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Characterization of repair mortars for the assessment of their compatibility in restoration projects: Research and practice

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ABSTRACT

Repair mortars used for restoration are assumed to be highly compatible with historic materials in terms of physical, chemical and mechanical properties in order to assure the durability of masonry on the long term. Compatibility criteria are defined based on the original mortar characteristics but the quality and the performance of the repair mortar after application on masonry are not generally evaluated. From this perspective, historic mortars and repair mortars from three historic masonry structures were analyzed in terms of chemical, mineralogical, and physical point of view. A methodology is given taking into account the added value of analytical techniques and the basic requirements from both practical and scientific point of view.

1. Introduction

This article aims at giving feedback related to the overall procedure followed to propose repair mortars and their application in restoration practice. Within the framework of a restoration project, the proposal of a compatible repair mortar often relies on an extensive on site campaign taking samples, followed by a laboratory study aiming at characterizing the original mortar composition. These findings are handed over towards the restoration engineer/architect who outlines the repair mortar recipe within the technical specifications to be used by the contractor.

Seldom, a quantitative verification of the actual composition used within the restoration works is performed. In addition, an overall judgement of the final result often only relies on visual inspection. In this article, compatibility of the repair mortars proposed by laboratory/academic research with those applied subsequently on masonry is assessed. Also, the possibilities and limitations of analytical techniques for mortar characterization are evaluated.

A research campaign was set up to outline the overall methodology used in practice and to seek for the compatibility performance requirements encountered [1]. Three case studies have been treated at which all chains within the procedure are considered in detail. The main findings are outlined in this article. Following steps within the analysis methodology are in common:

- In all case studies, a thorough pre-investigation of the historic mortars was performed by the Reyntjens Laboratory, KULeuven (B) on mortar samples collected from the historical buildings.
- Subsequently a recipe for the repair mortar(s) was proposed, prescribed within the technical specification by the restoration engineer/architect and subsequently applied on site.
- After application of the repair mortar, a 2nd on site campaign was performed to take samples of the repair mortars used and assess their compatibility. Interviews with the parties involved (contractor, architect, engineer) were performed to get full information on their experience and on their opinion on the compatibility performance of the repair mortars used.

In the first place, different performance requirements, which repair mortars should fullfil, have been assessed. What type of compatibility is to be aimed at? How does it relate to the pre-investigation required and performed? Subsequently, the general procedure of the laboratory analyses is presented and discussed. To what extent a compatible mortar recipe can be proposed, what type of compatibility is looked at? Which analytical tools are generally used and what tools can deliver additional and valuable information? Based on the subsequent on site campaign, the apparent differences in between the original and repair mortars are highlighted. Is compatibility achieved? How is it experienced by all parties involved within the restoration project? Based on these findings, an appraisal of the methodology and applied analytical techniques is given.

2. Performance requirements for repair mortars

In restoration works, design and application of a repair mortar that will closely match with the existing historic materials and that can replace the original mortar require an extensive and an elaborated work to be carried out within a complete framework: on site

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investigation and collecting original/historical mortar samples; characterization of the original mortar within its historical context; a damage analysis to retrieve the basic causes for which a repair mortar is to be applied; defining an optimal intervention strategy; formulation of a repair mortar composition based on above conclusions; and application of the repair mortar by suitable workmanship and technology.

Within the choice of a repair mortar, several (general) performance requirements are to be addressed or at least considered, such as: authenticity, reversibility, compatibility, retreatability, function, technology and durability [2–5], Fig. 1. Since these are general, the way in which they are to be considered, is to be judged by the responsible restoration architect for each particular case study in detail. The weight given to some of the requirements however can be crucial for the repair mortar that is proposed and applied in the end.

Within an intervention, the authenticity of the built heritage is to be understood and preserved as much as possible [7–10]. For that the heritage values attributed to the monument can be of various natures, such as: shape, design, materials and substance, use and function, tradition and techniques, workmanship, location and exposition, spirit and senses, and other tangible and intangible features. All of these aspects have on their turn an artistic, historical, social and scientific dimension. As a result, restoration operations should also respect the architectural features capable of transmitting information on intangible cultural values. Characterizing accurately all the values potentially embedded in a heritage structure requires significant effort in historical research, inspection and structural analysis. The Nara-grid can be a useful tool to assess the aspects in all of their dimensions [11,12]. It is clear that mortars have a great impact on the masonry and thus on the overall heritage values in several of the aforementioned aspects and dimensions. Only to consider some of them, shape and design, materials used and workmanship are often addressed as key heritage values.

The minimum intervention principle applies [7,9,10], to enable maximum preservation as possible. For that reason the interventions should aim to be reversible [3,13]. As such, an intervention that a-fortiori is judged to rely on wrong or incomplete information, or on choices that are not in line with preservation concepts of future generations, can be undone. Reversibility is to be aimed at but often is experienced to be an unreachable goal. For that reason, compatibility and retreatability offer a realistic outcome. Compatibility is defined as using materials that do not have negative consequences on the authentic materials. For repair mortars, the applied materials and techniques thus have to, under the given circumstances, fit with the original. As such, attention should go to physical, mechanical, chemical compatibility in between the repair and original mortar [14,15].

Retreatability is to be understood as applying a repair mortar (material and techniques) that does not jeopardizes future treatments. A compatible and retreatable repair mortar thus behaves similar as the original mortar and does not initiate new types of damage, such as for example due to a different freeze-thaw performance.

The mortar can have several functional requirements within the masonry and the masonry within the building [3,13]:

- Ascertain the load bearing capacity of the wall in combination with good seismic performance if applicable.
- Avoid water penetration through the wall.
- Resist different types of environmental influences and processes that act on the wall to protect the building resident from negative external influences.
- Prevent damage due to degradation effects.
- Improve esthetical aspect of the facade.
- Improve the durability of the wall.

In restoration works, these functional requirements are translated into technical requirements by means of material properties and requirements to be fullfilled. As such, following technical requirements can be listed.

- Esthetical: covering color, texture, visual appearance.
- Chemical: related to chemical composition, type of binder, binder/aggregate fraction, hydraulicity.
- Mineralogical: covers mineralogical phases, type of aggregate and binder.
- Physical: frost-resistance, particle size distribution, porosity, water retention.
- Mechanical: strength- and stiffness properties.

Within the intervention strategy different compatibility requirements might be searched for within the above mentioned list, which of course will influence one another to certain extents. An optimal intervention strategy is to be developed for a particular case [3,13]. The mortar recipe in the end is to be judged on the performance requirements outlined for the particular case at hand.

3. Methodology

A systematic approach for the characterization of historic mortars with respect to their repair has been defined by RILEM TC 167 COM which offers a valuable tool to identify mortar components, nature of binder, aggregate, additives, and their relative proportions [2–4]. Following the same approach, the methodology has been adopted to a limited set of tests that enables characterizing repair mortars for consultancy purposes in restoration projects in practice, Fig. 2. Dedicated site work and laboratory work were followed to achieve an effective characterization in terms of textural, physical, chemical, mineralogical and mechanical point of view [16–19].

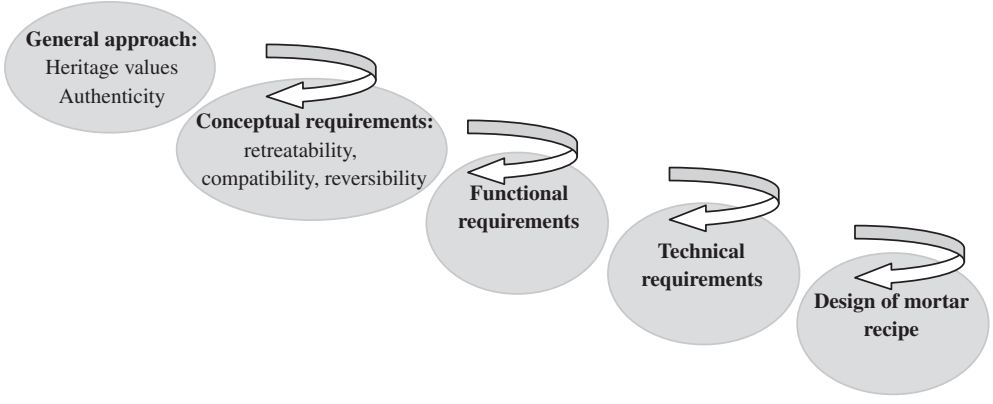

Fig. 1. Different levels/steps within the repair mortar recipe design methodology [6].