A Guide to Restoration:
Repointing Heritage Masonry

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Table of Contents: Pg.

About this guide:

In Canada, the restoration masonry trade is unregulated and underestimated. Repairs to historic buildings across the country are being done without the knowledge and skills required. This is usually not entirely the tradespersons fault, rather a lack of overall public awareness. It is shocking when you consider the value and importance we put on our heritage buildings in this country.

The purpose of this guide is to help educate an Architect/conservator, skilled mason or a heritage building owner on the materials and methods related to restoring historic masonry - repointing in particular. Specific materials and proper technique will be discussed in order to provide a thorough understanding of durable mortar and correct technique. This guide is not intended to be a "how to" manual on repointing. Nor does it provide you with enough skills needed to evaluate and repair your deteriorated masonry. It will, however, serve as a reference for specifications related to restoration and summarizes what you will need to know before finding a heritage mason. It should also reinforce that historic masonry requires special considerations when diagnosing problems from a project to project basis.

Introduction:
What is masonry?

Masonry is a material such as concrete block, bricks, or stone bonded together with mortar to form a wall or structure. A mason's job is to build these structures with knowledge and experience so that they not only meet the requirements of the building code, but also are constructed with durability to withstand local weather conditions. The history of masonry in Canada began when skilled European immigrants settled on the East Coast and slowly made their way West. They brought with them a trade that has been passed down through centuries of tradition and experimentation. Today, modern masonry has a broader meaning in that there are cement masons who pour and finish concrete, and masons who lay brick, block and stone to form walls and structures. Masons skilled in the craft of modern building are expected to have a good knowledge of the Provincial Building Code and how it relates to the units they are laying.

Heritage masonry uses some of the same skills and current building theories while combining experience with historic building materials and knowledge relating to deterioration. A trained heritage mason will have sensitivity to old masonry and will know, through previous training, what materials and techniques will help prolong the life of an ageing building. A heritage trained mason has the ability to understand the complexities of deterioration in rural towns as well as polluted urban areas. Factors like, acid rain, harsh freeze thaw cycles and pollution all have compounding effects unless maintained with conservation skills and a sound knowledge of quality workmanship.

How masonry behaves in our Canadian environment:

Canada's climate is very diverse across the entire country. Climates can range from hot summers, to cold winters. Some areas have very cold and dry winters, while others have winters with heavy rain and wet snow. Regions with more snow and rain with many freeze thaw cycles are worse for masonry than regions that are cold and dry.

In Ontario, moisture through ice, snow and rain is the number one enemy to any masonry unit. During a freeze/thaw cycle water enters the masonry pore system and begins to freeze. Ice crystals expand and fill the pore structure until the unit is full. Pressure builds until there is warmth and thaw occurs. The repetition of this cycle is what weakens the unit, forcing the face to spall off. The mortar joint serves as an exit door for water once it fills the unit. By design, the mortar bed is supposed to be sacrificial to the brick or stone. If the bed is functioning well it eventually gets overworked and fails. The failed joint then requires repointing, or replacing old mortar with new mortar softer than the original

unit. This is very important and is often either overlooked or miscalculated in terms of mortar strength. If the old joints are left untreated, water penetration will destroy the unit and eventually the entire wall system (Scott, 2005).

The National Research Council has completed tests on Ottawa buildings attempting to determine how masonry units and the mortar between them behave in an average winter. They found that during an average winter in Ottawa, the total number of freeze thaw cycles on a brick veneer facing SW was 100. That is a considerable amount of pressure for a wall to be under year after year.

Besides moisture, salt from de-icing roads and sidewalks is another problem for masonry in our harsh winters. If salt is needed on entranceways, steps or driveways it should be used with caution around historic buildings. Through capillary action the salt will soak into the bottom of the building resulting in harmful and visually detracting efflorescence, or salt crystals leaching out of the pore structure. Sand and salt alternatives should be used near heritage buildings.

Mortar Introduction:

A wall is only as good as the unit itself, mortar that binds it and the quality of workmanship. Mortar performs many functions within a wall system: it is the strength that holds the masonry units; it is the cushion between the units, and a weather resistant barrier that prevents moisture from entering the building. A mason will have to account for different compressive strengths, flexibility, and shrinkage rates when choosing the correct mortar to match the needs of a particular job. Balancing the right mortar mix with the structural and environmental requirements could be the difference between long-term success and short-term failure (Kreh, 2003, p. 113).

Lime: The Basics:

The term lime is made from pieces of limestone (calcium carbonate) that are burned producing a new material called quicklime. The quicklime is then slaked with water and lime putty or hydrated lime powder is produced. Traditional mortars are basically composed of a binder (lime), aggregate (sand), water, and additives if necessary. Up until the late 19th century lime was the most common binder in mortar. After the invention of Portland cement, however, strictly lime-based mortars were soon replaced with a Portland/lime binder that increased building production and provided a stronger support for the bed joint. What the architects and masons didn't know was that Portland cement creates a chemical set that, over a long period of time, will become harder than the stone or brick which it is supporting. This fact alone is changing the approach to heritage repair and construction on historic buildings. Parliament Hill in Ottawa is currently being repointed with a lime-based mortar that is softer than the stone, allowing for a sacrificial bed, ensuring long-term durability. Portland cement has many applications in the construction industry, yet many contractors and masons underestimate its strength and relative implications. Stronger is not always better.

When repairing a historic building, repairs should be carried out using materials and techniques that match those used originally as closely as possible. There are 3 reasons why a mason should do this:

1. Repairing materials to match the original will provide a connection to the past and maintain a buildings history.
2. Making every attempt to match the original materials and techniques will ensure the masonry will age in a similar way as the original.
3. In previous repairs modern material and techniques have often proved to be incompatible with the original building or structure, causing an accelerated deterioration of the masonry. Changes to the original materials should only be made when they have shown signs of failure (Ellis, 2002).

In the past 20 years, there has been a renewed interest in lime-based mortars. Specialists involved in the conservation of historic buildings are increasingly concerned about the harmful effects of Portland cement in certain types of mortar on historic brick and stonework. Tests have proven that traditional lime mortars are more compatible with old buildings. A mason must have a clear knowledge of lime mortars and their properties to either match the existing mortar or prepare an improved batch that correctly suits the wall. Through a process called acid digestion a heritage mason will be able to identify and match the pre-existing mortar properties.

Repointing Heritage Buildings:

All Masonry will eventually deteriorate, especially at the mortar joints. Repointing masonry units with the correct mortar and quality workmanship is one of the most important procedures performed on historic buildings. A proper repointing job can restore the physical integrity and overall appearance of the masonry. If repointing is poorly done, it not only detracts visually, it can cause irreversible damage to the units themselves (Mack, Speweik, 1998, p. 18).

Finding the appropriate mortar to match the building requires preliminary research to ensure the repointing work is durable and visually appropriate. Test panels and strict control of batching procedures will start the process. While traditional pure lime mortars are making a comeback in the conservation of older building, they have not gained general acceptance because of long-term results, accessibility, and high prices. One might think that lime mortars are simple to use, however the opposite holds true. Hydraulic lime mortars require a very controlled environment in order to set up slowly and must be used by experienced practitioners. They should also be used well before or ahead of winter. Unfortunately until future use in Canada, restoration mortars will most likely consist of a Portland cement, lime, sand i.e. **1-1-6** or a **1-2-8**, as commonly referred in the trade (Maurenbrecher, 2004, p. 5, Mortars…).

One word can sum up repair mortars and that's **"durability."** Repair or repointing mortars should be durable and sacrificial to the existing masonry. Not only is durability dependent on the mortar mix, it also relies on correct installation, curing conditions (weather, environmental exposure), and maintenance. Listed are the requirements of a durable repointing mortar:

Requirements for a Durable Repointing Mortar:

1. Mortar should be no stronger than needed. The long-term compressive strength should be less than the existing masonry and similar or lower in strength than the mortar to be replaced.
2. New mortar should be more permeable than the existing mortar. A restoration mix with only the required amount of Portland cement will encourage drying through the bed joint instead of the unit itself. During the freeze thaw cycle, moisture will fill the pores of the mortar, rather than the stone or brick. Harmful salts will be able to exit the permeable bed.
3. Repointing mortar should have little shrinkage. Washed sand with a good variation from small to large particles with no small clay "fine," will reduce shrinkage.
4. Absolute full contact between the new mortar and the masonry units is imperative. Water can infiltrate any gaps left unfilled and eventually harm the joint.
5. Mortar must be resistant to severe freeze thaw cycles. With Ontario's cold winters, at least 8 to 15% of every mix should consist of air. The air must be intentionally entrained so that freezing moisture can be accommodated by the voids without damage to the mortar. An SA hydrated lime will have air entrainment, as well as the use of the previous mentioned sand specifications.
6. Texture and colour of the repointing mortar are important if matching existing mortar.
7. Mortars should be consistently batched and applied with good technique. A mason skilled in restoration will be required to know the difference between repointing for durability and repointing for failure (Maurenbrecher, 2004 p. 3,4, Mortars….).

Mortar selection must take into account the worst possible environment for which it will be used. The environment depends on the severity of winter and the exposure of the masonry elements. For example, a more suitable, softer for a wall with protection from the environment should not be used on an exposed chimney (Maurenbrecher, Trischuk, Rousseau, 2001, p.4). Careful consideration to the amount of exposure to harmful elements must be used in determining the correct mortar mix.

Possible Forms of Joint Failure:

Moisture and temperature are the most common environmental factors that will cause masonry to fail. Temperature influences the way in which moisture, through ice, snow, and rain, affects the durability of a joint. Through expansion and contraction, an overworked joint will eventually cause **cracking** and separation from the unit. Other potential problems are:

Spalling: occurs when small pieces of masonry become loosened from the unit.
Crumbling: occurs when the face of the unit begins to deteriorate due to a fault in the mortar joint, usually from repeated moisture exiting the masonry unit.
Efflorescence: the result of soluble salts leaching out of a wall, causing a white substance on the exterior of the masonry units.
Erosion: deterioration caused by the loss of mortar from the surfaces by constant water flow, sand, and human traffic.
Biological growth: tree roots and vines will enter masonry and expand into pores causing cracking.
Environmental pollution: acidic rainwater washes across upper masonry and dissolves minerals in the units. The mixed chemical dissolves the binder in the joint, leaving it vulnerable for water infiltration.
Water migration: water can eventually overwork a joint and cause it to become impermeable (Heritage Ottawa, 1998).

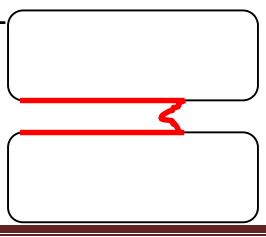
Repointing With Attention to Detail:

Since masonry is labour intensive, many problems can originate from poor workmanship. Successful repointing depends on the masons themselves. All problems related to quality of workmanship can be prevented by clearly specifying the appropriated materials and job procedures by the supervisor of the crew. Quality on-site practice includes the following steps:

Joint Preparation:

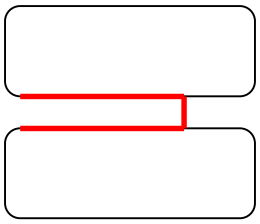
Old mortar should be raked out of the joint to a minimum depth of 2- 2 ½ times the width of the joint to ensure a strong bond and to prevent new mortar from popping out. For most brick joints it will be approximately 1inch. Careful consideration must be given to the arises, or the edges of the stone. Masons using power grinders should exercise extreme caution, as it could prove disastrous to historic masonry. Grinders are only used to release the tension, through scoring the joint. Supervision by an experienced mason will be the key to preventing mistakes and exercising attention to detail at all times.
Joint preparation diagrams:

Incorrect -



- Mortar not cleaned out to the right depth and not raked back square.

Correct -



- Mortar cleaned out to a square back and uniform depth.

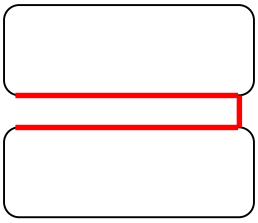
Mortar Preparation:

Masons should measure exact proportions of each mortar batch, making sure to maintain uniform visual and physical characteristics. Dry ingredients are to be mixed first and clean water is added slowly after. Sand should be used dry. Wet or damp sand can reduce the overall proportions. Adding the correct amount of water will result in a mortar with no excess water to evaporate and minimal shrinkage. It is recommended that only one person do all the mixing on the job to maintain overall consistency (Mack, Speweik, p. 17, 1998).

Filling the Joint:

Good compaction is crucial for joint durability. Mortar is applied in layers for joints more than 1 inch. The final layer of the joint is most important as it will come in direct contact with water. The surface should never extend past the edge of the stone or brick. This "feathering" of mortar is common in poor repairs. It will inevitably fail.

Proper Joint -



- Mortar is set back approx. $1/16^{th}$ in. from the arise.

Curing Conditions:

Repointing does not end when the joint is finally tooled. Managing the curing conditions is equally important as filling or striking the joint. Actual curing times will depend on the environmental conditions. Temperatures between 8 and 30 degrees are optimum for curing. During hot weather, repointing must be done in the shade and away from strong winds. Three layers of wet burlap kept wet for 24 hours will ensure humidity and slow curing. The masons should avoid rainy days, as well as water sprayed directly onto the new joints. If repointing is done in the winter months, at least 7 days of warmth is recommended (Maurenbrecher, Trischuk, Rousseau, 2001, p.8). Caution should be used when using propane or kerosene heaters under tarps. Heat loss in certain areas and complete heat loss over night is a constant problem.

Overview of Joint Finishes:

When deciding which joint finish to use on you building, several things must be considered. First, is matching the original joint finish going to restore the exterior walls authenticity and historical relevance? Does changing the joint finish detract or add to the heritage character? Different joint finishes

can transform the appearance of a wall by emphasizing horizontal and vertical lines. When choosing a heritage joint finish style, one must consider:

- Flush joint pointing is simple and fast with little difficulty.
- A Concave joint is popular and provides a good slope for moisture run-off.
- Struck pointing should be simple, not angled too far back from the outer face.
- Not as popular as the raised bead, the Grapevine joint is just the opposite.
- Moving up the scale of difficulty, Raised Ribbon or Raised Bead joints can create the illusion of an orderly masonry wall that once had inconsistent edges to each unit. These two finishes require painstaking skill and unless practiced, are beyond most masons.
- The ultimate joint finish is tuck-pointing. This term is often used as a general term for repointing. The true form of the style is coloured lime putty is pressed against a uniform flush joint that produces a very unique contrast and dramatic effect. Many colonial buildings and arches use this technique. It is time consuming and labour intensive.

Repointing precautions to be considered:

It is beneficial for the tradesperson or building owner to recognize correct and incorrect repointing. Given that masonry is very labour intensive, it is common to see inconsistencies and problems related to poor workmanship. Listed below are situations that are typical under poor supervision or training:

1. Partial filling of the joints and deep raking can lead to faulty mortar joints, and future moisture related problems.
2. Adding too much water for increased workability can produce porous mortar joints.
3. Improperly tooled joints will have an unstable exterior against weather.
4. Hydrochloric acid, commonly used as a cleaning agent, can create efflorescence and weaken the mortar joints.
5. High absorption masonry units that are not adequately pre-wetted will produce weak mortar joints.
6. Pre-wetting raked joints and masonry units excessively can produce problems on the interior wall and porous mortar joints.
7. Widening the original joint width by spreading mortar on the face of the masonry not only distorts the overall appearance of the wall but also is difficult to repair in the future.
8. Flashing (a type of metal used to prevent the entrance of moisture and provide drainage) is re-used or improperly reconstructed by inexperienced masonry. Metal flashing, when installed correctly, plays an integral role in moisture defense. It is good practice to install new flashing on any repointing job (PWC, Vol. IV, 1997, p.9).

Protecting work is important:

Effective curing is essential to control the rate of drying and to provide freeze/thaw durability for future winters. It is critical to protect newly repointed walls immediately against wind, sun, and artificial heat. Good curing conditions promote gradual drying when combined with a well-mixed, low shrinkage mortar. Any work that has “flashed,” or dried out too fast and not allowed to strengthen, will have to be cut out and replaced. In addition to excessive shrinkage cracking, rapid drying can also separate the units from the backing. Joints that have dried too fast will have a whiteness that does not match the existing mortar, usually caused by lime being drawn to the face of the mortar. A new repointing mortar needs to dry slowly and be maintained in a moist but not wet condition for up to a week. Three layers of wet burlap hung inside a plastic exterior is good practice. This will keep strong winds, sun and rain away from the wall (Heritage Scotland, 1995, p.39).

All mortars require protection from freezing until they are dry and cured. Repointing in the winter can be done with a well-ventilated, fully enclosed scaffold. Propane heaters can be used and require specific safety precautions. It should be noted that the enclosed heated area will reduce humidity and might create poor drying conditions. The extra cost of set-up during winter conditions should be considered when pricing and scheduling larger jobs.

Application expectations that reflect proper technique:

In Order to assess the properties of the mortar, types of masonry, joint styles, mortar colour, and other problems related to the individual project, it is good practice for the mason to prepare test panels. These small 4' by 4' panels should be carried out on a section that is less visible to the average viewer. The panels will display various joint finishes, cleaning tests, and generally serve as a benchmark for what is to be expected for the entire project.

Raised ribbon, bead, or tuck pointing requires extra attention when deciphering between good and mediocre technique. Although technique may vary, listed below are the basic steps to performing these joints properly:

1. Before beginning to fill the raked and square joint, all the dust must be vacuumed or blown out with compressed air. The joints will then be wetted but not soaked with water. The surface must be controlled in order to maintain wetness.
2. Repointing will be built up in layers, not exceeding ½ inch in depth. Additional layers can be added once the previous has set.
3. After the final layer has set, the mason will tool the joint – making sure to cut back the mortar to the arise of the stone or brick. This is very important for moister defense. The joint must not be overworked as this draws lime to the surface.
4. Every attempt to match up with the existing joint must be made when joining old with new. Horizontal and vertical lines are to be straight and connect at 90 degrees.
5. All excess mortar from the face of the masonry must be removed before it sets. The rest of the joint will have to be finished at this time. The mason must not rush these steps, as they are all crucial in completing a well-tooled joint (Heritage Ottawa, 1988).

Maintenance or control of water:

Regular maintenance has a large influence on the performance of the repointed wall. Bi-annual visual inspections, along with this guide would be ideal. Other protection features, such as eaves troughs and downspouts, must be kept in working order, especially in cold climates. Immediate repair of these water-shedding features, along with regular mortar repair, will reduce any further damage to any heritage building.

Warning signs to typical masonry failures and how they behave:

The interior of a building is a good place to look for signs of masonry failure. If the plaster on your walls is cracking, chances are it is masonry related. Signs of usual exterior cracking (from 2.00mm to 5.00mm in width) may indicate trouble on the interior walls. Visual symptoms might indicate deformed edges of doors and window, moisture spots on ceilings and drafts penetrating through walls.

The two major causes of cracking are foundation settlement and thermal movement. The uneven foundation of posts, columns, footings; or the bending of trusses or beams will have tell tale signs of settlement and thermal movement. Structural movement patterns related to settlement often show signs on the interior. Doors and windows may be jammed, walls may be cracked right through, falling plaster

and collapsing arches. These failures can have cracks ranging from 5.mm to 15mm (Weaver, 1995, p.5). The typical pattern of shear cracking related to tension (masonry is pulling away from itself during cracking) on exterior masonry will be evident above and below any opening, such as lintels, arches and windowsills. Tension occurs when a foundation shifts due to:

- Shift in water content of soil.
- Compaction of soil.
- Rotting wood beams, joists or trusses.
- Lintel or arch failure.

When masonry pushes down on itself and damage occurs, it is known as a compression related shear crack. Compression usually takes place when there is a change in load (heavy appliances, filling the bathroom tub, and even renovations). Cracking, due to structural instability, can be corrected by removing and strengthening the structural members or supports (Scott, 2005).

Other than cracking related to mortar shrinkage, the restraint of thermal movement affects cracking by temperature changes throughout the freeze/thaw cycles. If mortar is not performing its function i.e. flexibility, an ability to re-heal itself, structural elements like the foundation, intersecting walls, and roof will induce cracking because of their engineered properties. Thermal movement, regardless of whether the building was built sound, will exist on any building, but may vary in terms of materials used, environmental exposure, and ongoing maintenance. Even small cracks in masonry should be repaired, as cracking can enlarge with time due to moisture penetration, frost action, and thermal cycles (PWC, Vol. VI., 1997, p.6).

What to look for regarding past repairs:

Repointing is recognized as a demanding and skilled technique. If heritage building owners are not aware of this it will be left to the lowest bid and will most likely be detrimental to the entire structure. To be done well, repointing will have to comply with the specifications discussed earlier in this guide. Poor craftsmanship will be easy to spot by looking at the joint finish. Did the previous mason cut his joints back to the arises or did he feather the edges? Masons who are not careful with grinders or chisels around the edges of the stone will leave chips and cuts in the units. Lazy and impatient work will introduce moisture problems that will have to be fixed in the near future. The overall impression of a well- executed repointing job should be clean and consistent. The eye should not be drawn to the pointing, but to the overall effect of the wall. A good mason will have the sensitivity to search for the best possible mortar or units that will closely match the original colour and texture of the building.

Job access and minimum requirements for repairing masonry:

Safe and secure access to each section of the masonry walls will have to be organized prior to commencing a job. A mason will most likely require:

- Set of scaffolding properly anchored into the building.
- Access to clean water.
- Access to an electrical outlet.
- Access to a washroom.
- Access to a driveway leading to the building and parking.
- Access to keys or any parking permits.
- Onsite area to mix mortar.
- Onsite area to store materials and debris.

Repairing masonry is a time consuming and messy project. The use of grinders and chisels can generate large amounts of dust, which must be controlled especially around doors and windows. Entrances may be blocked from time to time making it challenging for tenants and visitors. Plastic tarps should be used around any vulnerable areas like and entranceway, patio, or garden. Clear communication is important between the building owner and contractor. Preparing a thorough list of materials and a time estimation sheet will omit any problems that may arise in the future. Providing a schedule and time estimation sheet will help keep the work on track and will help the owner understand how long the work is expected to take. The time estimation sheet should be set up with working times, dates and completion goals. This document will serve as a mutual agreement and can coincide with the payment schedule.

Fixed fee or a time and materials contract:

The type of contract you will sign will depend on the amount and degree of work to be done. On smaller jobs, where the work is straightforward with no surprises, it may be more beneficial to decide on a set price. The cost is agreed on in advance… "I will pay ABC masonry X$ when they have repaired my home." With this contract the details are fixed in relation to the price. The easiest way to settle on a price is work completed by the square foot. Each type of repointing – brick or stone – will have its own unit price. Replacing units to match the existing wall will most likely be a separate price. If the repointing is scattered in areas around the building or house it may cost more because of the time and access to these various locations. Test panels, discussed earlier, will help determine how to price a job this way.

If you are open to input and decisions as the work unfolds, a time and materials contract might be more suitable. You must be able to communicate with the contractor well and feel comfortable with his/her advice. The advantage to this agreement is that details of the job can be discussed as time progresses. The basic form of the contract might be "We, ABC masonry, will repoint the entire home of the Smith residence as specified. Mr. and Mrs. Smith agree to pay for the time and materials required to complete the work. The estimated cost is X$, with 20% held until final completion." The disadvantage to this type of contract is that the completion date and the final costs are just estimates. It will be important to check your contractor's references for satisfactory work, completed on time (Lewis, 2005).

Conclusion:

Long term durability of a repointed mortar joint depends on many factors. Poor workmanship and skipping the required steps will result in a building that looks unlike the original and will also require future repairs much sooner than if the work was completed correctly. Masonry joints, by design, are supposed to fail. Choosing a mortar that is sacrificial to the masonry unit, as well as understanding its properties will ensure a durable joint. Regular inspections and careful repair to any failed areas will guarantee your masonry ages in a way that would make the original builders proud. Preservation is important.

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