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ON THE CONSERVATION OF THE EARTHEN BUILT HERITAGE: MUD GROUTS INJECTION

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EXTENDED ABSTRACT

Earth constructions constitute an important and significant part of the World's built heritage. This type of constructions shows also great presence in Portugal, specially, in the regions of Aveiro (Silveira et al. 2010), Alentejo and Algarve (Correia et al. 2007), despite that building in earth gradually felled into disuse during the last century. In these regions, the existing earth constructions are, however, found often extensively degraded and structurally damaged. The responsibility for this situation can be partially attributed to the systematic abandon of these buildings by the inhabitants, who leave them unprotected and without their required and essential maintenance. Nevertheless, there is, currently, lack of knowledge and of tools that would allow repairing and strengthening adequately this kind of buildings. Generating this knowledge and tools would aid opposing to the gradual disappearing of earth constructions, and eventually, lead to the reversing of this abandon tendency.

Nowadays, grout injection is a feasible and a reliable solution to consolidate historical masonry structures. Nevertheless it requires a design methodology to be followed in order to result on a successful and adequate intervention, since the composition of the grout must fulfill requirements demanded by the construction, such as the compatibility between materials and the level of improvement of the structural behavior. In this context, years of practice and research led to the development of ternary grouts (composed by cement, lime and pozzolan) as an alternative to grouts based exclusively on cement or on organic resins, which have, in general, compatibility problems with historical masonry. On the other hand, the composition of ternary grouts is more similar to that of historical mortars, so they are expected to have improved compatibility. A similar analogy can be made for the case of grouting interventions on earth constructions. Thereby, a compatible grout would, necessarily, require the incorporation of earth in its composition (mud grout). Accordingly, some researchers and conservationists have already performed some tests and trials on mud grouts used for repairing cracks on adobe walls (e.g.: Vargas et al. 2008). They showed to be possible recovering, or even surpassing, the initial strength of the walls after repairing them through grouting with unstabilized mud grouts (without addition of mineral binders). Moreover, repairs with unstabilized mud grouts showed better mechanical performance than those with addition of cement and lime (Vargas et al. 2008). However, the knowledge about this type of grouts is still at an initial stage. Problems, such as the excessive shrinkage, the incapacity to inject smaller cracks and low fluidity, demand further research on the material and structural fields.

In this context, the current PhD research aims at further developing the knowledge on mud grouts, by understanding their behavior as a repairing material and their effect/improvement on the structural behavior of earth constructions. Designing a mud grout is a complex task, since its required properties are defined as function of characteristics of the earth construction. These properties must regard not only the structural behavior of the construction, but also the durability. Thus, the main properties that control the design of a mud grout are: strength, fresh-state rheology, fresh-state stability, bond, chemical stability and microstructure. Since these properties are related between each other, adjusting the composition in order to improve one property has consequences on the others (Silva et al. 2010a). In addition, the heterogeneity of the main component, which is earth, influences greatly the behavior of the mud grout. Therefore, it is extremely complex to design a grout without deeply knowing the components to be incorporated.

Recent tests performed by the authors on aqueous suspensions of kaolin revealed that the clay fraction (size < 2 μm) composing a mud grout greatly influences its behavior during the fresh state (Silva et al. 2010b). This fraction limits the fluidity of the mud grout (rheologic behavior) due to its colloid behavior, which depends mainly on the particle size distribution and shape, clay mineralogy, and pH and ionic strength of the suspension. Nevertheless, non-purified clay particles tend to associate in aqueous suspension (pH close to neutral values and high ionic strength), forming a gel that opposes to the flowing (e.g.: Van Olphen 1977). As consequence, the mud grout needs very high water content in order to reach adequate fluidity, which results on excessive drying shrinkage of the hardened grout. Reducing the clay fraction in the mud grout allows

further decreasing the demand of water. Thus, the particle size distribution (PSD) of the solid phase can be corrected by adding coarse material. This material needs to be mainly constituted by particles with the size of the silt fraction (size between 60 and 2 μm), in order to grant a stable suspension and thus avoid segregation and bleeding. Accordingly, the authors tested kaolin suspensions corrected with different percentages of limestone powder, which allowed, in fact, decreasing substantially the demand of water. Still, the water content was too high for a grout. Further improvement was achieved by adding little quantities of sodium hexametaphosphate (HMP), i.e., a deflocculant /dispersant for clays. The combined action of the addition of HMP and the correction of the PSD with limestone powder allowed decreasing the water content to values close to 30%, and at the same time, obtaining fluid suspensions. Other properties, besides rheological parameters, were evaluated in a composition study, where the variables were the water content, the kaolin/limestone powder ratio and amount of added HMP. Such properties were the fresh state stability, the strength and the bond between the grout and earthen beams of small dimension. The results showed that the strength (flexural and compressive) of the grouts rather depends on the clay content, and the higher, the stronger is the grout. Regarding the bond, the tested grouts granted at least a recovery of 60% of the original flexural strength of the earthen beams after being repaired. However, further investigation requires using larger specimens, since the earth used to prepare the beams was sieved to remove the particles larger than 2 mm, which resulted on flexural strength values higher than those of ordinary earthen materials.

Further research is required at a macro-level. Thereby, the following step is to test the mud grouts applied to earth constructions walls. Thus, an experimental program is being prepared at the Civil Engineering Lab of University of Minho. Several adobe masonry and rammed earth walls are going to be tested under compression, diagonal compression and shear-compression, which will be subsequently repaired by grout injection, and then they will be retested. In advance, the composition of the grouts will be defined, based on the knowledge obtained from the previous studies. Later on, the selected grout compositions will be fully characterized.

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