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Repointing Mortars for Older Masonry Buildings– Design Considerations

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Permanent damage to older masonry walls and premature failure of repointing work can result from improper selection and application of repointing mortars. This Update describes key design elements for achieving successful repointing of masonry walls to provide a longer service life for both the masonry units and the mortar.

This Update should be read in conjunction with Update No. 68, Repointing Mortars for Older Masonry Buildings—Site Considerations.

Traditional masonry buildings built from the 19th Century to about 1940 make up much of the inventory of older buildings in Canada. Churches, hospitals, museums, courthouses, university buildings, government offices, industrial warehouses as well as apartment buildings are common examples of this type of construction (Figure 1).

Figure 1. The Connaught Building in Ottawa, built in 1913-14, is clad with Nepean and Wallace sandstone, with granite at grade.

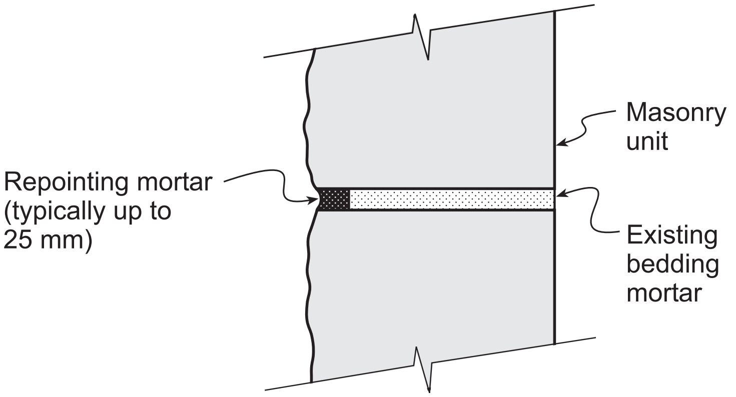

Figure 2. Repointing involves removing the outer damaged layer of mortar and replacing it with new mortar.

The masonry in older buildings will eventually require conservation work to extend the service life. The repointing of mortar joints (Figure 2) is generally undertaken as part of a regular maintenance or rehabilitation program to restore the ability of the masonry to control water ingress and preserve its historical authenticity.

Risks Related to Repointing Work

Everything about the repointing process—from preparation of the joints, selecting the mortar mix, installing the mortar, and curing conditions—can have a permanent effect on the visual and functional integrity of a historic building. Improperly done, the repointing can detract from the appearance of the masonry and lead to premature deterioration of the mortar and the masonry. Common types of damage are:

- Chipping or sawcuts on the edges of the masonry units caused during the raking of the joint prior to repointing, particularly when power tools are used. This will result in a widening of the joints and damaging of the masonry.
- Discolouration of the masonry units caused by lime leaching from fresh lime-based mortar that has not been protected from rain during early stages of curing.
- Disfigurement of the masonry façade due to a poor match of colour, texture and tool finish of the mortar joints.
- Erosion of the edges of soft masonry units resulting from the use of a hard (more impermeable) mortar.
- Erosion and spalling of the mortar resulting from insufficient freeze-thaw resistance and poor water management detailing on the façade (Figure 3).

Figure 3. Damage from frost and salt results in erosion of the mortar.

Before Proceeding

Before considering repointing work, it is important to do an evaluation of the structural integrity and condition of the masonry walls and the foundations. A building condition survey will assist the designers to achieve a thorough understanding of its performance over time, any alterations over its lifetime and the reasons for any damage. It will also provide a historical perspective on the heritage character of the building. This will ensure that repairs, maintenance and conservation work can be planned and carried out for best results.

All elements of a building envelope do not get exposed to the same environmental loads. Walls near grade may be exposed to de-icing salts used on sidewalks and roadways. Chimneys and decorative horizontal projections at windows and parapets are often exposed to severe environmental loads, melting snow and freeze-thaw action. An assessment of the types of loads the different areas of the masonry are exposed to will be valuable in the selection of mortar properties suitable for particular applications. Corrective interventions to reduce the moisture loads on masonry elements can greatly assist in extending service life.

Masonry conservation and repointing of older masonry buildings, often of heritage value, is a relatively new field in Canada and not all design professionals possess the knowledge and experience needed for this specialized work. For more important buildings, the design team should consider engaging a masonry conservation specialist to assist with issues of historic authenticity, specifications for mortar mixes and application, quality control and curing, as well as appropriate laboratory and on-site testing to support decisions.

Selection and Design of Mortar Mixes

A repointing mortar should be 1) compatible with the properties of the masonry units and the original mortar; 2) resistant to agents of deterioration likely to cause premature failure (e.g., frost action); and 3) compatible with the heritage character of the building.

> A single mortar mix suitable for all types of masonry assemblies and all Canadian climatic conditions does not exist. In fact, more than one mix may be used on a single project to address different masonry and environmental loading characteristics.

The following guidelines on compatibility of repointing mortars with the existing assembly are for the most part qualitative in nature; only when more research data and field experience are available can quantitative guidelines be given.

Compressive strength. The compressive strength of the repointing mortar should be lower than that of the existing masonry units, and similar to or lower than that of the existing bedding mortar. The intuitive approach of "the stronger the better" can lead to spalling of the masonry units or shortened mortar service life. Specifications for compressive strength should therefore include an *upper* as well as a lower limit. A lower-strength mortar will tend to be "soft" or more flexible, a property that permits it to respond to small amounts of differential movement without cracking. Low-strength mortars are referred to as "sacrificial"; they will absorb the stress of the assembly and experience the potential resulting damage, protecting the masonry units themselves from damage. In the spirit of sustainability and reversibility, weaker mortars will also be easier to remove in future maintenance and repair.

Wetting and drying potential. Repointing mortar should exhibit water absorption and vapour transmission rates similar to or greater than those of the bedding mortar and masonry units. A more permeable mortar will promote drying at the joints, a mechanism quite useful for avoiding moisture accumulation in the masonry (especially in buildings with dense masonry units). As well, any salts in the masonry will tend to migrate out through the mortar instead of the masonry units.

Bond. Full contact between the repointing mortar and the masonry units and bedding mortar (good bond, not necessarily strong) will reduce water ingress into the joint, a key factor in reducing the risk of frost damage. Well-graded, washed sand, with no clay fines (conforming to CSA A179), a low water-to-binder ratio and a low proportion of cement in the mix tend to reduce the potential for mortar shrinkage and crack formation. Mortars with higher lime content are softer and more flexible, thereby reducing the risk of cracks developing. On-site conditions such as cleaning of the joints, mortar compaction and curing also affect bond characteristics.

Appearance. Texture and colour of the repointing mortar should be matched to a reference mortar as required for historic authenticity and aesthetics. Sand, the main ingredient in mortar, contributes most to colour and texture. In some cases, pigments are added; these should be inorganic oxides and the proportion added should not alter the properties of the mortar significantly (no more than 10 per cent by weight of the dry binder).

Resistance to frost action. Most regions in Canada are subjected to significant freeze-thaw action (temperature fluctuations about the freezing point). Combined with wetting, freeze-thaw action can cause spalling and crumbling of the mortar. Typically, chimneys, parapets, freestanding walls, window sills, exterior steps and pavement, and masonry below or at ground level are most exposed to extreme wetting. A design approach that combines improved freeze-thaw resistance of the mortars with effective detailing to avoid water saturation of these masonry elements when practical, can improve the service life of the mortars as well as that of the masonry units. Adding an air-entraining agent to the mortar mix can improve frost resistance and workability. Preferably this additive should be premixed into one of the mortar ingredients to avoid errors on site (e.g., SA hydrated lime is Type S lime with an air-entraining agent). Other factors include adequate bond to minimize water ingress into the joint. Laboratory testing of freeze-thaw resistance of small-scale masonry specimens can provide useful data on the performance of different mortar mixes applied to specific masonry units.

Resistance to salts (e.g., chlorides and sulphates). A common problem is the migration of de-icing salts into masonry adjacent to roads and streets. The salts can be absorbed by the masonry units (depending on their porosity), after which they crystallize and expand when the masonry dries, resulting in damage. The best approach is to protect the masonry from de-icing salts. For masonry already containing high levels of salts, such as sulphates or chlorides, mortars should be assessed beforehand. If Portland cement is used in the mortar it should be sulphate resistant.

Typical Mortar Mixes

Mortar mixes are defined by the binder in the mix: (hydrated) lime mortars, hydraulic lime mortars and cement/lime mortars. The current industry standard is to express a mortar mix in terms of the volume of the main ingredients. For instance a 1:2:9 mix will contain 1 volume of cement, 2 volumes of lime and 9 volumes of sand. The ingredients can be mixed on site or obtained as a pre-mix (either proprietary or as specified for the project). Table 1 presents information on the different types of mortar used in restoration today. The information should be considered in the context of the mortar properties discussed above in order to specify an appropriate mix. Typical mix proportions for cement/lime mortars can be found in CSA standard A179.

Binders can be classified as follows: *1) Air hardening binders* (e.g., lime putty and hydrated lime) gain strength by reaction with carbonic acid derived from carbon dioxide and moisture in the air—a very slow process called carbonation; *2) Air and hydraulic hardening binders* (e.g., hydraulic lime [clay impurities present in the raw limestone give the lime its hydraulic property] and hydrated lime with pozzolan additives) gain strength by reaction with carbon dioxide as well as directly with water; *3) Hydraulic binders* (e.g., Portland cement, masonry cement and mortar cement) gain nearly all their strength by reaction with water.

Pre-construction testing can assist the designer in determining a suitable mortar mix and/or in analyzing the characteristics of the existing mortar. Analysis of existing mortar samples can provide a benchmark for selecting a compatible new repointing mortar. Compressive strength, sand grading and flexural bond strength can be determined using standard tests (see CSA A179). Frost resistance can be evaluated if the size of the project warrants a detailed investigation. A uni-directional freeze-thaw test procedure is recommended to best represent the service conditions of the masonry.

Site Practices and Maintenance

The best mortar mix for the job may perform poorly because of inadequate execution and curing practices. Site supervision is critical as lower strength mortars are less forgiving of poor construction practices than mortars used in modern masonry. The designer should provide the building owner/manager with a program for regular inspection and maintenance following completion of the work. Construction Technology Update No. 68 presents key on-site considerations.

Table 1. General characteristics of mortar mixes

	Lime mortar	Hydraulic lime mortar	Portland cement-lime mortars*
Composition	Hydrated lime (powder) or lime putty and sand in a 1:2-3 mix	Hydraulic lime and sand in a 1:2-3 mix.	Type N: 1:1:5-6 Type O: 1:2:8-9 Type K: 1:3:10-12 (see CSA A179 standards – annex A)
Properties	• Gains strength by reaction with carbon dioxide and moisture in the air • Low compressive strength (0.5-2 MPa) • High vapour and water transmission properties • Capability for self-healing of fine cracks • Very flexible and soft. Can accommodate small movements without cracking • Low shrinkage	• Gains strength by reaction with carbon dioxide as well as directly with water • Hydraulic limes can be feebly, moderately or eminently hydraulic • Broad range of compressive strength (1-10 MPa) • Gains strength at a faster rate than lime-sand mortars, but at a much lower rate than Portland cement-based mixes • Properties of mixes can vary widely between different manufacturers of hydraulic lime	• Gains nearly all strength by reaction with water • Faster rate of strength gain • Broad range of compressive strength (2-15 MPa) • A mix richer in Portland cement will exhibit higher compressive strength, more shrinkage, lower vapour transmission, and lower workability than a mix rich in lime
Uses	• Sheltered areas with low exposure to wetting and frost action • Locations where lime mortar provided satisfactory performance previously, assuming environment has not changed	• Experience and research gained on a few historic properties in Canada showed they can exhibit adequate frost resistance in moderate exposure when site quality control is rigorous.	• Considerable experience and research in Canada indicate that a Type O mortar with an air-entraining agent (compressive strength of 3-9 MPa) can provide satisfactory performance in a broad range of conditions.
Cautions	• Gains strength very slowly • Low initial frost resistance • Controlled curing is essential for performance and to prevent leaching of lime and staining of masonry. • A given volume of lime putty contains significantly more lime than the same volume of hydrated lime.	• Gains strength slowly • Little documented performance in Canadian climate • Involvement of a masonry conservation specialist is recommended. • Quality control on the execution and curing must be rigorous.	• Can result in too high a compressive strength for the hardness of the masonry units, resulting in damage to the units. • Where historic authenticity is important these mortars may not be appropriate.

* An alternative to Portland cement/lime is masonry or mortar cement often used in modern masonry construction (these already incorporate an air-entraining agent). Conservation practitioners who want to know all the ingredients in their mortar mixes do not use them because the ingredients are proprietary and are subject to change.

Summary

- Repointing older masonry carries risks of permanent damage to the masonry units, but when properly done it can restore the aesthetics of the façade and improve the weather resistance of the building.
- The properties of the repointing mortar should be compatible with the existing masonry units and bedding mortar while still displaying reasonable durability. The mortar mix of a previous repair should not be replicated without an assessment.
- No single mortar mix fits all needs. The mix must be adapted to the masonry units (e.g., strength and bond) and to the severity of the environmental loads specific to the project; hence the importance of exhaustive pre-design condition surveys and reviews.
- Low-strength mortars are less forgiving of poor execution and curing than mortars used in modern masonry and this needs to be accounted for in every step of the process, from design and specification of the mix to quality control on site.

Supplementary Reading

Maurenbrecher, A.H.P., Trischuk, K., Rousseau, M.Z., Subercaseaux, M.I., Repointing Mortars for Older Masonry Buildings – Site Considerations, Construction Technology Update No. 68, Institute for Research in Construction National Research Council of Canada, March 2008.

Maurenbrecher, A.H.P., Trischuk, K., Rousseau, M.Z., Subercaseaux, M.I., Key Considerations for Repointing Mortars for Conservation of Older Masonry, Research Report 225, Institute for Research in Construction, National Research Council of Canada, Jan. 2007. http://irc.nrc-cnrc.gc.ca/pubs/rr/rr225/index.php?lang=e

Maurenbrecher, A.H.P., Water-shedding Details Improve Masonry Performance, Construction Technology Update No. 23, Institute for Research in Construction, National Research Council of Canada, Dec. 1998. http://irc.nrc-cnrc.gc.ca/pubs/ctus/23_e.html

CSA standard A179-04 Mortar and Grout for Unit Masonry, Canadian Standards Association, 2004. The standard focuses on modern masonry mortars but Annex A discusses mortars for older masonry.

The masonry Web site of the NRC Institute for Research in Construction provides further information about repointing mortars and links to other Web sites: http://irc.nrc-cnrc.gc.ca/bes/hmpe/masonry/index_e.html

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