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ON THE DEVELOPMENT OF MUD GROUTS: RHEOLOGY

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Mud grout, rheology, strength, adhesion.

EXTENDED ABSTRACT

Raw earth is one of the most ancient building materials, as is confirmed by archaeological evidences from millenarian cities that were built entirely with earth, such as Jericho (Israel), Çatal Huyuk (Turkey), Harappa (Pakistan), Akhlet-Aton (Egypt), Chan-Chan (Peru), Babylonia (Iraq) and Duheros (Spain) (Lacouture *et al.* 2007). Moreover, building with earth is currently a solution very popular in several developing countries. As consequence, there are several world-wide spread heritage sites and a large housing stock built from earth (Delgado and Guerrero 2007, Jaquin *et al.* 2008). The conservation and rehabilitation of this heritage requires the development of techniques and materials compatible with this kind of buildings. Grout injection is one repair solution which has been put forward over the last few years, whereas, in the case of earth constructions, there is preference for employing grouts that incorporate earth in their composition (mud grouts). However, knowledge on such grouts is still very limited and requires further research.

In this background, an experimental investigation was carried out by means of a composition study. This aimed at studying and clarifying the influence of mud grouts composition, namely the clay content, on the rheological behaviour of fresh-state mud grouts. Several aqueous mixes were prepared using kaolin powder (Wienerberger, Kaolin RR40) and limestone powder (Carmeuse, Calcitec 2001 S) as solid phases, which represent, respectively, the clay and silt fractions of a mud grout (Silva *et al.* 2010). A deflocculant for clays, namely sodium hexametaphosphate (HMP), was also used. Four types of mixes were prepared by incorporating different proportions of these materials: (i) kaolin mixes (K); (ii) kaolin and limestone powder mixes (KL); (iii) kaolin and HMP mixes (KH); (iv) and kaolin, limestone powder and HMP mixes (KLH). The rheological behaviour at the fresh-state of each mix was tested by measuring the flow time through a Marsh cone (Silva *et al.* 2010) and by determining their flow curves, resorting to a Viskomat PC mixer-type rheometer.

Figure 1 shows the flow time results of the K mixes, which were prepared with different solid fractions (ϕ_v). It is observed that higher the ϕ_v, the higher the measured flow time, and that the mixes stop flowing for a critical solid fraction (ϕ_{vcr}), which is reached between 9% and 10%. The fluidifying action of the HMP is evidenced in Figure 2. The HMP allowed increasing further ϕ_{vcr} to, approximately, 21%. A similar effect was achieved by incorporating the limestone powder. The flow curves of the KLH mixes were fitted to a Bingham's law, which relates the torque (T) with the rotation speed (Ω) by means of the parameters g and h, which are characteristic constants of each mix and are related to the Bingham yield stress and plastic viscosity, respectively. As can be seen in Figure 3, the HMP has greater impact on the reduction of the parameter g than it has on the parameter h. The latter parameter is the mainly responsible for flow resistance when an adequate amount of HMP is added. Moreover, the h values obtained from the KLH mixes are substantially higher than those obtained from the KH mixes, as a result of the substantially higher ϕ_v of the KLH mixes.

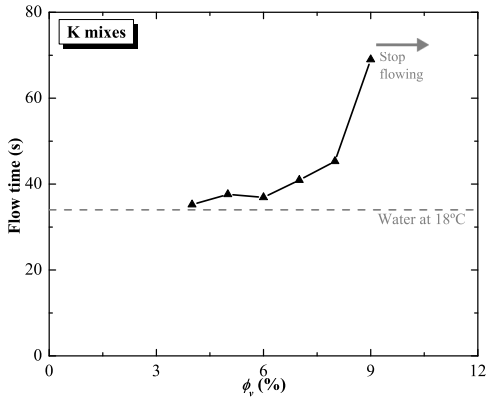

Figure 1: Flow time measurements of the K mixes.

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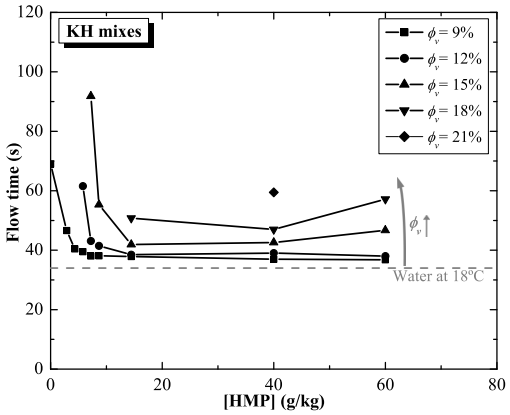

Figure 2: Flow time measurements of the KH mixes.

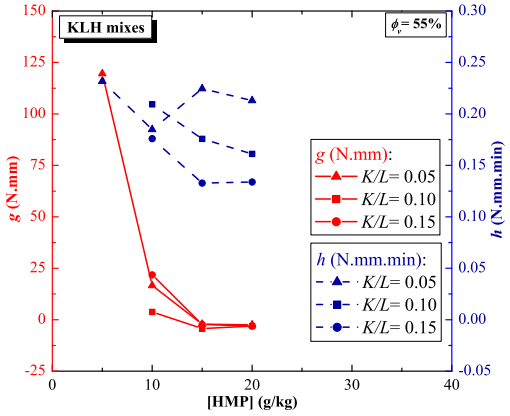

Figure 3: Bingham's parameters of KLH mixes (ϕ_v=55%).

MAIN CONCLUSIONS

The composition study performed indicates that the clay fraction has great influence on the rheological behaviour of a mud grout. Increasing the ϕ_v of an aqueous mix of clay promotes the flocculation of clay particles which is responsible for the formation of an internal house-of-cards or scaffold structure that hinders the flow. The combined effect of the addition of HMP and of the reduction of the clay content (by addition of limestone powder) allows to increase the solid fraction of a mud grout, while obtaining flowing mixes. This is an important feature with regard to control the drying shrinkage. Moreover, the addition of HMP was mainly reflected in the reduction of parameter *g* to values close to zero, which is an important feature when a mud grout is to be injected at low pressure. Further research will consist in applying these conclusions in the formulation of mud grouts, whose efficiency will be assessed in an experimental program.

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