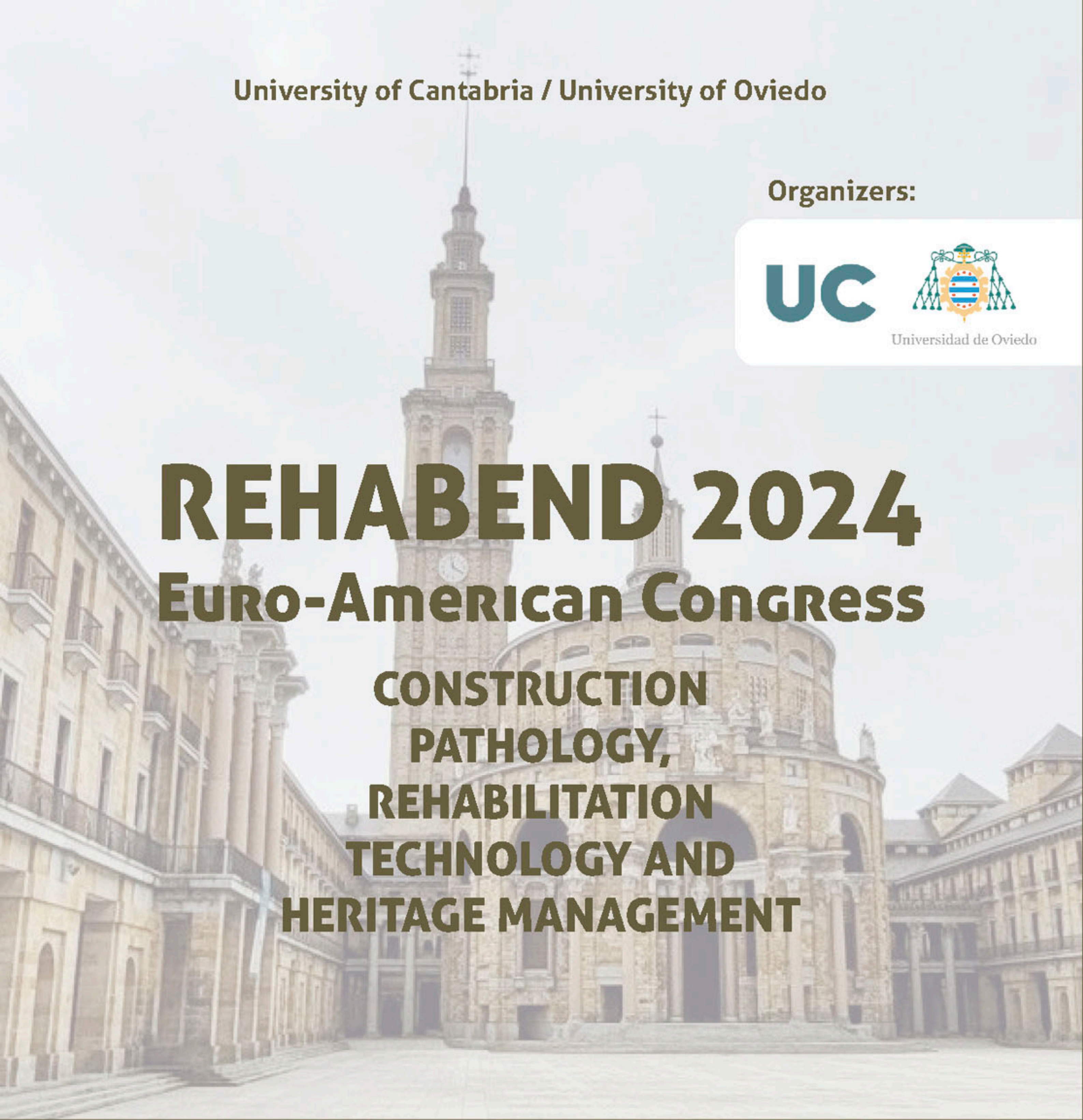

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REHABEND 2024

Euro-American Congress

CONSTRUCTION PATHOLOGY, REHABILITATION TECHNOLOGY AND HERITAGE MANAGEMENT

Gijón (Spain) - May 7th - 10th, 2024

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REHABEND 2024

CONSTRUCTION PATHOLOGY, REHABILITATION TECHNOLOGY AND HERITAGE MANAGEMENT

(10th REHABEND Congress)

Gijón (Spain), May 7th-10th, 2024

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Building Technology R&D Group (GTED-UC)
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10th Euro-American Congress on Construction Pathology, Rehabilitation Technology and Heritage Management

REHABEND 2024

Organized by:

University of Cantabria (Spain)
www.unican.es

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The **Euro-American Congress REHABEND 2024** on **Construction Pathology, Rehabilitation Technology and Heritage Management** was held in **Gijón (Spain)**, in **May 2024**. The event was co-chaired by the **University of Cantabria** and the **University of Oviedo**.

REHABEND 2024 **continued the series of the nine previous REHABEND international events**, which had been held **since 2006 in different Spanish cities**. The previous one, in **2022**, took place in **Granada, Spain**. In 2022 edition, approximately **280 papers** from around **30 countries** were presented, making it a conference of great interest to those who attended.

Construction Pathology, Rehabilitation Technology and Heritage Management currently hold significant importance in the construction sector. This prompted the organizers to propose a **technical event on these topics in Gijón**. The event aimed to collect the **advances obtained in the last two years** in the **theoretical knowledge** and **practical realizations** carried out on the referred topics. The Congress met around **275 technical contributions** coming from professionals, academics and specialists from more than **30 countries**.

Based on previous experiences, the Congress **was once again proposed within the Euro-American cultural space**. The **official languages** were **English**, **Italian**, **Portuguese** and **Spanish**. Organizers understand that technical articles and oral presentations, with the support of graphic material and schemes, would be understood by participants, as evidenced by previous editions of REHABEND.

Under these premises and the success of previous editions, the Congress was sponsored by the **Government of Spain**, the **Regional Government of Asturias**, **the Municipality of Gijón**, **Laboral Ciudad de la Cultura**, **Gijón Convention Bureau**, **Grupo Puma**, **Mapei, Sika, Tecnalia,** the **University of Cantabria** and the **University of Oviedo**. Additionally, several universities, technical and professional associations, institutes, foundations and companies pledged their collaboration to ensure the success of this initiative.

The organizers of REHABEND 2024 extend their gratitude to the **sponsors and collaborating entities**; the **Scientific Committee members** for their diligent review of technical contributions to ensure the required level of quality for an international event, to the **keynote speakers**, to the different s**peakers** for their valuable contributions, and **all attendees** for their confidence in the event. Sincerely, many thanks to all.

Dr. Ignacio Lombillo
Chairman of the REHABEND 2024 Congress
Associate Professor
University of Cantabria

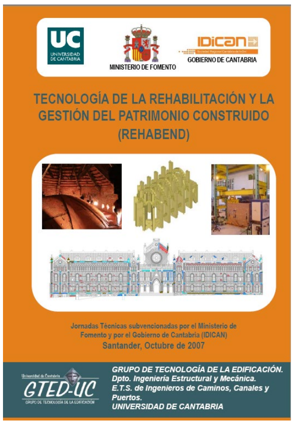
Dr. Alfonso Lozano
Chairman of the REHABEND 2024 Congress
Associate Professor
University of Oviedo

The University of Cantabria, through its Building Technology R&D Group (GTED-UC), was the promoter of the REHABEND Congresses on Construction Pathology, Rehabilitation Technology and Heritage Management.

The 1st REHABEND Congress was set in motion in Santander, Spain, in November 2006. It became established in the 2nd (Santander, 2007), 3rd (Valencia, 2008), 4th (Bilbao, 2009), 5th (Santander, 2014), 6th (Burgos, 2016) and 7th Congress (Caceres, 2018), all of them carried out in Spanish cities. The 2020 edition was to be held in person in Granada in March 2020, but due to the global health emergency resulting from Covid-19, it had to be held online in September 2020. The 9th edition (REHABEND 2022) took place in Granada, featuring a hybrid format combining in-person presentations with other asynchronous online sessions.

The ability to convene of the nine perfomed editions was prominent, gathering an appreciable number of experts in the topics of the Congress. As a reference, in REHABEND 2022 Congress took part approximately 280 speakers from around 30 countries worldwide.

The covers and ISBN of some the books of papers corresponding to the previous congresses are attached below. The ISSN of the series of REHABEND books is 2386-8198. In addition, since REHABEND 2014, the papers presented at the congress have been indexed in Scopus.



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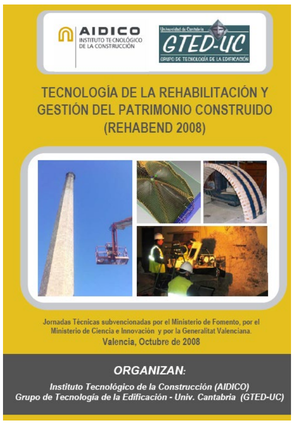

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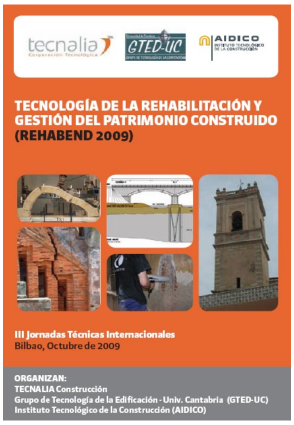

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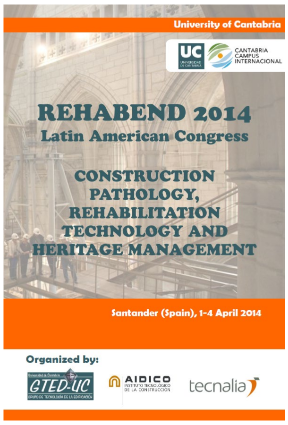

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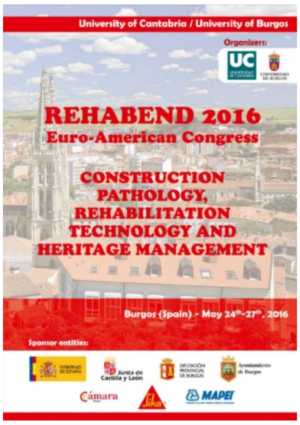

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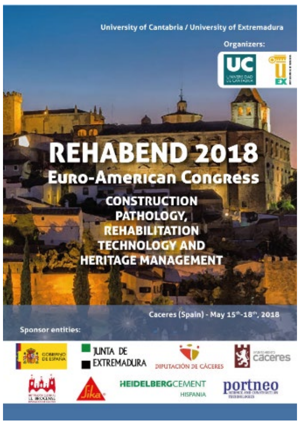

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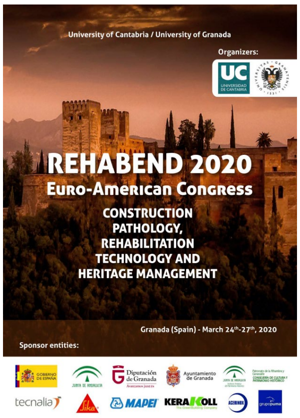

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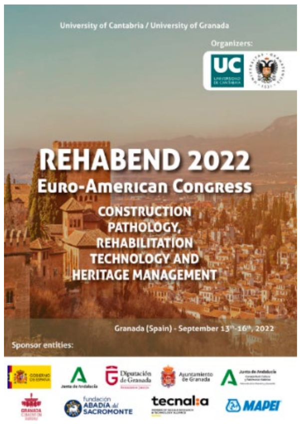

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The Collaborating Entities have been presented grouped in countries, following an alphabetical order. As Collaborating Entities have been considered to all that have contributed at least with two accepted articles in the Congress, or that some of its members formed part of the International Scientific Committee of the Congress / keynote speakers. Finally, in each country, the Collaborating Entities have been ordered according to the number of accepted articles.

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Argentina-LEMIT Laboratorio de Entrenamiento Multidisciplinario para la Investigación

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Uruguay	Dr. Gemma Rodriguez de Sensale	Universidad de la República
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1.- PREVIOUS STUDIES	1.1.- Multidisciplinary studies (historical, archaeological, etc.). 1.2.- Heritage and territory. 1.3.- Urban regeneration. 1.4.- Economical and financial policies. 1.5.- Social participation processes and socio-cultural aspects in rehabilitation projects. 1.6.- Construction pathology. 1.7.- Diagnostic techniques and structural assessment. 1.8.- Vulnerability studies and risk management. 1.9.- Guides and regulations.
2.- PROJECT	2.1.- Theoretical criteria of the intervention project. 2.2.- Traditional materials and construction methods. 2.3.- Novelty products applicable and new technologies. 2.4.- Sustainable design and energy efficiency.
3.- BUILDING INTERVENTION	3.1.- Intervention plans. 3.2.- Rehabilitation and durability. 3.3.- Reinforcement technologies. 3.4.- Restoration of artworks. 3.5.- Conservation of industrial heritage. 3.6.- Examples of intervention.
4.- MAINTENANCE	4.1.- Construction maintenance and infrastructures. 4.2.- Preventive conservation of built heritage.
5.- DIFFUSION AND PROMOTION	5.1.- Heritage and cultural tourism. 5.2.- Teaching and training. 5.3.- New technologies applied to the heritage diffusion. 5.4.- Accessibility to cultural heritage. 5.5.- Built heritage management.

ABSTRACTS OF THE CONGRESS

KEYNOTE LECTURES

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1.3.- Urban regeneration.

1.5.- Social participation processes and socio-cultural aspects in rehabilitation projects.

1.6.- Construction pathology.

1.7.- Diagnostic techniques and structural assessment (no destructive testing, monitoring and numerical modeling).

1.8.- Vulnerability studies and risk management.

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CODE 146

DIATOMACEOUS EARTH AS A PARTIAL REPLACEMENT FOR PORTLAND CEMENT IN MORTARS - A REVIEW

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KEYWORDS: “Sustainability”; “Waste valorisation”; “Diatomaceous earth”; “Cement mortars”.

ABSTRACT

Over the last years, the increase in CO_2 emissions into the atmosphere, its impact in climate change, and issues related to the sustainability and environmental impacts generated by the participation of construction industry in the global warming, which is responsible for about 8% of world CO_2 emissions, have led to countless research, several of them looking for modernize cement production with alternative binders. In the present paper, it is researched the possibility of the use of diatomaceous earth as an alternative binder.

The most known alternative binders used nowadays in construction industry are slag, metakaolin and fly ashes. These materials are known for its pozzolanic properties, and when used in cement mixtures, they can improve the concrete and mortars mechanical characteristics. Focus of this paper, and very similar to metakaolin and fly ash, there is the residual diatomaceous earth, a material with high porosity and low thermal conductivity, with pozzolanic properties and another waste product that can be used in the construction sector.

Following the concept of sustainable construction, this work shows an extensive review of studies about introduction of residual diatomaceous earth in cement mortars, and the feasibility of using this material as a binder in cement mortars. Also, this paper brings details of some physical and mechanical properties of mortars made with diatomaceous earth, such as compression and flexural strength, and water absorption; and some features of residual diatomaceous earth like mineralogical analysis, chemical analysis, bulk density and particles size.

1. INTRODUCTION

In the construction industry, the production of cement has led to severe environmental impacts, being a threating contributor for the global warming crisis. Cement production is responsible for about 8% of global CO_2 emissions, revealing the necessity to implement more sustainable materials in the construction industry. Therefore, several studies on making cement production more eco-friendly have been conducted, as the use of alternative binders in the manufacture of cement mortars [1].

Many ancient structures, that are still standing today, used mortars manufactured with materials of volcanic origin, which is a proof of the high durability of these lime-based cements and mortars with materials with pozzolanic properties. The chemical and physical properties of these structures are still on investigation, in particular for restoration purposes and to meet new alternative materials able to be used in mortars in replacement of cement [2].

Currently, cements based on alternative binders are already being used and have become an interest of research around the world, aiming to modernize the cement production. The alternative binders used nowadays are materials with pozzolanic properties, such as metakaolin, fly ashes obtained from burning coal in thermoelectric power stations, and slag obtained in blast furnaces. Another studied material capable to use as a new alternative binder is the diatomaceous earth, a natural material formed by diatomites deposited in the ocean and lakes over thousands of years, with pozzolanic properties similar to metakaolin and fly ashes [3,4].

Diatomaceous earth can be used as an ecological fertilizer in agriculture or as a filter agent in swimming pools. To use this material in these ways, a calcination process is required. This process modifies the chemical composition of diatomaceous earth, improving both pozzolanic and physical characteristics. For that reason, recent studies research the use of diatomaceous earth as an alternative binder in mortars and concretes, and in other eco-friendly construction materials [4].

With this purpose, a bibliographic review of studies related to the manufacture of cements based on diatomaceous earth is presented in this work. Some characteristics of diatomaceous earth, just like its chemical composition, density, different drying methods and different calcination process are investigated. Also, other subjects are analysed in this study, such as mortar blends based on diatomaceous earth, and physical and mechanical properties of the obtained samples are studied through several essays, such as: compressive and flexural strengths, water absorption by immersion and freeze-thaw resistance. These essays lead to better knowledge about physical and mechanical mortars properties, and, the most important conclusion, the improvement in mechanical resistance in manufactured mortars with diatomaceous earth.

2. DIATOMACEOUS EARTH USED IN CEMENT MORTARS

2.1. Alternative binders

For the time being, slag obtained in blast furnaces, metakaolin, and fly ashes obtained from burning coal in thermoelectric power stations, are the main examples of alternative binders used in construction sector in concretes and mortars manufacture [5].

Formed inside the furnaces of steel mills, and a result of iron ore's melting and dripping of liquid pig iron, blast furnace slag is an example of waste product used in cement mortars. Usually composed by SiO_2 (silicon oxide), Al_2O_3 (aluminium oxide) and Fe_2O_3 (iron oxide), the density of the material presents values between 2.9-3.2 g/cm^3, however its composition depends on the ores and the type of fuel used - mineral coal or wood coal. The applicability of blast furnace slag in the constitution of compound cements for the manufacture of concretes and mortars has been studied by several research, where it is explained how to use it as a more sustainable option in construction industry. Thus, many environmental, socio-economic, and compressive strength benefits are seen when blast furnace slag is used, and it has been pointed out, by many researchers, that there are, in this waste product, enough characteristics for partial replacement of cement, even in large quantities [6].

Regarding metakaolin, it is a material of pozzolanic origin obtained from kaolinitic clays. Its properties are highly dependent on the raw material from which it comes and on the calcination temperature to which it was submitted. Often, the calcination temperature for treatment of metakaolin is around 700-800°C. Metakaolin density presents values between 2.4-2.7 g/m^3, and is usually composed by SiO_2 and Al_2O_3. When it comes about the size of its particles, some authors refer to an average of approximately 3 μm in diameter and all its particles being smaller than 16 μm [7].

Normally obtained from burning coal, fly ash is easily found in market since it is cheaper than Portland cement and metakaolin, even though it doesn't present mechanical characteristics as high and as fast in curing time as these mentioned constituents. Its density presents values around 2.3 g/m^3 and it is usually composed by SiO_2, Al_2O_3, and Fe_2O_3. Furthermore, fly ashes provide low mixing water requirements, good levels of durability, and, in the long term, higher mechanical resistances [8].

2.2. Diatomaceous earth

Diatomaceous earth is a natural material formed by diatomites deposited in the ocean and in lakes over thousands of years. It is a mineral of biogenic and sedimentary origin, formed by the accumulation of fossilised diatomaceous algae, presenting a white colour and highly rich in silica [4]. It is a material with high porosity and low thermal conductivity, and it also has pozzolanic properties very similar to fly ashes and metakaolin [3]. Several physical properties of diatomite add commercial value to this raw material, such as low apparent density, high porosity, and surface area, which are extremely necessary and important properties for different kinds of industries [4].

Diatomaceous earth can be found in market in two types regarding on what purpose it is used for: calcined and non-calcined. Calcined diatomaceous earth is used mainly as water filters in swimming pools and as absorbents for heavy liquids. It has been treated at a temperature above 1000 ºC, in order to further harden the exoskeletons of the diatoms to create a better filtering agent. Calcined diatomaceous earth is not used for animal feed and is not food grade, moreover the crystalline silica can be toxic to humans and animals when inhaled. After use and when calcined, diatomaceous earth loses its filtering capacity, becoming a residue with toxic properties to the environment. In relation to non-calcined diatomaceous earth, it has not been treated at a high temperature, so the amorphous silica remains in its natural state and is not considered harmful to animal or human health. It is marketed in its dry state, a fine white powder, used in the agricultural sector as an insecticide and/or ecological fertilizer [9].

2.3. Cement mortars with diatomaceous earth

As well as these alternative binders, it is believed to be possible the use of residual diatomaceous earth in cement binders. Several studies are dedicated to investigate natural, raw and calcined diatomaceous earth properties, and physical and mechanical characteristics of manufactured mortars with these diatomaceous earths.

In [10] diatomite characterized as natural pozzolan according EN 197-1 [11] was used as a partial replacement for Portland cement in mortars production. The authors investigated the influence of diatomite on the following properties of cement mortars: compressive and flexural strength, water absorption, and freeze-thaw resistance. To this end, the mortar mixture proportions were 1:3:0.5 by weight of cement, sand, and water, respectively. Regarding diatomite, it was used at 0%, 5%, 10% and 15% replacement by weight for cement. Quantities of water and sand were kept constant. For each mixture, three 40×40×160 mm prisms and 50 mm cubes were manufactured, and the specimens were kept in moulds for 24 hours at room temperature of 20℃. For the compressive strength test of the mortar, they used six broken pieces of test prisms left flexural strength test, and it was determined at 2, 14, 28 and 56 days. It was showed that the compressive strength test increased with age. Also, the rate of increase depended upon the level of diatomite replacement, except the mortar with 5% diatomite content after 25 freeze-thaw cycles, which decreased the compressive strength after freeze-thaw test. However, mortars containing 10% and 15% diatomite showed higher durability resistance to freezing and thawing damage. Mortar's flexural strength test was determined at 2, 7, 28 and 56 days, and showed that flexural strength decreased by increasing diatomite content. To determine both strengths, the authors took the average of three tests results for flexural strength, whereas the compressive strength were determined by taking the average of six test results. Finally, the studied showed that increasing diatomite content, water absorption of the mortars decreases, except the mortars containing 15% diatomite. Water absorption changed between 8.57% and 10.11% for the mortars aged 28 days.

In [12] residual and calcined diatomaceous earth were used in cement and gypsum mixtures, reducing the cement quantities of the mixtures by introducing diatomaceous earth. The residual diatomaceous earth was calcined at 1000°C for 1 hour, and its chemical analysis was performed with X-ray spectrophotometer. This test verifies that the residual diatomaceous earth presents a SiO_2 value equal to 78.24%, and the calcined diatomaceous earth presents a SiO_2 value equal to 93.60%. Mortar compositions with 5%, 10% and 15% cement reduction and introduction of residual and calcined diatomaceous earth were used. The specimens were then subjected to flexural and compressive tests after 2, 7 and 28 days. Cement and gypsum mixtures with residual diatomaceous earth, in compression and flexural tests, showed lower strength values at the end of 2, 7 and 28 days. On the other hand, cement and gypsum mixtures with calcined diatomaceous earth, in compression and flexural tests, showed slightly lower strength values at the end of 2 and 7 days, but at 28 days they showed strength values equal to or greater than the mixture without diatomaceous earth.

In [13] diatomaceous earth was used in cement, sand and water mixtures, reducing the cement quantities of the mixtures by introducing diatomaceous earth. The residual diatomaceous earth was calcined at 500°C for 5 hours. The density of the material after calcination was equal to 770 kg/m^3. The chemical analysis was performed with X-ray spectrophotometer. This test verifies that the diatomaceous earth has a SiO_2 value of more than 78%. Mortar compositions with 10%, 20%, 30% and 40% cement reduction and introduction of diatomaceous earth were manufactured. The specimens were then subjected to immersion water absorption and compressive strength tests after 7 and 28 days. The immersion water absorption tests showed that the introduction of diatomaceous earth in mortars increases the water absorption content of the mortar (3%). Compression tests on cement mortars with 10% or 20% diatomaceous earth showed lower strength values at the end of 7 days, but at 28 days, cement mortars with 10% and 20% diatomaceous earth showed strength values equal to or higher than the mixture without diatomaceous earth.

In [14] natural diatomaceous earths and two types of calcined diatomaceous earths were used in cement mixtures, reducing the cement quantities of the mixtures with the introduction of diatomaceous earths. Mortar compositions with 5%, 10%, 15% and 20% cement reduction and introduction of natural and calcined diatomaceous earths were used. The samples were manufactured with the dimension of 40×40×160 mm then subjected to flexural and compressive tests at the end of 28 and 90 days. Cement mixtures with natural diatomaceous earth, in compression and flexural tests, showed lower strength values at the end of 28 and 90 days. On the other hand, cement mixtures with calcined diatomaceous earth, in compression and bending tests, presented slightly similar strength values at the end of 28 days, but at 90 days they presented strength values equal to or higher than the reference mixtures and with commercial diatomaceous earth.

In [15] diatomaceous earth is not used in cement replacement of mortars; the aim was to evaluate the applicability of spent diatomaceous earth as a raw material in friendly brick production. For that, the authors used spent diatomaceous earth utilized as a filter material in breweries from Sri Lanka. The bricks were manufactured with clay, spent diatomaceous earth and water. The collected clay was combined with 0%, 5%, 10% and 15% of dried spent diatomaceous earth, and the mould's dimensions were 200×105×65 mm. Then, the sun-dried mixture (spent diatomaceous earth + clay) was burnt at 950°C, for 6 hours with 10°C/min temperature ramp. To analyse the physical properties of spent diatomaceous earth and clay, X-ray fluorescence and Thermo Gravimetric Analysis were conducted, which showed a SiO_2 value of 95.43% for spent diatomaceous earth and 55.28% for clay. Furthermore, the study showed that a higher spent diatomaceous earth percentage has a favourable impact on a brick's compressive strength, and raising the spent diatomaceous earth weight percentage improves compressive and flexural strength. In addition, the specimens generated with 15% of spent diatomaceous earth had the maximum compressive strength of 4.78 MPa and flexural strength of 0.57 MPa.

3. CONCLUSIONS

The studies gathered in this paper revealed important information about the dry process of diatomaceous earth, quantities used in replacement of cement in mortars, and physical and mechanical characteristics of mortars based in diatomaceous earth.

These studies showed that diatomaceous earth needs to undergo a calcination process in order to obtain a material completely inorganic and capable of being used in cement mixtures. It was revealed that the percentage of SiO_2 present in the diatomaceous earth is improved after the calcination process, and so does its density. Also, they showed that the high values of moisture present in the residue is due to its porosity and high absorption capacity.

They also revealed that the introduction of different percentages of diatomaceous earth in mortars influenced physical and mechanical characteristics of the mortars. Compression and flexural tests showed an enhance in their mechanical resistance over time. The absorption tests showed that increasing the introduction of diatomaceous earth increases the mortar water absorption by immersion, however the increase is not significant. Lastly, in the freeze-thaw tests, mortars with diatomaceous earth showed higher durability resistance to freezing and thawing damage.

The filler effect, the pertinent acceleration of ordinary Portland cement hydration, and the pozzolanic reaction of diatomite with cement hydrates are the three basic factors that influence the contribution of diatomaceous earth to cement mixture`s strength when Portland cement is partially replaced.

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