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Absorbent materials in waterproofing barriers, analysis of the role of diatomaceous earth

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HIGHLIGHTS

- Calcined diatomite mortars retain and transport water above waterproofing barriers.
- The volumetric dosage changed from 1:3 to 1:2 reduces capillary coefficient levels.
- Non-calcined diatomite mortar showed better results in comparison with NHL3.5.
- Non-calcined diatomite shows better results in opposition to calcined diatomite.

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ABSTRACT

This paper presents recent development in experimental assessment of the capillarity involving the effect of diatomaceous earth in water proofing barriers (1940s and 1950s solutions). The introduction of diatomite in hydraulic lime mortars as a waterproofing barrier was firstly reported in licensed architectural plans after 1945 in the central region of Portugal. This was the period of Modernist buildings, a recent heritage to preserve and widely disseminated worldwide, recognised as the 20th century heritage. A methodology was presented to test these types of solutions considering the calcined and not calcined diatomite. Experiments reveal that two aspects need to take into account: (1) the presence of not calcined diatomite tends to have a better behaviour in relation to calcined diatomite; (2) the type of diatomite—calcined or not calcined—has influence in the capacity of retaining water in the barrier, as well as the variation of volumetric dosage of the components.

1. Introduction

The introduction of diatomaceous earth in mortars as a waterproofing barrier was first reported in licensed architectural plans after 1945 in the central region of Portugal. This region is characterised by traditional earthen architecture; however, in most situations, the architectural plans were proposed by civil engineers from the north of Portugal, namely, from Porto, a region with traditional stone masonry construction. Further research by the first author in the archives of Porto concluded that diatomaceous earth was used in this type of construction in Porto until at least the 1950s. The reason behind this particular use over this short period of time is not fully understood. It is known that the Second World War made access to some construction materials difficult, even in countries that were not directly involved in the war, such as Portugal. Consequently, some changes were introduced in traditional and engineered construction systems to overcome the temporary lack of materials [22]. This could be the case for the introduction of diatomaceous earth in waterproofing barriers during the 1940s in Portugal rather than a crude oil substitute. The crude oil substitute was applied before 1940 in the base of the construction but also in the exterior walls up to a level at least 0.50 m above the ground as an independent layer [23], instead of an addition to the mix (2%) as described by Goma [12] in relation to the technique applied in Peru to stabilise adobe construction. In the north of Portugal, it was applied to the entire height of the exterior walls. If access to the crude oil substitute was restricted during this period, and the extraction of diatomaceous earth (diatomite) was carrying out, it would justify the use of this natural material, which was more readily available in Portugal.

Diatomite has many uses and is a natural material highly appreciated for the improvement of soils because it increases air penetration, water retention capacity, infiltration and other aspects,

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due to its small particle size, high surface and high porosity (website: [20]. Accessed 09/06/2015; [2,4]. It is also used as a mechanism for insect and fungus control and to reduce the bulk density of mortars. Studies about the characterisation of ancient hydraulic mortars from historical buildings were undertaken to extend the collection of data about rendering mortars with diatomite [24,19,11,6,18], including the possibility for its use in restoration rendering works in more recent buildings. From those studies the variations can be observed depending on the characteristics of diatomite, but also in the materials quantities. In some of these studies the diatomite was activated thermally and chemically modified to increase its strength [13,18]. In studies about the relevance of change the percentage of diatomite in cement production showed the interrelation between this and the strength [27], even in the production of lightweight bricks where the use of diatomite calcinations (500 °C) already enhance strength [21]. The replacement of natural hydraulic lime by diatomite again shows advantages on strength characteristics of NHL2 mortars [26], and the strategy was also used for Portland cement with strength advantages [5], involving changes in microstructure characteristics [17].

Although most of the research is focused on the mechanical characteristics of mixed mortars with diatomite, as involving material replacement as temperature or chemical changes in the production of mortars, there is a serious lack of studies that involve the particular subject of waterproofing barriers at the level of the foundations using diatomite.

This apparent contradiction—the use of an absorbent material in the construction of a waterproof barrier—was prescribed by technicians who understood the need to control humidity in a region with a high phreatic level.

The present study aims to contribute to the understanding of the role of diatomaceous earth in waterproofing barrier solutions for that period and to assess its effectiveness for earthen construction barriers. To fulfil this goal, several mortar solutions were prepared based on the previously identified data and analysed in a laboratory using a number of different characterisation techniques, namely, capillarity measurements, mercury intrusion porosimetry measurements of the sample materials and other complementary tests.

One of the most disseminated pathologies in the earthen construction of this coastal region is associated with defects due to rising dampness in these heritage buildings. This particular problem is also observed in many other regions and even with other construction systems such as stone or brick masonry [7,15]. For this reason, this research is important not only as a historical record of the evolution of the construction system but also to understand the natural capacity of this material to improve the performance of building barriers against rising dampness and to potentially promote its use in new rehabilitation actions for this type of buildings.

The interest in lime mortars research is growing and has been carried out in order to achieve proper combinations for rehabilitation of heritage buildings [25]. Rising dampness continues to be a challenge to overcome, involving presently not only the study of drying and wetting characteristics of building materials or components [3], but also methodologies to control degradation of historical walls [14].

2. Composition of the waterproofing barriers of the 1940s in earthen construction

In order to fulfil the objective of characterisation of the main compositions of joint mortars from 1940 to 1956, different periods were assessed and more than 725 architectural files of the Aveiro district archives were analysed.

Table 1
Identification of specimens type and volumetric dosage.

Identification of specimen	Binder	Aggregate	5% diatomite	Description
CH	1	3	–	Hydraulic lime/sand
CHDn	1	3	X	Hydraulic lime/sand + diatomite (not calcined)
CHD	1	3	X	Hydraulic lime/sand + diatomite (calcined)
CHDt	1	2	X	Hydraulic lime/sand + diatomite (calcined)
CHDnB	1	3	X	Hydraulic lime/sand + diatomite (not calcined) + crude

After 1945, air lime was gradually substituted by hydraulic lime in mortars, namely, in waterproofing barriers with the addition of diatomite. In this study, the most common solutions were used to understand the interaction between these binders with the supplementation of diatomite. The volumetric dosage (ratio) was normally 1:3 (binder:aggregate), to which 5% diatomite in terms of the total volume, was added. In other cases, hydraulic lime binder was used in a specific ratio of 1:2 just for this type of barrier. In the written architectural plans, it was not possible to confirm whether the diatomite used was calcined or not calcined; therefore, this study involves both states of diatomite. The crude oil substitute used as waterproofing material was also added to one solution of the study.

The *in situ* assessments and also the descriptions from the archive documents showed that the waterproofing barrier was applied below the floor structure. This occurred independently of the type of structure—timber beams or concrete slabs. Nevertheless, when a substitute of crude oil was added, it was applied below the waterproofing mortar. For this reason, the test specimens follow the same strategy.

The following solutions were used for the study with specific ratio, shown in Table 1.

3. Materials and methods

This assay was conducted according to the procedure of AASTHO: T162-04—ASTM C 305-99—mechanical mixing of hydraulic cement pastes and mortars of plastic consistency—for the preparation of mortars. The capillarity tests were conducted taking into account the recommendations of EN 15801 and EN 1015-18 [9].

3.1. Characterisation of the specimen materials

3.1.1. Characterisation sand

The sand used was calibrated using a mixture of two types of sand from the Aveiro region (Portugal), sand from Vale de Ílhavo (75%—AF) and sand from Salgueiro (25%—AG) to achieve a grading curve that allowed for a higher type of grain (up to a dimension of approximately 2 mm), Table 2.

3.1.2. Hydraulic lime characterisation

The type of hydraulic lime used was NHL3.5 (Natural lime, SECIL, following NP EN459-1), with the characteristics present in Table 3.

3.1.3. Diatomaceous earth (not calcined)

Diatomite (diatomaceous earth) is a powdery, non-metallic mineral composed of fossilised skeletal remains of microscopic single-cell aquatic plants called diatoms, each with its own distinct shape, ranging in size from under 5 μ to over 100 μ [16]. The chemical composition and the physical structure of diatomite allow a wide spectrum of uses, including filter aids, functional fillers and as a component of aggregates [16,8].

The non-calcined diatomaceous earth (from Portugal) was prepared to remove impurities, after which it was ground until a medium diameter of 10 μ was achieved.