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In situ characterization of external ancient renderings of rammed earth constructions in the Algarve and of potential replacement commercial pre-mixed renderings

The Algarve region in southern Portugal has one of the most significant rammed earth construction legacies in the country. This construction method is characterized by its high susceptibility to water damage and external renderings are essential to the longevity of these buildings. The use of specific pre-mixed rendering formulations in the rehabilitation process may be an option to enhance the durability and quality of the interventions. The main objective of this characterization study of the renderings is to identify composition and behaviour patterns in order to understand the natural degradation phenomena and how they are associated with the background characterization. With this purpose, 15 ancient earth buildings were selected to represent this heritage and its composition diversity. In situ tests are carried out to evaluate hydric and mechanical properties of the ancient renderings and rammed earth substrates. Five pre-mixed renderings solutions available in the market are also evaluated through in situ tests, regarding hydric and mechanical response.

Scope and objectives

Within a PhD study at Instituto Superior Técnico, characterization tests were performed on site, allowing the establishment of analysis criteria aiming at understanding the degradation phenomena of ancient renderings and the potential use of pre-mixed renderings available in the market for ancient buildings. The use of protective renderings is common in Portugal. These constructions have external renderings made of coats of mortar with lime, clay and sand, made on site (Margalha et al. 2011). Renderings are the first physical barrier inhibiting the direct contact of water with rammed earth substrates, preventing leaching of the fine aggregates and loss of load bearing cross-section. The renderings must also allow the exchange of water vapour between the earth substrate and the exterior, preventing large periods of water retention in the substrate and rendering. The main objective of the characterization process of the renderings is to understand the natural degradation phenomena and how they are associated with the background characterization (Mateus et al. 2014). A set of ancient rendering were selected for their hydric and mechanical characterization using in situ procedures. In addition, some pre-mixed mortars were applied in an ancient rammed earth construction, in order to evaluate some of their hydric and mechanical features using the same characterization procedures. The ancient renderings are air lime based. According to the manufacturers information, CBR1, CBR3 and CBR5 pre-mixed renderings are hydraulic lime based mixes with synthetic fibers, CBR2 is an air lime based mix, and CBR4 is an hydraulic-based mix with cork aggregates.

Characterization methodology

The ancient renderings tested have the following aspects in common: i) type of substrate: rammed earth; ii) type of coating: exterior; iii) geographical area: western Algarve; iv) type of construction: current dwelling 1 to 2 storeys above ground; v) construction period: from 1850 to 1950. Five pre-mixed commercial brand rendering samples were applied on one of the ancient buildings. Each pre-mixed rendering sample is 1.80 × 1.00 m wide. In situ tests were performed to evaluate the water absorption and surface hardness, both in ancient and pre-mixed renderings, using specific test procedures also used in former characterization processes at L.N.E.C. (Mateus et al, 2014). The tests in pre-mixed renderings were carried out 90 days after in situ application. The water absorption test using Karsten tubes aimed at establishing the renderings response to water contact, as it simulates the real scenario of rain exposition. This methodology follows the EN16302 and LNEC Pa39 test procedures. The water absorption was measured every

Figure 1 Water absorption using Karsten tubes, in ancient rendering.

Figure 2 Water absorption using Karsten tubes, in pre-mixed commercial rendering.

Figure 3 Mechanical strength test using the Schmidt pendulum hammer, in pre-mixed commercial rendering.

Figure 4 Water absorption using Karsten tubes, in ancient rammed earth substrate.

minute in the first 5 minutes, and every 5 minutes for an hour period (Fig. 1 and Fig. 2). The same test was carried out in the ancient rammed earth substrates in order to compare the absorption rates with the corresponding rendering ones. To evaluate the mechanical capacity of the renderings, mechanical strength tests were carried out using the Schmidt pendulum hammer model PM (Fig. 3). These tests were carried out according to RILEM TC 127 MS procedures, using the pendulum hammer model PM, more suitable for the low level of mechanical strength of these renderings. This non-intrusive method measures the rendering surface hardness. The output is the rebound of the pendulum mass, measured using the equipment degree scale. Since these pre-mixed renderings are available in the market, compression strength reference values provided by the rendering manufacturers can be taken to evaluate the reliability of this test. Twenty tests were performed per pre-mixed rendering, in a total of 100 tests. Twenty tests were also performed in each of the ancient renderings. The absorption test of the "Monte Ruivo" rendering was not performed because of difficulties in accessing the test area. The absorption test of the "Bensafrim" rammed earth substrate was not performed because of its highly irregular surface that did not allow the proper bonding of the tubes.

Results and discussion

The air lime-based ancient renderings show higher absorption rates than most of the new pre-mixed commercial renderings. The absorption lines of those ancient renderings are marked in red in Fig 5 below. The water absorption rates of new commercial renderings have a wide range of values. Three of the pre-mixed renderings have lower absorption rates then the ancient renderings and two others have higher absorption rates then most of the ancient renderings – CBR 2, which is air lime-based (grey line in Fig 5); and CBR4, which is an hydraulic lime-based rendering exclusively with cork aggregates. The cork aggregates are responsible for its high water absorption

Figure 5 Water absorption of commercial renderings versus ancient renderings – in situ test (Karsten tubes)

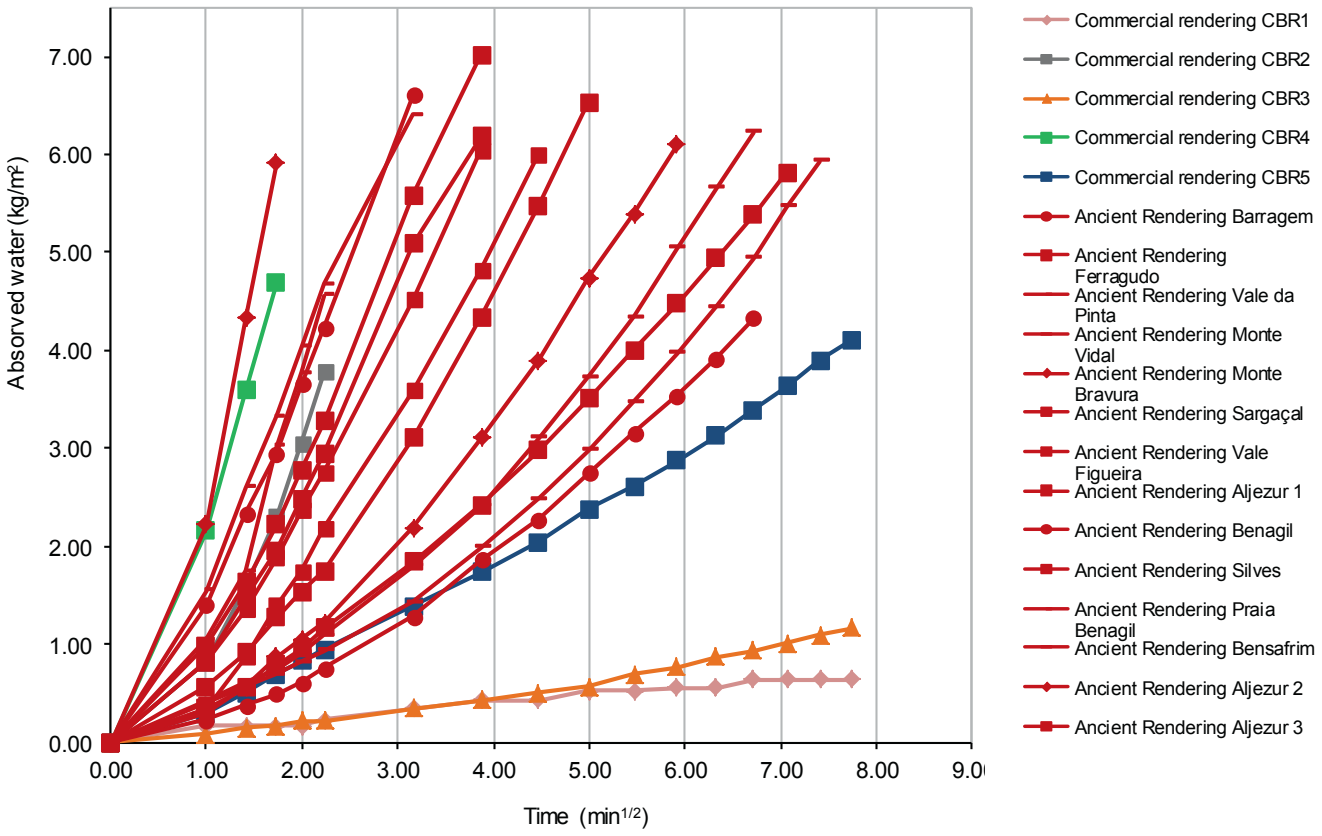


Figure 6 Water absorption of ancient rammed earth substrates–in situ test (Karsten tubes)

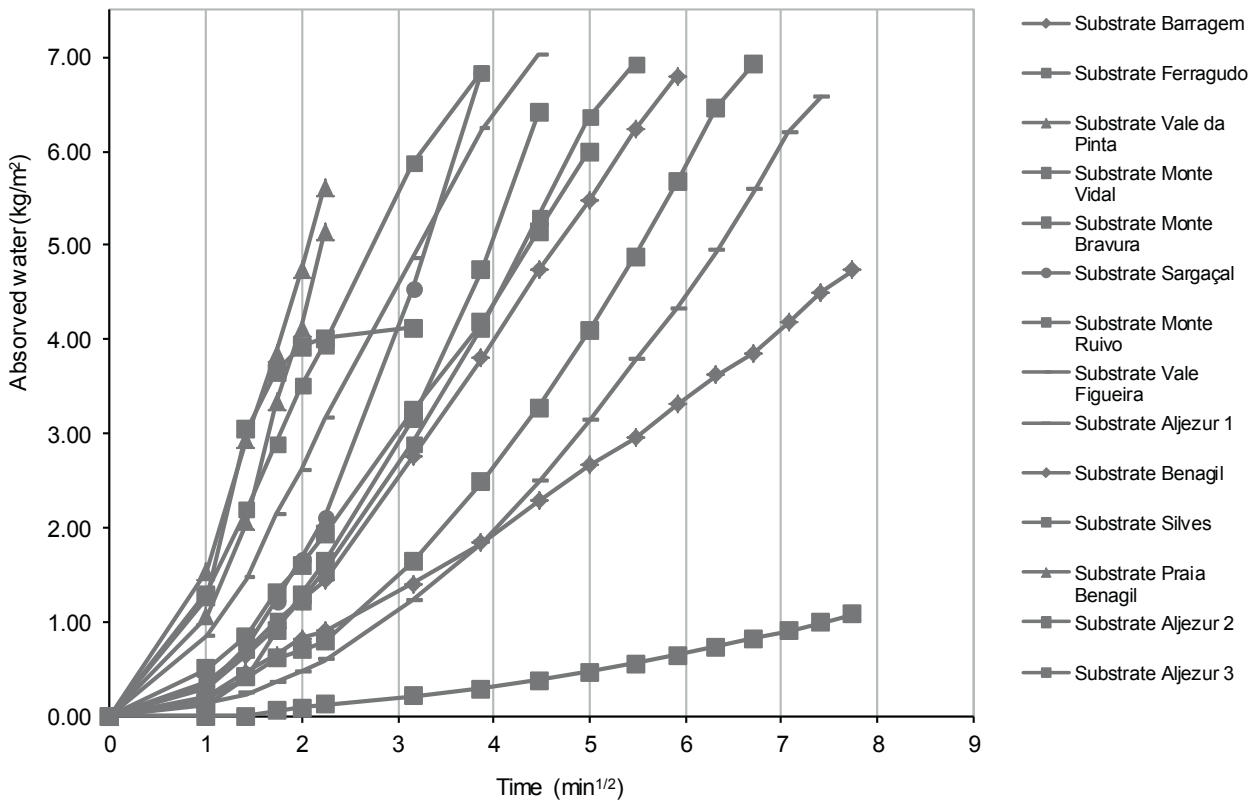


Figure 7 Superficial hardness of commercial versus ancient renderings–in situ test (pendulum hammer)

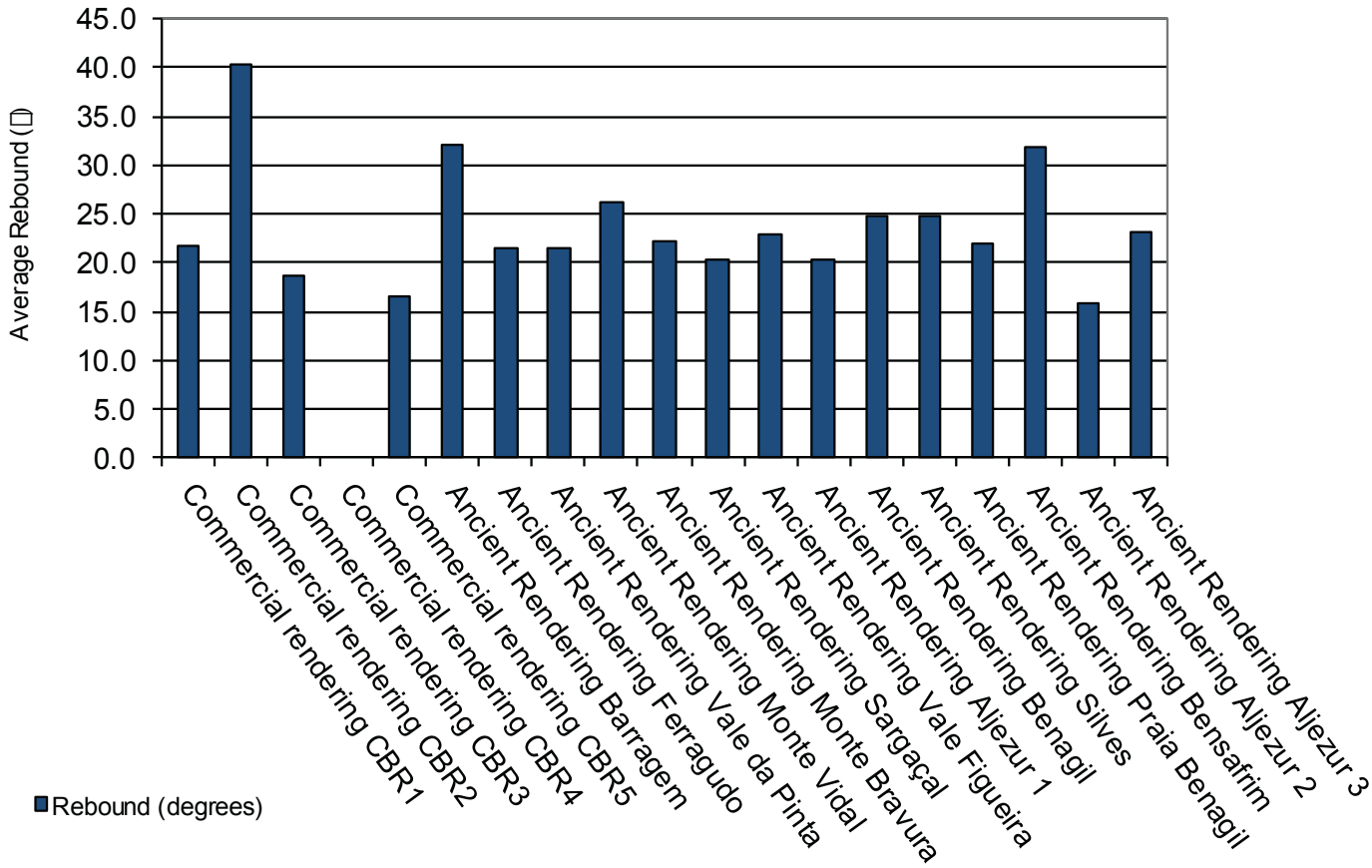
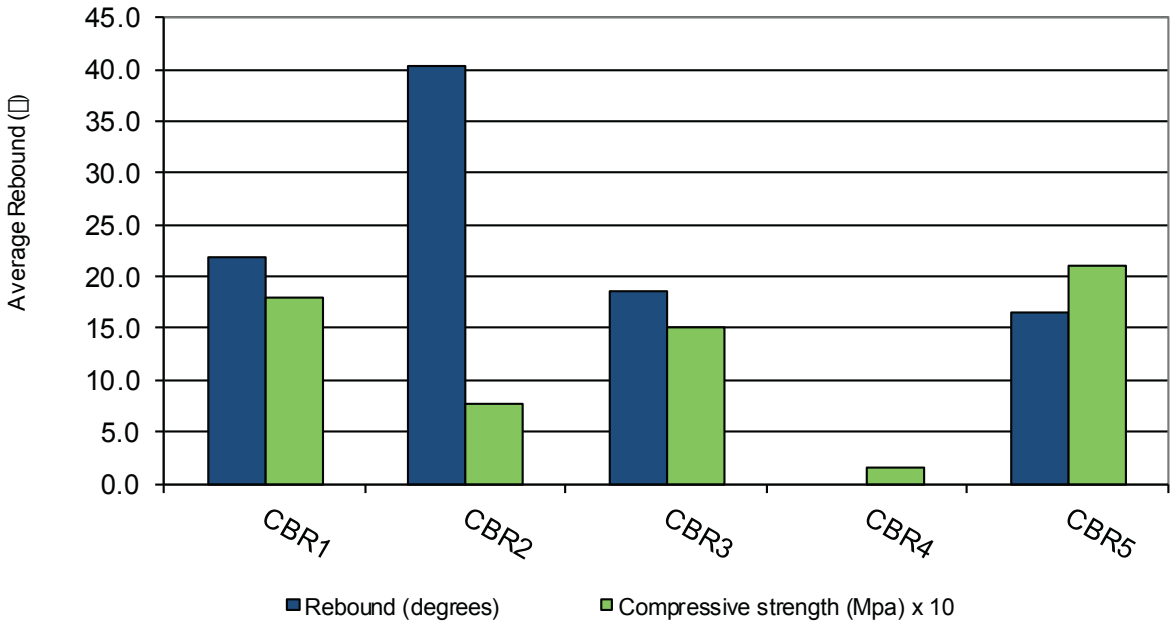


Figure 8 Superficial hardness versus compressive strength of commercial renderings



rate (green line in Fig. 5). The ancient substrates have a wider range of water absorption rates (Fig. 8): five of them have similar rates than their renderings; two of them have higher water absorption rates then their renderings. Six of them have lower water absorption rates than the corresponding renderings implying a water retention period in the interface between the coating and the rammed earth substrate, and the contact of infiltrated water with the rammed earth substrates. Pre-mixed renderings CBR1, CBR3 and CBR5 have similar levels of mechanical strength. It was not possible to perform this test in the CBR4 rendering because of its very low strength (Fig. 7). Most of these pre-mixed renderings have similar surface hardness; exception is made for CBR2, a pre-mixed air-lime based rendering, which has a higher surface hardness value, related to its higher stiffness; CBR1, CBR3 and CBR5 have synthetic fibers in their composition that reduce their surface hardness. In spite of that, these three commercial renderings have higher compressive strength than the common traditional air-lime based renderings (Magalhães et. al 2009). This data is provided in Fig 8.

Conclusions

The present rebirth of rammed earth construction is often linked to the acknowledgement of its advantages in terms of traditional construction identity. However, it also reveals some drawbacks, namely concerning susceptibility to water action. These in situ tests were performed for comparison purposes, in order to evaluate the susceptibility to water contact and the mechanical strength of ancient renderings and new pre-mixed external renderings. In situ absorption tests were also carried out in the ancient rammed earth substrates, in order to acknowledge the potential of water retention between the rendering layer and the rammed earth surface. Tests performed in situ in the scope of this study revealed the existence of response patterns common to all the ancient renderings tested: they show low mechanical strength and they reveal high susceptibility to water. High water absorption rates often allow high water retention periods in contact with the earth substrate surface, promoting their degradation. 6 of the constructions showed higher water absorption rates in the rendering than in the substrate, meaning higher water retention periods in contact with the earth substrate surface, promoting their degradation. Three months after application, there were no relevant signs of superficial cracking in pre-mixed commercial renderings. Most of the commercial renderings – CBR1, CBR3 and CBR5 – showed better characteristics then the ancient renderings regarding water absorption rates. Most of the commercial renderings have higher mechanical strength than the ancient renderings (according to the manufacturers information), however they do not have significantly higher levels of surface hardness, due to the presence of synthetic fibers in their composition, compromising a secure comparison of compressive strength levels using this kind of test. A complete laboratory campaign should be performed to obtain more feasible results and to establish correlation rules that can be used in further similar characterization processes. Therefore, none of the commercial renderings tested showed and ideal performance regarding both water absorption rates and mechanical strength level. Pre-mixed lime and clay-based mixes are now being tested, both in laboratory and in situ, in order to improve some of the features of pre-mixed mixtures, more compatible with the rammed earth substrates, particularly regarding water absorption and drying rates, mechanical and chemical compatibility with the rammed earth substrates.

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