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CONSERVATION-RESTORATION
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SUPSI

Master-Thesis in Conservation-Restoration:

Development of a site specific injection grout for gypsum based plaster in the Ateni Sioni church in Georgia

Fig. 1: Ateni Sioni church (Georgia).

Fig. 2: Delaminated gypsum-based plaster in the Ateni Sioni church.

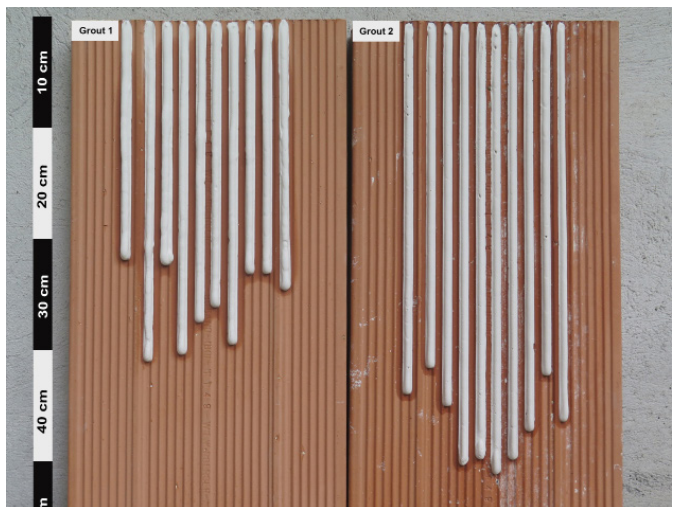

Fig. 3: Flow test of the two grouts (*Grout 1* and *Grout 2*) developed in the laboratory; test was performed to assess the flow distance and time of the freshly prepared grout when injected in the vertically carved chanells of the brick tile.

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Abstract

This research focuses on the delamination problem of the highly significant 11th century wall paintings at the church of Ateni Sioni in Georgia (Fig. 1). Delamination is a widespread wall paintings deterioration phenomenon and is due to a lack of adhesion between plaster layers or between plaster and primary support. A variety of methods have been used to address this problem and one of them is injection grouting which has been developed in the last two decades.

Most of the literature describing grouting for the stabilisation of delaminating wall paintings focuses on lime-based and/or earthen-based grouting. Gypsum has never been considered for grouting even if it has been used as the constituent of wall paintings since ancient times. There is a significant lack of conservation literature regarding gypsum-based plasters, and particularly injection grouting treatment methodologies and materials.

During this research grout mixtures were developed specifically for this site through a methodology which started with the identification of the site specific requirements and involved extensive laboratory testing to assess the working properties (properties of a grout in its fluid state, i.e. during the intervention) and the performance characteristics (characteristics of a harden grout, i.e. after the intervention) defined for the site.

General requirements for a grout include adequate adhesion properties, in the case of Ateni where semi-horizontal and/or horizontal surfaces suffer from severe delamination. In addition, due to the gypsum sensibility to water (in which it is slight soluble) it was important to reduce the water content of the grout. This was achieved by substituting part of the water with ethyl alcohol in the dispersion medium.

Laboratory testing has provided two formulations which fully satisfy the requirements set to address the delamination in Ateni.

Due to the time constrains in situ testing and evaluation of the grouts is not included in this research but the issues and constrains regarding in situ testing and possible implementation were established.

Objective of the research

The objective of this research was to develop a grout for the stabilisation of the paintings of gypsum plaster (Fig. 2) in the Ateni Sioni church in the laboratory and, through qualitative and quantitative laboratory testing, assess its compatibility and suitability for its in situ testing and possible implementation. The extensive laboratory testing program was preceded by the following investigations:

• Condition assessment on site: definition and description of delamination categories and graphical documentation of their distribution. This was performed to provide the scale of severity of the plaster delamination phenomenon throughout the church;

• Characterisation of the original materials (delaminating plasters and stone support) in the laboratory using different analytical techniques;

• Definition of the specific criteria, requierements and constraints or the injection grouting intervention.

Choice of materials and laboratory testing

Initially, a wide range of materials (binder, fillers and suspension media) were considered for this research. Due to the lack of literature regarding materials used for stabilisation of gypsum-based plaster, a literature review was carried out to identify the materials which have been used most commonly for injection grouting treatment of lime- and/or earthen-based plasters and it was assessed if some of these materials in combination with gypsum could have satisfactory results in the development of a gypsum-based injection grout.

Preliminary laboratory testing showed that a grout with gypsum as the binder as well as a grout with gypsum and the slaked lime as the binder have satisfactory working properties such as: flow (Fig. 3), injectability, shrinkage and hardening time. However, adhesion to the gypsum or stone supports was found to be unsatisfactory. This raised necessity to consider addition of an adhesive. Aqueous dispersion Primal ® B60A was selected for testing and it was found that addition of 2 mL of Primal ® B60A (in a grout where 1 pt/V is 100 mL) increases suficently the adhesion property of the grouts.

Further, such parameters as porosity, capillary water absorption, water vapour diffusion, cohesion and adhesion were assessed. During these tests, *Grout 1* and *Grout 2* (with Primal ® B60A) were tested as well as their counterpart *Mix 1* and *Mix 2* (without Primal ® B60A) to assess the influence of the polymer added to the grouts.

Conclusions

This research aimed to produce a material compatible to the original gypsum-based plaster in the Ateni Sioni church. Although the gypsum-based plaster is the most spread type inside the church, the second most common plaster type is the lime-based. Two grouts (*Grout 1* and *Grout 2*) with a composition similar to the original materials (plasters and the tuff stone primary support) were developed during this research through an extensive laboratory testing and are ready for *in situ* testing.

Bench tests revealed that original gypsum-based plaster is susceptibility towards water and therefore objective was to formulate a grout with the minimal water content. This was successfully achieved by partially substituting the water in the suspension media of the grout with ethyl alcohol. Based on the numerous bench tests it was concluded that the solution of 50% water-50% ethyl alcohol has the most satisfactory results for the grouts developed.

Moreover, the important was to assess the feasibility of the use of gypsum as the binder for the grout. It is well known that gypsum has a rapid hardening time; thus this may be a hindrance for the implementation of an injection grout, which needs to remain fluid during the intervention. However, results obtained for *Grout 1* (gypsum-based) proved that gypsum (in combination with the fillers [Pumice and glass microspheres], an adhesive [Primal ® B60A] and a suspension media [water:ethyl alcohol]) has satisfactory working properties and performance characteristics for its in situ testing and possible implementation. Furthermore, second grout formulation (*Grout 2*) with 50% gypsum and 50% slaked lime used as a binder (in combination with the fillers [Pumice and glass microspheres], an adhesive [Primal ® B60A] and a suspension media [water:ethyl alcohol] showed equally satisfactory results compared to *Grout 1* and can be further tested *in situ*.
Testing did not show any significant differences between the grouts with and without Primal, this is what desirable.

However, it is suggested to undertake another stage of testing of the performance characteristics such as porosity, capillary water absorption, water vapour diffusion and cohesion on the grout specimens after one year aging, for example. This is especially important for *Grout 2* as slaked lime takes longer to set rather than gypsum and thus properties of such specimens containing slaked lime can change over time.