TC.03
Repair Mortars for Historic Masonry. From Problem to Intervention: a decision process

Members of RILEM TC 203-RHM

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Abstract This article focuses on repair or replacement of mortars for historic buildings. With practical situations in mind, both the decision process and questions arising are dealt with in order to better define and illustrate technical requirements for mortars to be used for the repair or restoration (masonry mortars, plasters, renders). This article summarizes a document, meant to help professionals in their decisions on interventions, taking into account aspects ranging from the ethics of restoration to technical requirements.

1 Introduction

For those responsible for the execution of a restoration project, technical problems are only a part of the task that has to be dealt with. Redesign and re-use, i.e. the transformation of historic buildings, in order to meet present needs may be the main challenge for the architect. However, at the same time be aware that aspects like authenticity, conceptual, and functional requirements represent questions that have to be answered as well. In fact the architect, engineer or conservation specialist is going through a continuous process of decision-making during the realization of a restoration project.
Given the complexity of many restoration projects, it is considered important that all involved disciplines cooperate and arrive at well balanced decisions. Here a guideline is proposed that deals with these decisions in a logical way.

When dealing with the conservation of monuments and historic buildings, including replacement and restoration of historic mortars, decisions should be made from several points of view. Therefore a complete framework was proposed by RILEM TC 167- COM [1], ranging from the (more abstract) philosophical and authenticity questions to the (practical) mix design as a basis for the description of functional and technical requirements for repair mortars.

2 Assessment of the state of conservation

In the practical situation of a restoration, an assessment of the state of conservation of the building or construction concerned is the first and necessary step for defining the problem to be solved. This step also includes the decision on which investigations have to be performed.

After the assessment, major decisions have to be made:

Theoretically, two directions could be followed for the intervention, i.e. for the choice of the repair mortar:

• a mortar based on authentic materials (that theoretically might be the most compatible solution);
• a mortar that is inherently durable.

The historical assessment and the value assessment of the building should include past interventions. Their possible (historical) value should also be taken into consideration.

The assessment of the state of conservation (technical assessment), includes [2]:

• damage assessment
• exposure conditions
• description and identification of materials
• diagnosis

In addition several decisions are necessary:

• on the (technical) requirements for the mortar mix
• on suitable raw materials (salt content, pozzolanicity, reactivity, …)

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1 In what follows, reference will be made to the materials issues only. Structural issues or issues of morphological restoration are not considered here.

2 Compatible is defined as: not causing any damage (in a broad sense, ranging from technical to aesthetical and historical) to the existing fabric and being as durable as possible under that condition
Table 1 Survey and interventions in historic buildings: steps to be taken

Assessment and documentation of heritage significance & state of conservation
Historical assessment
Technical assessment
Location, extent of different damaged building parts (show in plan of building)

Analysis and diagnosis of degradation phenomena
- Analysis and diagnosis of damages (e.g. by NDT methods)
- Assess properties existing mortar and masonry units (and masonry)
- Monitoring of degradation and damage
- Risk analysis related to environmental influences (earthquake, flood, storm, fire, …)

Compatible (and as durable as possible) intervention and strengthening
- Decide on concept: balance compatibility <=> durability
- Quality assurance of intervention and risk assessment
- Assess technical requirements / decide on composition / make trial mixes
- Plan side measures

Plan future maintenance activities and monitoring of the state of conservation

Finally, sound documentation of all decisions made is of utmost importance, not only for the particular structure, but also as a basis for future knowledge development.

3 Functional (design) issues, exposure and specific threats

Functional (or design) requirements are a set of qualitative imperatives that should be defined on the basis of the historical and technical assessment of the structure. They provide a rational basis for the choice of the raw materials and compositions to be used and the tests to be carried out. Requirements for a repair mortar are based upon its function inside the structure and its exposure or on specific threats it may be subjected to. Each of those issues provides a set of different requirements. The aim here is to describe how to arrive at the definition of those requirements in a concise way.

Function of a mortar
The main functional applications of a mortar can be categorised as: bedding, pointing, infill, render, plaster, and stone repair.
Exposure

Masonry, and therefore the mortar that is part of it, can be exposed to (environmental) conditions of varying severity, e.g. driving rain, freeze–thaw cycles or sea spray, or to a high permanent load and/or dynamic action, e.g. dead load, soil settlements, traffic or earthquakes.

Specific threats

A repair mortar, especially in historic masonry, may also be subjected to specific threats that should be dealt with, although the compatibility with the existing fabric should be given priority. These threats can derive from, for example, the presence of salts and/or rising damp, the presence of biological growth, use of frost sensitive materials, or human behaviour.

Damage can be classified according to its origin, i.e. chemical, physical or mechanical (Fig. 1).

Set of simple recommendations for repair mortars

In general, the following aspects have to be taken into account:

- existing mortar and masonry
- surrounding materials and structure
- environment
- costs
The mortar should be made as workable and durable as possible (taking into account compatibility). The following aspects need a decision (keeping in mind the needed strength and stiffness):

- Binder and aggregate type
- Binder / aggregate ratio
- Additives
- Colour
- Porosity and pore size distribution
- Water absorption and drying behaviour

4 Frequently asked questions

Practical problems are described in terms of frequently asked questions, which are as much as possible answered in a general way. Both general questions and particular problems due to exposure or special threats are dealt with. This paper gives just one example of these questions. A description of the cause(s) of the problem is given, together with the possible mechanism that may have resulted in the observed damage. Then, a possible composition of the proposed repair mortar is given, and a description of how this mortar reduces the risk of new damage.

*Which mortar composition is best to deal with sea salts?*

The presence of sea salts in mortars may be the result of different events or conditions: direct contact in case of buildings constructed in seawater or subjected to flooding, deposit of sea salt in the form of aerosol on the surface; the salt may also be present due to the use of unwashed sand from the beach or even from the use of seawater in mortar preparation.

Damage to mortars (pointing, plaster or render) due to sea salts generally shows up as sanding or powdering or as a kind of pitting.

*Fig. 2* Examples of the damaging effects of sea salts on respectively masonry and in lime mortar joints (pitting in the pointing mortar).
In lime pointing the damage (pitting) concentrates in the centre of the joints; re-pointing either with lime or cement mortars leads to the formation of voids at the brick (stone) mortar interface, where the salt present in the masonry units may quickly and in considerable amounts contaminate the mortar. In plasters or renders, pitting may occur, but also phenomena such as exfoliation and loss of adhesion between plaster and substrate.

The damage can be considered mainly the result of a physical process (cycles of crystallisation and dissolution); a chemical process (chemical transformation of calcite and sodium chloride into easily soluble calcium chloride), is considered less probable.

Traditionally lime-pozzolan-sand mortars were used under these conditions (for example 1:1:4 or 1:0.5:2.5 by volume).

**Repair**

For interventions, repair mortars in principle should be sacrificial, i.e. help protect the surrounding brick or stone from decay.

Lime-pozzolan-sand, lime-pozzolan-cement-sand, cement-pozzolan-sand, or hydraulic lime-sand can be used as repair mortars for masonry that was originally constructed with mortars on the basis of lime, lime-pozzolan or hydraulic lime. Examples of mortars used for renders can be found in [3]. In order to limit the risk of the repair mortar being too strong and stiff with respect to the strength of the brick or stone, and in order to create internal space for the salts, the use of an air entraining agent could be considered.

The addition of natural polymers (for example linseed oil; 2% of the binder weight) seems also to contribute to the mortar’s resistance to the penetration of new sea salts [4].

**References**