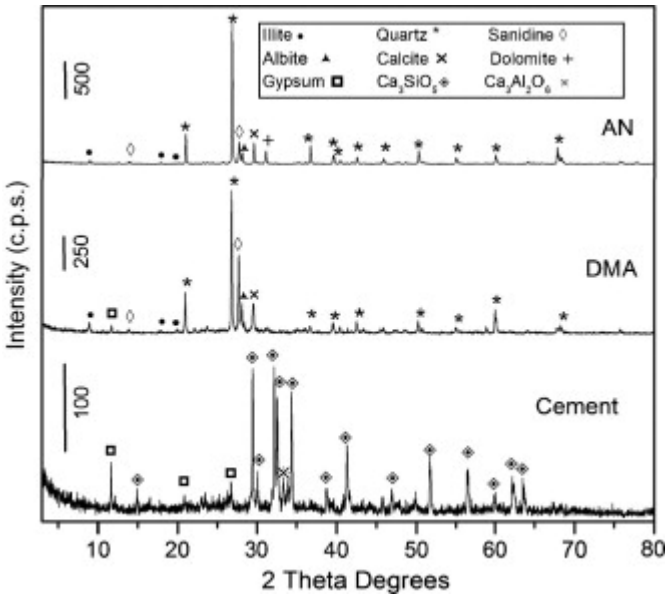

Fig. 5 Diffractogram of the different composites studied by Jiménez et al. (2013)

García-Lodeiro et al. (2016) compare cement mortars incorporating fly ash and others containing ash from a solid waste incinerator. To make this comparison they use a diffractogram of each material (ashes and cements) to compare the difference of crystalline phases between both types of cement according to the type of ash they contain. They use this technique in parallel to scanning electron microscopy, identifying each element present and associating it with its diffractogram (Fig. 6).

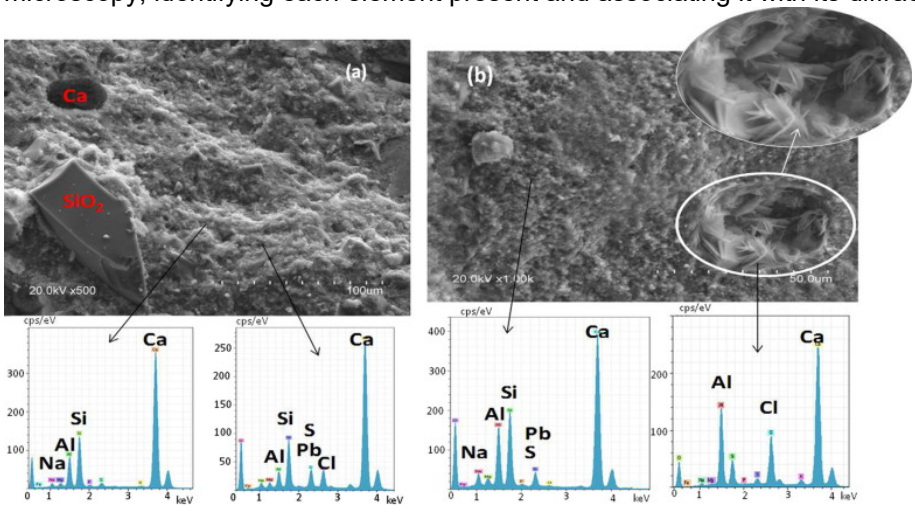

Fig. 6 SEM images of the compound RS 60/40 showing (a) quartz particles (SiO 2) and Ca deposits (b) AFm-Cl crystals precipitating in a pore embedded in the matrix (García-Lodeiro et al., 2016).

Kannan et al. (2017) use X-ray diffraction with the objective of knowing the crystalline phases present at different percentages of substitution of ceramic wastes in concrete. The obtained results show the absence of significant differences in the crystalline phases SiO2, C-S-H and CH for substitution percentages of 20 and 40%.

3.3. *Results Discussion*

Table 2 summarizes the different tests analysed, the materials for which they can be used, the determined properties when performing them, as well as their strengths and weaknesses.

Table 2. Summary table of studied techniques.

Technique	Construction Material	Properties	Strengths	Weaknesses
X-ray Computed Tomography	Concrete, cement, gypsum and other composite materials	Internal composition of the material (distribution, porosity, etc.)	Non-destructive test. It allows to transfer that characterization to a finite element modeling	It is still necessary to refine its application to construction materials
Ultrasounds	Wood, concrete, ceramics, composite materials, etc.	Prediction of strength capacities and detection of internal faults	Easy to use and useful for an inspection. Very widespread	Incorrect measurement offers poor reliability in results
Infrared Thermography	In general large surface elements (wood, ceramics, concrete, etc.)	Evaluation of facades, location of thermal breakes, detection of defects	It allows to evaluate in a short time large surfaces	It must be improved to be applied in the characterization of new composites
Scanning Electron Microscopy	Concrete, cement, plaster and other composite materials	Internal composition of the material (distribution, porosity, etc.). Bonds	Very widespread use in the field of study	It is a semi-destructive technique
X-Rays Diffraction	Concrete, cement, plaster and other composite materials	Atomic and molecular characterization of materials. Detection of crystalline phases	Very widespread use in the field of study	It is a semi-destructive technique. Not applicable in materials that do not contain crystalline phases (eg. plastics)

4. Conclusions

This work analyses different techniques of characterization complementary to those already traditional and established by regulations. Some examples have been presented in which, in a representative way, the different methods have been used with different objectives, thus assessing the scope of each technique.

X-ray computed tomography demonstrates its usefulness in non-destructively obtaining knowledge of the internal structure of certain materials. The results obtained can be used for the finite element program definition of these materials.

Ultrasounds have been established as one of the most reliable non-destructive techniques for detecting internal faults in materials such as wood or concrete.

Despite having great advantages due to the ease and rapidity of the method, the infrared thermography still has to improve for a correct application in the inspection of composite materials.

Scanning electron microscopy offers high quality images in which the internal composition of the materials is observed, thus justifying the behaviour of these materials under certain circumstances or tests.

Finally, the X-ray diffraction is strengthened as one of the most used techniques for the correct atomic and molecular characterization of these materials. It is considered fundamental to have a correct characterization of the product to obtain significant results in any research.

It is observed that there are complementary methods that allow us to predict or justify a posteriori, depending on the cases, the behavior of certain materials or products before certain circumstances or tests, obtaining explanations until now inappreciable by traditional methods. It is emphasized that all the techniques described here are complementary to each other and the joint use of some of them will favor a better characterization of this type of materials.

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