TC.09

Performance and Repair Requirements for Surface Repairs

Members of RILEM TC 203-RHM

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Abstract This paper is a summary of a document prepared by RILEM TC 203-RHM on Repair mortars for historic masonry. It deals with requirements for the design of a repair mortar used for surface repairs of architectural surfaces. It considers design issues and requirements for mortar mixes which can be made at the construction site and it focuses on mortar mixes based on lime, lime-pozzolana and cement binding systems.

1 Introduction

Various terms are used, which have the same or very similar meaning to surface repair actions, such as application of plastic repairs, surface fills, loss compensation mortars, and artificial stone mixtures. All these methods have in common that a missing part of an original material is modelled by a new material which is pliable when applied and therefore can be adapted into various shapes and finished with required surface textures. All these repair actions are usually carried out on a small scale, with each particular case approached individually.
The individual approach to each case (modelling a material and/or an architectural detail) is the main difference from other repair actions when mortar is used.

Surface repair is a restoration treatment, where a new material and modern techniques are applied. The General Approach and Conceptual Requirements are set out by the Charter of Venice [1] as the following:

- no conjectural repairs
- efficiency of materials and techniques used for repair should be shown by scientific data and proved by experience
- replacement of missing parts must integrate harmoniously with the whole, but at the same time must be distinguishable from the original (no falsification of the artistic or historic evidence)

Mortar repairs used to replace deteriorated stone units have been in common use for some time and many historic stone buildings contain such repairs. Figs. 1 and 2 show an example of the application of surface repair.

The performance of surface repairs carried out in the past can, after some time of exposure, be evaluated. Fig. 3 demonstrates a repair which can be regarded as successful and Fig. 4 shows a surface repair which in a complex view is not performing satisfactorily any more. There exist also cases where the properties of the new mortar repair caused, along with the specific exposure conditions, accelerated deterioration of original material, which is not acceptable from a cultural heritage preservation point of view.
In order to prevent potential damage to the original material (stone) a compatibility concept has been previously introduced. The technical definition of material compatibility of repair mortars with the original material suggests that no damage should be allowed to the original material within the service life of the repair [2]. The specification of a repair mortar from the technical compatibility point of view is based on a comparison of the properties of the new mortar and the original material. A variety of important characteristics to be compared have been suggested in literature [3, 4] and the compatibility concept has been reviewed by Hughes and Valek [5]. The compatibility requirement is one of the main factors to be considered when a new repair mortar for historic masonry is designed.

It should be recognised that the surface repair technique is often more complex including also treatment of substrate, application of reinforcement and surface finishing techniques. It also has to be acknowledged that various commercial pre-mixed mortar products are available from local and international companies. The advantage of these products lies in their consistent composition and working properties. The disadvantage of these mixes is an uncertainty about the ingredients they contain. A thorough review of the materials and methods has been published by Griswold and Uricheck [6].

This document does not deal with these mixes as they have their own specifications, however, they should, in principle, comply with the functional and performance requirements set generally in this document and their compatibility with the substrate should be evaluated before their application.

2 Pre-design issues

First of all, it is important to decide, whether the use of mortar for repair is the optimal repair action. This decision should be based on a global repair strategy.
Decision factors (based on Ashurst [7]) when considering surface repairs are the following:

- Preservation of more original material than (stone) replacement
- Less disruption of fragile areas of original material
- Avoid removal of structural elements
- Sacrificial performance of mortar should be considered and designed
- Size of areas to be repaired has to be considered
- Visual appearance of mortar repair versus (stone) replacement
- Are there sufficient available skills and knowledge to carry out a high quality repair

3 Design issues

When surface repair is selected as the most suitable repair method then a set of requirements, which the repair action has to fulfil, should be considered. For an historic building, this should follow the general concept of a repair mortar design considering general values, and conceptual, functional and technical requirements [8].

3.1 Design of surface repair mortars – points to be considered

Materials

The use of individual mortar components depends on the type, colour and texture of the material to be reinstated. The final visual appearance imitating or matching the substrate is in many cases the paramount criterion. The selection of a binder (binding system) is a starting point of the mix design as it predetermines the physical and mechanical properties of the mortar mix as well as the capacity of the mix to be adapted to the appropriate form and appearance. Filler and additives can however significantly modify the properties of mortar. Standards (EN, ASTM, BS etc.) specifying individual components for mortars and concretes are available. They may not exactly apply to this specific type of application but should be referred to in general for characterisation of the individual components.

State of substrate and its treatment

Substrate is the material that is being reinstated, usually a part of a masonry unit within a masonry structure. Mortar used for surface repairs without reinforcement has to adhere to the substrate. In this case, the substrate must not be friable and the deteriorated parts have to be cut out. Good adhesion (bond) between the substrate and the repair mortar is commonly presented as one of the main measures of success of repair and its long term durability. However, the bond surface is also the zone, where two different materials have to perform
together (stresses from differential thermal expansion, water and water vapour transports etc). Having a bond strength higher than the tensile strength of the substrate is understood as being incompatible in the case of historic structures [4].

Preparation of repair area
  The stone/brick should be chiselled back to sound material. A minimum depth of approx. 20mm for the repair is required and the edges should not feather out. For masonry units a rectangular shape with the edges parallel to the joints is recommended.

Reinforcement
  A surface repair of thickness above approx. 50mm generally requires reinforcement. Stainless steel and/or non-ferrous metals should be used. Dowels and reinforcement rods should be set back from the mortar’s surface, typically a minimum of 10mm or two bar diameters, in order not to be exposed when the mortar weathers.

Mortar mixing procedures and fresh mortar properties
  A relatively small amount of water is added to obtain the consistency of damp sand. Basic principles of mortar mixing apply also for surface repair mortars.

Application procedures, curing and protection
  Mortar is applied in well pressed and compacted layers around 20mm thick and usually no thicker than 30mm. The final layer is built beyond the surface of the original stone and after reaching initial set it is scraped away and tooled to obtain the required appearance. Curing and protection applies according to the common principles of masonry practice.

Number of layers
  Deeper cavities are filled in several layers in order to reduce the shrinkage and improve the compaction of mortar. Thickness of a layer depends on the consistency of mortar and relates to the size of filler particles. Optimum thickness is around 10-15mm. It has been a common practice that a special thin layer of diluted mortar mixture is applied before the application of the mortar. The mortar is applied directly on the wet layer.

Finishing techniques and coatings
  The appearance of the mortar is related to the approach adopted for the restoration. The colouring can be integral, through the whole mortar layer, which is usually recommended for long lasting repairs.

Quality control
  The surface repair is typically carried out in small batches. Therefore it is possible to pay attention to precise gauging of mortar ingredients and to follow the
specific application procedures. Workmanship, experience and skills are the important factors for successful work. A small initial project with trial panels should be carried out for the proposed mortar mix and repair procedure. The colour and final surface finish has to be agreed in advance and the procedure should be adhered to.

Maintenance plans and consideration of long term durability
Long term performance of the repair should be considered during the design of the repair intervention. Recommendations for regular visual inspection for signs of deterioration should be provided.

3.2 Functional requirements

Aesthetic appearance
- Appropriate colour, texture and final finishing.
- No mortar staining resulting from the application.
- Low risk of lime leaching.

Compatibility with the substrate – no damage to substrate as a condition
- Similar vapour permeability (drying rate) to the substrate.
- Similar thermal and moisture expansion properties to the substrate.
- Mortar should be slightly softer/sacrificial.
- Adequate bond and interface allowing moisture and vapour transport (if needed reinforcement is applied).
- Mortar should release the least possible amount of salts.

Adequate service life
- Careful execution of the work including adequate curing conditions.
- Low risk of cracks development. Low shrinkage.
- Resistance to expected environmental loads. Ageing and weathering should not significantly change the colour and the texture.
- Weathering and deterioration similar to the adjacent materials (e.g. stone).

Reversibility
- Mortar no stronger than needed for durability requirements.
- Adequate bond strength but no stronger than needed.

3.3 Possible failures

- Difficult to match the surface appearance and colour.
- Low durability of final finishing and colouring.
- Problems with incompatibility of original and new material.
• Low quality of work execution (it is a specialized repair requiring experience).
• Inappropriate bond.

4 References