

REVIEW OF FACTORS AFFECTING THE DURABILITY OF REPOINTING MORTARS FOR OLDER MASONRY

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ABSTRACT

In older masonry structures, the mortar properties need to be compatible with the existing mortars and be “sacrificial” to the masonry. Inappropriate repointing materials and execution practices can result in permanent damage to older masonry assemblies, affecting their aesthetics qualities, historical value, performance, and service life. Public Works and Government Services Canada (PWGSC), which is faced with the maintenance and refurbishing of the Canadian government’s older building stock, including the Parliament buildings, has been grappling with this problem for years. PWGSC and the National Research Council of Canada’s Institute for Research in Construction (NRC-IRC) have carried out considerable research in the last two decades to evaluate mortar mixes properties for application in cold climates susceptible to freeze-thaw action and salt damage. This paper will describe critical elements of mix selection, on-site execution, and curing to obtain a durable mortar that has no detrimental effects on the masonry.

SPEAKER

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Madeleine Rousseau is an architect with 25 years experience in the area of moisture migration in exterior walls at the National Research Council Canada (NRC). For the last 10 years, Madeleine has participated in NRC research for durable repointing mortars that do not have a detrimental effect on older masonry, in the context of cold climates experiencing freeze-thaw action. In 1998, Madeleine also initiated a multi-disciplinary forum of masonry restoration specialists aimed at enhancing exchange of technical information on repointing mortar technologies. The working group, made up of trades, design professionals, building owners and managers, and manufacturers involved in masonry repointing work, has met twice a year since 1998.

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INTRODUCTION

The selection of repointing mortars for older masonry in cold climates is a subject of debate. Standards for modern masonry construction are not necessarily appropriate for the needs of older masonry structures, which can have unique performance requirements. As such, determining an appropriate mortar mix to use in the repair of masonry buildings can be a challenge. Repointing mortars should be durable, practical in application (e.g., workmanship and quality control), and not have a negative effect on the durability of the existing masonry. Durability is not only dependent on the mortar mix used, but also on how it is installed and cured (workmanship) and on the severity of the environmental exposure, which in turn depends on weather, design, construction, operation, and maintenance.

Public Works and Government Services Canada - Heritage Conservation Directorate (PWGSC - HCD) is responsible for the maintenance and repair of a considerable number of older masonry buildings, including the Parliamentary Precinct in Ottawa (*Figure 1*). For the past two decades, PWGSC-HCD has teamed up with NRC-IRC to carry out research projects which will help to define performance objectives of repointing mortars and assess a variety of mortar mixes in order to determine appropriate mixes for use in the repair of older masonry buildings. This ongoing work has been carried out to help fill a need for clear performance objectives for repointing mortars so that an appropriate repointing mortar can be chosen for a particular building. Performance objectives then need to be translated into set criteria that in many cases are still a subject of debate and research.

This paper reviews literature dealing with the selection and performance of mortars used in the repair of older masonry. Particular emphasis is given to factors affecting the resistance to freeze-thaw damage, a major consideration in a cold climate. Examples from Parliament Hill in Ottawa will be given as illustration of the text. (See *Figure 1*.)

WHAT IS REPOINTING MORTAR?

Repointing mortars replace the outer deteriorated or damaged mortar in masonry joints. The deteriorated mortar needs to be carefully removed without damaging the masonry units. The resulting gap is then cleaned and filled (repointed) with a compatible repair mortar to stop further deterioration and water penetration (*Figure 2*). Repointing mortar mixes are drier and stiffer than bedding mortars to reduce shrinkage and avoid staining of the masonry. For the repair of older brick and stone masonry walls, there is an increasing use of traditional mortar mixes, largely driven by the wish to have compatibility with the original mortar used and the existing bedding mortar (from historic, aesthetic, and material property perspectives). Modern, higher-

strength mortars are often not appropriate and may cause damage.

Challenges to mortar selection include:

- Original mortar materials are no longer available.
- Difficulty in determining the exact composition and properties of the existing mortar.
- Issues of historic authenticity.
- Lack of trades specializing in old materials and techniques. Many of the materials and techniques for producing and applying traditional mortars were lost and substitutes may have to be found and techniques learned again.
- Little published information on the performance of traditional mortars in the Canadian climate.



Figure 1 – The Center Block of Parliament Hill in Ottawa, Canada.

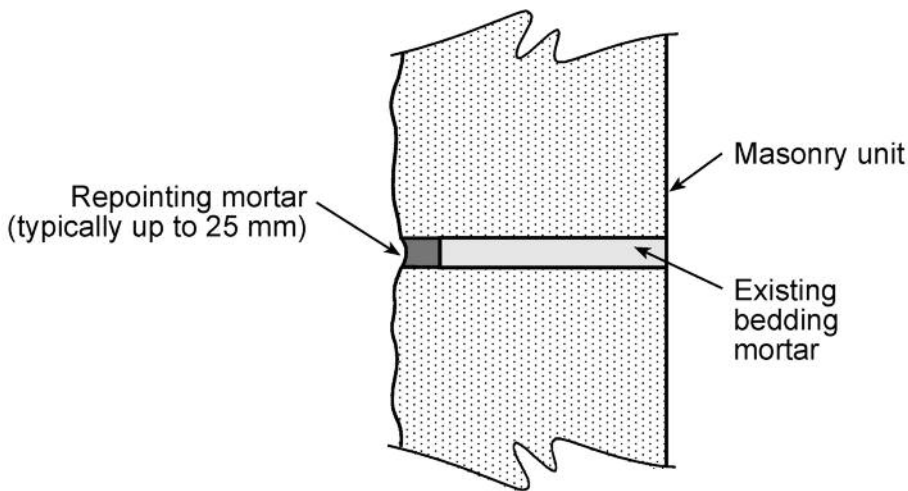


Figure 2 – Example of a mortar joint with repointing mortar.

- Traditional mortars, usually weaker than modern mortars, are less forgiving of poor construction practices; good quality control and site supervision are needed to ensure success.
- Difficulty in correlating laboratory tests to actual field exposure conditions.
- Few standards on use and testing of traditional mortar mixes. Modern standards have often deleted reference to older mortars but this trend is beginning to reverse.

Mortars are basically composed of a binder, aggregate (sand), water, and additives. Traditional mortars usually have lime as the major component of the binder. Today, many restoration mortars have a cement/lime binder – usually with more lime than cement. There is also increasing interest in the use of pure lime mortars, hydraulic lime mortars, and proprietary pre-mix mortars to which only water needs to be added. In contrast, binders for modern mortars have cement as the major component with either lime added in equal or less proportion, or with proprietary additives (e.g., masonry cement).

POSSIBLE FORMS OF FAILURE

Potential problems with mortar include spalling, crumbling, efflorescence, biological growth, and cracking (within the mortar

and at the mortar/unit interface). These, in turn, are caused by frost action, salt crystallization (sulphates and chlorides – *Figure 3*), movement (settlement, differential, thermal, and moisture), dissolution, environmental pollution (acid rain), water migration (*Figure 4*), and biological attack in wet areas of the building.

Moisture is the environmental factor commonly associated with most of these problems, although temperature also has a significant influence on the rate and extent of damage caused by the moisture. Temperature and moisture also directly affect expansion and contraction movements in the masonry. Mortar can also cause problems for the masonry units such as lime leaching out of the mortar causing staining (*Figure 5*) or spalling with too strong a pointing mortar.

Traditional mortars with high lime content have more initial flexibility and higher porosity than modern mortars, and hence, they can better accommodate minor movements in the wall without cracking. Cracks lead to increased ingress of water into the



Figure 3 – Salt damage to stone and mortar is apparent beside an entryway where salt is used to remove ice in the winter.

Below: Figure 4 – Water-shedding details deflect water off the upper surface of the masonry. Unfortunately, the water is deflected onto lower surfaces.



masonry that in turn affects durability. If cracks do occur, they are more likely to occur along the weaker mortar joints and not through the masonry units (this is preferable, simply because it is easier and cheaper to repoint mortar joints than to repair or replace damaged brick or stone). Fine cracks may reseal due to redeposition of lime within the crack.

DURABLE REPOINTING

Repointing mortars should be as durable as possible without causing damage to the existing masonry (a dense mortar could retard the drying of the masonry assembly and cause frost or salt crystallization damage in the bedding mortar or masonry units). It is preferable to repoint mortar joints at more frequent intervals than to have to repair damaged masonry units. A building and its components should be durable enough to perform the required functions in its service environment over the design service life without unforeseen cost for maintenance or repair (CSA 1995). The design service life for masonry is usually 50 to 100 years. A normal expectation for pointing mortar is at least 30 years, but preferably 50 to 100 years (Mack & Speweik 1998). If a weak mix is required in more exposed areas, weathering of the mortar and more frequent repointing should be accepted as part of the maintenance of the masonry (BBA 1999).

The durability of mortar not only depends on the materials used, but on how they are installed and cured (workmanship) and on the severity of the exposure, which in turn depends on the local climate, design, construction, operation, and maintenance (Figure 6).

SEVERITY OF THE ENVIRONMENT

Mortar selection must take into account the severity of the environment in which it



Figure 5 - Lime leached out of the mortar joints onto the masonry surface leaves an unsightly stain. Had the lime had chance to carbonate before being exposed to the weather, this might not have occurred.

will be used. The severity of the environment depends both on the local weather and the exposure of the masonry elements. For example, relatively weak mortars can survive well in freezing climates, provided they are protected from excessive moisture (mortar in a wall protected by a roof over-

(Maurenbrecher, 1998). Melted water from snow is a major cause of frost damage in freezing climates (snow melt during the day is absorbed by the masonry underneath, which freezes at night; this cycle may be kept up for many days). Cracks, including hairline cracks at the mortar masonry unit

hang has less risk of damage than mortar in a chimney).

North America has a large climatic diversity. Climates vary from hot summers to cold winters. In winter, some areas can be cold and relatively dry, while others have large amounts of precipitation. Regions with more precipitation (snow and rain) and many freeze-thaw cycles are more severe for the masonry than regions that tend to stay cold or mild over the entire winter. Building orientation affects the local climate (e.g., prevailing driving rain and solar radiation). Not much can be done about the weather, but the design of the building, especially building details, can have a large influence on the local environment experienced by the masonry.

Attention to water-shedding architectural features, including their maintenance, will reduce the risk of occurrence of high moisture levels needed for frost damage

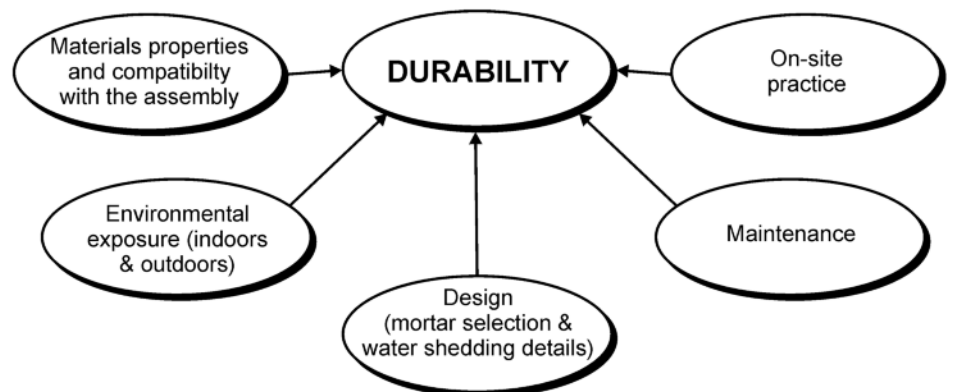


Figure 6 - Factors affecting durability.

interface, will also allow increased water ingress. This highlights the need for regular maintenance and attention to shrinkage and bonding properties of pointing mortars.

Moisture can also come from inside the building. For example, in cold weather, air exfiltration of indoor air of humidified buildings can lead to interstitial condensation in localized areas of the masonry assembly (based on the path and exit locations of the air). In addition to the risks associated with high moisture levels within the masonry, the subsequent outward drying of the moisture may carry efflorescence salts to the surface.

MATERIAL CHARACTERISTICS

Without going in detail about the characteristics of the materials that make mortars, here is a discussion of important elements that can affect the site execution as well as the in-service performance.

SAND

Sand is generally selected by what is locally available and what color and texture are desired for the mortar, but sand cleanliness, grading, and particle shape should also be considered, for they can have an important influence on overall durability.

Sand is normally made up of particles with a range of sizes, the smaller sizes filling in spaces between the larger sizes. In well-graded sands, the void space left over is assumed to be about one-third of the sand volume (the space varies depending on the sand particle shape and grading). Enough binder paste is then added to fill this void and provide a film between the sand particles to give the fresh mortar plasticity. This explains the binder to the aggregate ratio of 1:3 seen in most specifications. This ratio will vary, depending on the grading and particle shape, and on the binder. Mortar with too little binder will have poor water retention and workability, while too much binder will lead to higher strengths, increased shrinkage, and risk of cracks.

The effect of sand grading on durability needs further investigation. Coarser sand gradings for pointing mortars in modern masonry improved frost resistance (Elsen et al., 1993). Grading also influences mortar shrinkage and the bond between mortar and masonry units.

Sands can come from natural deposits or are manufactured by crushing stone. In general, crushed sand is considered most angular (sharpest), while quarry sands vary from a semi-angular to rounded shape.

Historic Scotland (1995) recommends sharp sand with a balanced range of particle shapes (coarse sand is also referred to as sharp). Although sharper sand makes the mix less workable, it provides more interlocking between particles, reducing shrinkage. On the other hand, Mack & Speweik (1998) recommend rounded sand particles because they give the mortar better plasticity, making it easier to compact into the joint. Rounded sand was often used in historic mortars. The easier compaction makes it more likely the joint is filled properly (good contact between the pointing mortar and the existing bedding mortar improves moisture transfer and durability). The need for less pressure to fill the joint is also preferable from the mason's point of view, reducing the risk of repetitive strain injury.

The moisture content of the sand affects its volume. Damp sand (2-6% water moisture content) occupies more volume than dry sand. A mix based on damp sand would likely be stronger and potentially experience more shrinkage than a mix with the same proportions of ingredients using dry sand. Consequently accounting for this property, it is good practice for the mortar mix designer/specifier to review and possibly adjust the mortar mix recipe the first day of mortar mixing (as well as regularly afterwards, depending on the weather conditions (e.g., heat spells), once the dampness of the sand available on site is defined (usually with a test consisting of drying the sand in an oven). Trial mortars are mixed with an effort to define the quantity of water to be used depending on the aggregate that will be used on site. North American mortar standards (ASTM 2006 and CSA 2004) refer to damp sand because that is usually the condition of sand on building sites.

Crushed limestone, crushed low-fired brick, and expanded vermiculite materials are among other aggregates which are sometimes added to mortar (Historic Scotland, 1995); however, these materials may have different water absorption rates than sand and this must be taken into consideration.

BINDERS

The most common binders in mortar are lime and Portland cement. Lime is obtained from limestone (CaCO_3) when it is burned at 900°C to drive off the carbon dioxide (CO_2), resulting in quicklime CaO . (Lime is also obtained from magnesium and dolomitic limestone; dolomitic contains 35 to 46% MgCO_3 , common in North America.) Water is

added to the quicklime to produce lime putty or, in modern production, a dry, hydrated lime powder, $\text{Ca}(\text{OH})_2$. Lime in a mortar mix hardens by carbonation; the lime recombines with CO_2 in the air and reverts back to limestone (to harden, lime mortars need access to both air and moisture). Lime mortars take much longer to gain strength than Portland cement-based mortars. Pozzolanic additives can be added to the mortar; these react directly with lime and water, allowing part of the lime to harden faster without the need for carbon dioxide from the air (hydraulic property).

In the late 1700s, it was discovered that burning limestone with clay impurities resulted in limes, which could also gain some of their strength by reacting directly with water (hydraulic limes). This also required increased firing temperatures (up to 1250°C). Hydraulic limes range from weakly hydraulic to eminently hydraulic (they are still made in Europe and by one manufacturer in the U.S.).

Further increases in clay content and firing temperatures resulted first in natural cements, and finally, Portland cement (named after its resemblance to Portland limestone). Portland cements require a firing temperature of around 1450°C . They gain nearly all their strength by reaction with water. Mortars using these cements are stronger and gain their strength more rapidly which also meant construction could proceed faster. As binders become more hydraulic, mortars made using them become denser and less porous. They are therefore better at keeping water out, but should water get into the masonry, it will also take much longer to dry out. Portland cements come in a variety of types (normal, white, and sulphate-resistant Portland cements). Portland cement-based masonry cements have been used in pointing mortars in Canada.

Hydrated lime powder from different manufacturers can have different bulk densities (largely due to particle size). Thus, volume batching results in different weights of lime. The finer the lime, the less weight for a given volume. Will the lower weight of the finer lime still provide the same workability to the mix because of the increased fineness? On the other hand, will the long-term strength of the mortar be less because of the lower weight of lime? In the case of lime putty, it usually contains more lime than an equivalent volume of dry, hydrated lime. Lime putties made from hydrated limes from different manufacturers were found to

have 16 to 56% more lime than the equivalent volume of dry, hydrated lime (Phillips 1994, Maurenbrecher et al., 2000). If no attention is paid to these aspects, the quantity of lime in a mortar can vary, leading to mortars with differing properties. The significance of these must be resolved.

Ingredients may also be added to the mortar to change its color or improve workability, water retentiveness, water repellancy, bonding with masonry units, and frost resistance. Additives are usually discouraged in restoration mortars, except for pigments for color and air-entraining agents in frost-susceptible areas. Air-entraining agents can enhance frost durability. Excessive air entrainment, however, reduces the bond of mortar to the masonry unit (normal recommended range is 10 -18% air). Hydrated lime can be obtained with an integral air-entraining agent; masonry and mortar cement and most pre-mix mortars have it added, too. This is often the best way to get an air-entraining agent mixed into a mortar. Trying to add dry or liquid air-entraining agents separately on site can be a difficult job, as very small quantities of additive are needed for a typical mortar mix and it can be difficult to get complete dispersion of the agent into the mortar. These agents do not work well in very dry pointing mortar mixes, as they require a minimum amount of water and good mixing to activate the entraining agent.

PRE-MIXED MORTARS

Use of pre-mixed mortar ingredients to which only water needs to be added gives the greatest control over mortar consistency on site. Such mixes are more expensive and the exact components are often proprietary. Caution should be taken when using pre-mixed mortars to avoid scooping the quantity of dry material needed for a repointing job off the "top of the bag." Finer ingredients, such as additives or binders, may have settled to the bottom during bagging and shipping. It is usually recommended to mix up all the contents of a single bag for a project or – if smaller quantities are needed – to blend the dry ingredients of a whole bag in a mixer and then subdivide it into smaller sealed containers for smaller repointing jobs.

DESIGN CONSIDERATIONS

The designer needs to take into account all the factors affecting durability. Performance requirements provide a good base for assessing appropriate repointing

mortars. From these, specific criteria can be developed. There is no miracle mortar mix suitable for all masonry; the design of a mortar mix should be adapted to the particular masonry assembly under consideration (e.g., in terms of the existing mortar and masonry units, and environmental exposure). Typical mixes are given by Mack and Speweik (1998), BRE (1999), Historic Scotland (1995), and BA (1999). There is little recent documented data on the use of pure lime and hydraulic lime mortars in Canada, so they must be used with caution until more experience is gained with their use. IRC/NRC, in conjunction with PWGSC-HCD, has done some preliminary investigation on durability of hydraulic, lime-based repair mortars (Maurenbrecher et al., 2005). Initial findings showed that hydraulic, lime-based mortars could provide a durable repair mortar. They are, however, much more sensitive to mixing and curing conditions, so care must be exercised if a good end result is to be obtained.

When selecting a mortar mix, the following performance requirements should be taken into consideration.

- Ensure the compressive strength is lower than that of the existing masonry units, and similar to or lower than the existing bedding mortar (if the pointing mortar is too strong, stress concentrations could cause spalling of the masonry units).

In future repairs and restoration, weaker mortars are also easier to remove without damaging the masonry units. Weaker mortars have less stiffness and greater creep, allowing accommodation of larger movements without cracking. Recommendations for maximum strength have ranged from 8 MPa (for Nepean sandstone; Suter et al., 1998) to 10 MPa (Knöfel et al., 1993). This still leaves questions on assessment of strength. Mortar cube strength can be quite different from the strength of the mortar in the joint. In addition, strength varies with age, the high-lime mortars gaining strength gradually.

- Aim for a water absorption and vapor transmission rates similar to or greater than those of the bedding mortar and masonry units.

The pointing mortar should facilitate

the drying of the masonry assembly through the mortar joints. This is especially important in masonry with dense masonry units. A more porous mortar will also encourage any salts in the masonry to migrate out through the mortar instead of the masonry units (salts can cause crumbling, spalling, or efflorescence).

- Minimize shrinkage after pointing (a maximum of 1 mm/m was recommended by Knöfel et al., 1993). Use well-graded, washed sand with no clay fines; low water-to-binder ratios; and proper curing to minimize evaporation in the first days after the mortar is laid. Sand particle shape may also have an effect (see section on materials).
- Promote good (not necessarily strong) bond with full contact between mortar and masonry units and existing bedding mortar. This can be achieved by clean removal of the deteriorated mortar when cutting out, good compaction of the fresh mortar, and proper curing.

Good bond and low shrinkage reduce the risk of fine cracks forming at the interface between the masonry units and mortar. Most water infiltration through a masonry assembly occurs at this interface and at poorly filled joints. Examples of minimum recommended flexural bond strengths are 0.2 MPa (Knöfel et al., 1993) and 0.3 MPa (with Nepean sandstone; Suter et al., 1998).

- Provide resistance to frost action where needed. An air-entraining agent added to the mortar will improve frost resistance.

High lime content mortars have less resistance to freeze-thaw action when they become saturated (they are most vulnerable early in their life because they take a longer time to harden). On the other hand, the more porous mortars tend to dry faster, thus reducing the risk of damage. Great care must be taken in selecting mortars for areas of severe exposure such as chimneys, parapets, free-standing walls, exterior steps, and masonry below or at ground level (base selection on expe-

rience and/or testing).

- Provide resistance to salts where needed (e.g., sulphates). Use of sulphate-resistant Portland cement reduces this risk.

If sulphates are present in existing masonry, they can react with binder components (e.g., uncarbonated lime and components of Portland cement) when the masonry is damp for extended periods of time (Harrison, 1990; BRE, 1991).

- Ensure compatibility of the thermal and moisture expansion properties of the repointing mortar to existing masonry.
- Encourage good workmanship by making mortars practical in application.
- Use contractors and masons experienced in the conservation of older masonry.

ON-SITE PRACTICE

On-site practice includes mortar joint preparation as well as mortar mixing, pointing, and curing (BRE, 1999; Mack and Speweik, 1998; Historic Scotland, 1995). All have an important influence on the long-term performance of the mortar. Supervision and quality control will help ensure the performance standards are reached.

JOINT PREPARATION

Raking out and cleaning of the joints must be carefully done to ensure no damage to the masonry units and ensure a clear, rectangular space for the repointing mortar (Figure 7). Then there is more likely to be a good contact between the pointing mortar and the masonry unit and the existing bedding mortar. Poor contact inhibits moisture transfer. The typical depth to be raked out is twice the width of the joint, but more material may need to be removed in order to get back to “sound” material before applying the pointing mortar.

Before pointing, the joint is usually pre-wetted to limit its water absorption rate. How best to do this is still a subject of debate. At the time of pointing, water is absorbed from the mortar by the

masonry unit (depending on type of unit, amount of pre-wetting, and the water retention capacity of the mortar). This can affect the bond of the mortar to the masonry units.

A study on modern bricks and pointing mortars found the water remaining in the mortar affected the frost durability: too much water in the mortar decreased frost resistance; too little water affected hydration and reduced strength (Elsen et al., 1993).

MORTAR MIXING

Batching (measuring) of mortar ingredients by weight gives better consistency than batching by volume, but batching by volume is still the most common procedure on site. Volume batching introduces larger variations in quantities because the level of compaction in measuring containers varies with the individual doing it. In addition, the volume of sand can vary with moisture content. Pre-mix mortars avoid most of the batching problems.

When lime is used in the mix, it can be added in the form of hydrated lime powder, lime putty, or “coarse stuff” (lime, sand, and water mixed ahead of time). The latter two give the best workability because the lime particles are fully wetted beforehand. The difference in lime content in dry lime and putty lime mentioned earlier must also be taken into account.

Mortar may be mixed by hand (only suitable for small amounts), in a standard paddle mortar mixer, or a mortar mill. The mortar mill is often used for high lime mortar mixes. Mixing time must be controlled, especially for mortars containing air-entraining agents (to avoid excessive air content). After mixing, the mortar is often allowed to stand for a while before use. Pure lime mortars can be kept for months before

use, provided they are kept damp and air is excluded (Historic Scotland, 1995). Mortars with hydraulic binders have to be used within a certain period. Mortars with Portland cement need to be used within two to three hours of mixing. The mortar may also be allowed to stand for a period after mixing to allow pre-hydration (and thereby reduce shrinkage and improve workability). ASTM C270 recommends 1-1/2 to 2 hours after mixing with sufficient water to produce a damp mix. After that period, further water is added until the right consistency is obtained. Another document does not mention this waiting period (BRE, 1999). The cement content and type of lime may also affect the need for a waiting period.

MORTAR APPLICATION

Good compaction of the pointing mortar in the joint is important to good performance. For deeper joints, it is usually done in more than one layer. The final finish of the mortar joint surface affects its water-shedding capabilities. The surface should not extend out over the surface of the masonry units (thin sections of mortar extending onto the face of the unit easily crack and collect water). Standard finishes range from a concave finish (best compaction and weathertightness) to a raked joint (worst) (BRE, 1999). For historic masonry, many other finishes have also been used.

CURING CONDITIONS

Curing conditions for freshly pointed joints have led to much debate, especially when there is the risk of frost (Historic Scotland, 1995; Mack and Speweik, 1998; BBA, 1999; BRE, 1999).

Rapid drying out of the mortar should be avoided. It can bring lime to the surface and increase the risk of shrinkage cracks; it also may not leave enough moisture for curing of hydraulic components in the mortar (Historic Scotland, 1995). Common recommendations include a damp cure of two to four days (longer for pure lime mortars), or protection for seven days (Mack and Speweik, 1998; BRE, 1999). Actual times will depend on environmental conditions. Damp curing may be achieved by wet burlap covered in plastic. Regular misting is an alternative. Water should not run off the joints while doing this; otherwise, staining may result from lime leaching out of the mortar. New repointing should therefore be protected from rain.

Where there is a risk of frost, protection from freezing for a minimum of seven days

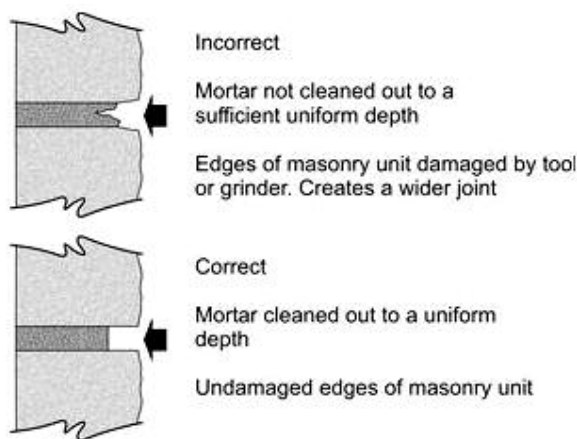


Figure 7 - Raking out mortar joints in brickwork.

is recommended for weaker mortars (BRE, 1999). Air entrainment will provide added protection. The effect of only seven days' initial protection on frost durability and long-term strength gain needs further investigation. Pointing should preferably be done well ahead of winter.

High lime mortars will slowly gain strength as the lime within the mortar carbonates. The outside surface of the joint carbonates within a few days, but within the joint, the process is much slower, taking a year or more, depending on the porosity of the mortar and masonry unit, the depth of the pointing mortar, and the environmental conditions. Favorable conditions for carbonation are relative humidities in the range of 60 to 75% or repeated wetting and drying. Full carbonation is likely to improve durability, including resistance to sulphate attack (Harrison, 1990) and frost resistance.

TESTING AND STANDARDS

Performance requirements and durability can be assessed by documenting actual performance in buildings, and by tests in the laboratory and in the field.

PRE-CONSTRUCTION TESTING

It is difficult to assess the exact composition of mortars used in the past; compounding this problem, there is also a lack of information on the properties of such mortars and their influence on performance in the Canadian climate. There is a need for standard tests, so that results from different laboratories and countries can be compared. A RILEM committee on the characterization of old mortars with respect to their repair is addressing the issues of sampling, analysis of physical and chemical characteristics, damage types, testing, and case studies.

Testing should take into account the performance of the mortar in combination with the masonry in which it will be used. Testing mortar using small masonry wall-ettes gives a better representation of actual practice. NRC/IRC, in association with PWGSC-HCD, is investigating the durability of pointing mortars for stone masonry. Small masonry prisms are used to assess the freeze-thaw durability of pointing mortars (Fontaine et al., 1998; Maurenbrecher et al., 2000; Suter et al., 1998; Thomson et al., 1998). Improving the freeze-thaw test to more accurately reflect conditions in practice is also an objective (e.g., freezing from one side only, rate of freezing).

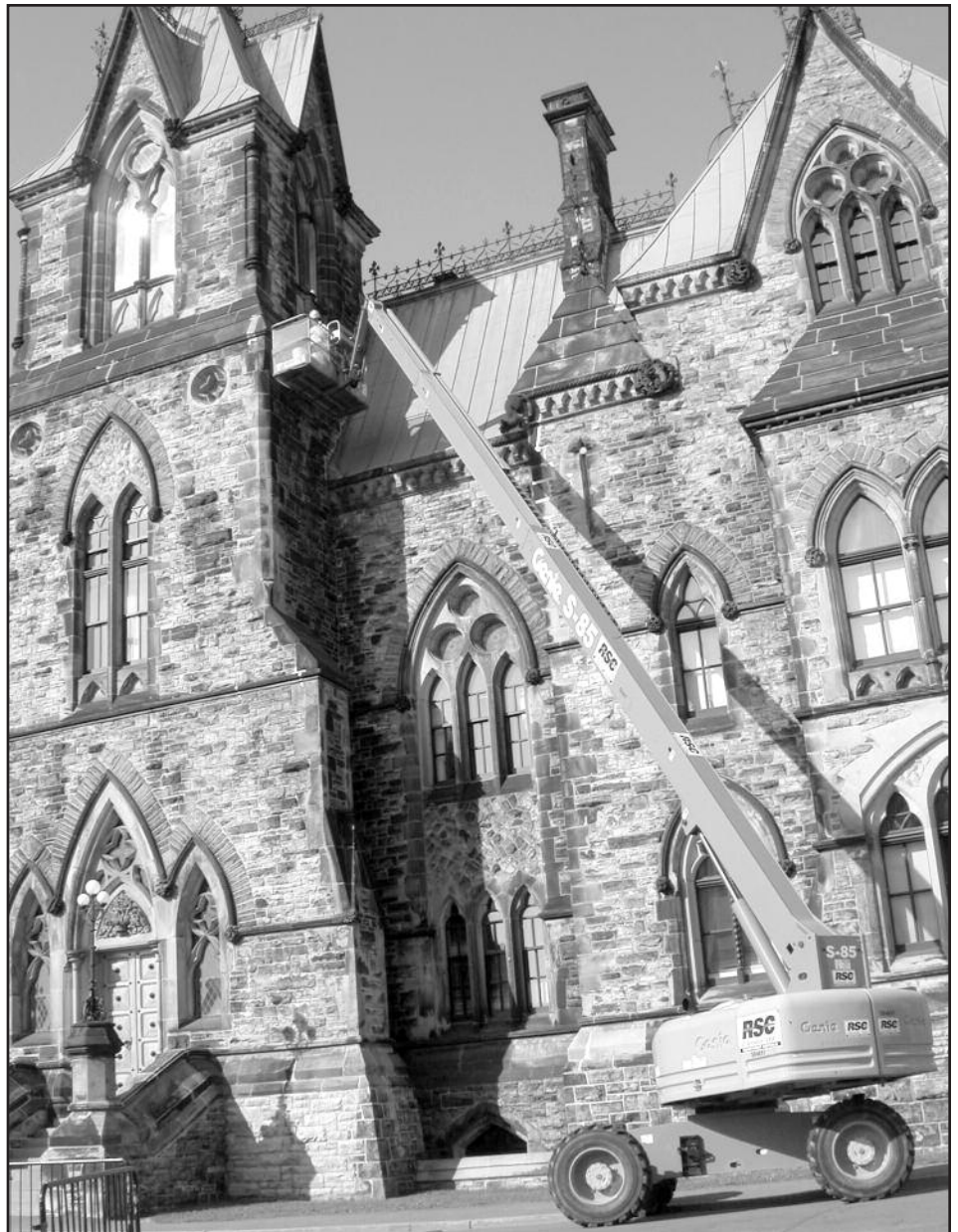


Figure 8 - Regular inspection of the masonry can be conducted using a hydraulic lift to access the structure.

QUALITY CONTROL DURING CONSTRUCTION

There is a need for simple and quick quality control tests on site. One example, employed by PWGSC-HCD on all of their repointing projects, which has worked well to assess the workability of a particular mix, is the cone penetration test (ASTM C270). This provides an immediate indication of the workability of the mix and provides a means of controlling consistency of fresh mortar and prevents excessive strength development that could occur from a dry mortar mix.

IN-SERVICE PERFORMANCE

The performance of pointing mortars in

actual buildings should be surveyed, monitored, and documented in Canadian conditions.

STANDARDS

The ASTM mortar standard has a short section on pointing mortar (ASTM C270-06). There is currently a draft standard being put together by ASTM to develop guidelines for repair mortars. The CSA mortar standard (A179-04) currently includes a non-mandatory appendix that was developed to provide some guidance on repair mortars for older masonry. More guidance is needed in both these standards on the repointing of older masonry.


MAINTENANCE

Good durability is not only a design and construction consideration. Ongoing maintenance has a large influence on performance as well. Regular visual inspections, coupled with a maintenance guide, would be ideal (Figure 8). Failure of water-shedding elements, such as gutters and downspouts, can result in rapid deterioration, especially in cold climates. Prompt repair of these elements, along with the damaged mortar joints, will greatly reduce the extent of further damage.

CONCLUSION

This paper highlights some of the issues affecting the durability of repointing mortars. With an increase in popularity of repair and restoration of old masonry buildings, there is pressure to produce design and construction guidelines for practitioners to use for best results. Care is needed in determining which mortar mixes are best for a particular building. It is recommended to use experienced practitioners in the field who manage to negotiate the minefield of new products, on-site practices, and research documentation. This has led to a relatively young research field exploring the interrelation of these factors.

Over the last 20 years, PWGSC-HCD has conducted research in conjunction with IRC/NRC in an effort to increase the level of understanding of materials and methods of repair of older masonry structures. This is the only government branch doing this type of work in an effort to preserve Canada's historic masonry buildings. There remains a need for documented data on performance and testing of repointing mortars in relation to the Canadian climate and on-site practices. Without documentation and analysis, codes and standards cannot be improved to meet the current demands.

This paper is a step towards documenting the current issues and, as can be seen, there are many gaps. IRC/NRC has made efforts to address these gaps through research and information exchange. A working group of architects, engineers, materials suppliers, material scientists, researchers, contractors, and masons meets twice a year to discuss current challenges and areas requiring further work. To support this effort, IRC has also developed a Web site that provides information on its current masonry projects and selected bibliographies on relevant topics (www.nrc.ca/irc/bes/masonry). 

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