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Development of grouts for consolidation of old renders

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HIGHLIGHTS

- Development of a composition that is deemed consistent with the original render.
- Development of lime based grouts for consolidation.
- Rheological behaviour of analysis grouts.
- The rheological behaviour was evaluated with a proper mortar rheometer.
- Study of the hardened state properties of grouts.

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ABSTRACT

A study was conducted on the development of lime based grouts for consolidation of renders and plasters detached from the support. The aim is to develop grouts that should be compatible with the pre-existing materials and allow the restoring of the adherence of coatings to the background. Special attention was paid to the rheological behaviour of the grouts and to other features of the fresh state. The role of components such as binders, aggregates and admixtures used in the formulations was tested through an outlined series of mechanical and physical tests. In terms of hardened state properties, a set of basic requirements (related to strength and capillarity) were evaluated and a test for adhesion loss measurement was developed in order to test the ability of developed grouts to restore adhesion of coating layers.

The rheological behaviour was evaluated through a distinct procedure, which involved the test with a specific speed profile (dwell profile). The dwell profile allows studying the rheological behaviour along measuring time, making possible to observe changes in rheological parameters in mortar suspensions, through the measurement of flow curves along the time test. The dwell profile allowed obtaining the rheological parameters (viscosity and yield stress) according to the Bingham model.

Grouts based on lime, fine sand and metakaolin together with the right amount of water and admixtures were developed and adjusted in order to be used in consolidation works of old renders.

1. Introduction

In Europe the importance of old buildings restoration is growing in the construction sector. The use of cement mortar for the replacement of old renders does not in many cases respect the features of the original applied materials, as well as their traditional process of application. Therefore, problems such as detachments, cracking and crystallization of soluble salts, among others, appear or are accentuated. It is very important to achieve a composition that is deemed consistent and compatible with the original render at both chemical and physical levels. The aim of any action of restoration and maintenance of old renders is to solve the problems accumulated over the years. Equally important, is the safeguard for future generations of a valuable urban and architectural heritage. Indeed, a rehabilitation intervention begins as an operation that aims to conserve the largest part of various elements and materials of the property over which rehabilitation is focused on [1].

A grout is a mortar used to fill or to ensure homogenization, consolidation and the improvement of mechanical properties of systems that present cavities, cracks or loss of adhesion [2].

The loss of adhesion in old renders has a destructive effect, requiring the application of specific techniques such as the use of

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grouts. Grouts based in lime mortars have a good compatibility potential with old supports, but may need several additions with the aim to grant some hydraulic character and to model performance in the fresh state. The development of grouts should involve the study of their rheological behaviour, because this is essential for their penetration inside thin cavities between detached layers and fulfillment of existent voids. The mixing water and admixtures content are factors under consideration [3].

Grout must be compatible with the original coating and one must realize that repair or restoration with grouts is practically an irreversible technique, since it involves works that are difficult to be removed. The injection of the grout in existing holes in the wall aims to fill cavities, whether internal cracks or detachments. This technique becomes more effective if inside the intervening elements there is a communicating network of open porosity. In such delicate cases, the injection should be done by gravity, vertically or with a minimum inclination [3,4]. This technique consists in the introduction of a fluid lime paste into the void area in the detachment occurring between the substrate and the render layers [5,6].

Table 1 summarizes the requirements for the development and performance of grouts.

Rheology can be defined as the science that studies the flow of materials, evaluating the relationship between the applied shear stress and deformation in a given period of time [7,8]. Banfill [8] demonstrated that mortars have a rheological behaviour that generally follows the Bingham model, expressed as:

$$\tau = \tau_0 + \eta\gamma \quad (1)$$

In this model, there is a linear relationship between stress (τ) and the deformation (γ) from a certain value of shear stress (Bingham stress or yield stress, τ_0). In other words, these materials resist without flowing to shear stresses below the yield stress, but above that, they have a linear relationship between the shear stress and deformation, and this relation is characterized by the plastic viscosity (η) [9,10]. It is very important to evaluate the rheological behaviour of the grouts due to its relevance to their injection and dispersion capacity through the voids.

Slump in a flow table is a technique commonly used for the assessment of mortars workability, and it is a valuable help for fresh state basic characterization.

However, the use of rheometers allows determining, separately, two important rheological parameters, yield stress and plastic viscosity (τ_0, η) and, by doing so, to evaluate the role of different components in a formulation separately on each parameter. The main objective of this work is assessing and optimising the viability of grouts for consolidation of old renders through rheometry and other relevant characteristics.

2. Experimental

2.1. Materials

All grouts formulations included air lime as binder and fine sand as aggregate in a binder/aggregate of 1:6.65(w/w). The binder is a CL90 air lime (Calcidrata SA, Portugal) the aggregate is a fine sand (SS-160 from Sifucel SA, Portugal). The aggregate used was a very fine silica sand (<200 μm) and its particle size distribution is shown in Fig. 1.

The grouts development began with the study of the rheological behaviour of a base grout mortar, consisting of air lime, sand and water. Admixtures were then added to control the rheological behaviour and, in a second phase, a pozzolanic additive (metakaolin), Table 2, was also introduced to improve lime based grouts hardened state characteristics. The manufacturer of metakaolin (Argical 1200) is AGS Mineraux and its particle size distribution is in Fig. 2. This pozzolanic addition was made in amounts of 10%, 20% and 30% of the total mass of the binder.

The admixtures used were a water retaining agent (cellulose ether), a plasticizer (sodium gluconate) and an adhesive agent (Acril33), with contents varying between 0.5% and 1% of the total mass of solids. This adhesive agent is an acrylic resin in aqueous dispersion characterized by excellent resistance to atmospheric agents and chemical stability, good freeze–thaw stability and binding power and a high resistance to yellowing. The manufacturer is CTS Spain (Products and equipment for restoration, S.L.).

Developed grouts were also compared in terms of rheological behaviour with two commercial grouts (PMLA and PMLI). The PMLA grout is an injection grout, based on air lime, which is used to consolidate wall painting and old renders of historical interest. The PMLI grout is an injection grout based on hydraulic lime, which is used to consolidate old renders and plasters of historical interest. Tables 3 and 4 presents the characterization of these materials developed by Tavares and Monte [11,12].

2.2. Methods

2.2.1. Rheological characterization

Fresh mortar can be considered as a fluid material, where the yield stress represents the initial resistance to the flow, caused by contact between grains, while the plastic viscosity control the behaviour once the required torque was achieved to initiate the movement [13].

For the characterization of the rheological behaviour a specific rheometer for mortars (Viskomat NT – Schleibinger Gerate, Germany) was used. In this equipment, as the cylindrical sample container rotates (Fig. 3), the mortar flows through the blades of the impeller and exerts a torque measured by a transducer [9,10]. This rheometer measures the torque along the test duration time as a function of rotation speed for different speed-time profiles. The characteristic Bingham fluid relation of torque (T) with rotation speed (N) is $T = g + h\ N$, where g (N mm) and h (N mm min) are coefficients proportional to yield stress and plastic viscosity, respectively [10,14].

The rheological behaviour was evaluated through a distinct speed-time profile at constant rotation speed. The dwell profile allows the study of the rheological behaviour over time, making it possible to measure flow curves (T vs. N) along the test time. The dwell profile allowed a precise evolution of the rheological parameters, determined according to the Bingham model, e.g., the yield stress and the plastic viscosity related coefficients, g and h, respectively [9,15,16].

In this study, the rotation speed profile was defined for 60 min at 0 rpm with speed rising to 160 rpm every 15 min followed by a drop back to 0 rpm again (Fig. 4). The change of speed from 0 to 160 rpm and from 160 to 0 rpm is 30 s. In the speed variation areas, flow curves of torque (T) vs. rotation speed (N) can be constructed [6].

Table 1
Summary of requirements for grouts [4].

Rheological requirements	Enough fluidity and uniform penetration capacity, to a better filling of voids – injectability Lack of segregation (avoid heterogeneity) Minimum exudation, reducing the presence of voids
Chemical requirements	Chemical characteristics stable over time Resistance to sulphate salts, preventing efflorescence and expansive products Minimum alkali content
Physical requirements	The setting time should be appropriate for injection Insolubility in water and volumetric stability in presence of humidity Low shrinkage
Mechanical requirements	Similar characteristics to the original material Good adherence to the substrate, for good efficacy in consolidation
Thermal requirements	Low heat of hydration to prevent the development of thermal gradients that can affect the adhesion to the substrate