Background

Historic brickwork falls under the major heading of Historic Masonry, which includes Stonework, Terra-cotta, Tiles and Mortars.

Brickwork has been a building material for thousands of years. The earliest recorded use of brick as a construction material dates back to the third millennium. B.C. The early Romans introduced it to Europe. In Canada, the earliest recorded use of brick dates back to Champlain's Port Royal settlement of 1605. Locally manufactured bricks were used in the early settlements for the construction of fireplaces and chimneys.

Because of differences in materials and methods of construction, a restoration project containing historic brickwork requires a thorough understanding of the materials of construction as well as the science of building envelopes. The following is a brief dialog on some of the major issues.

Bricks

Period bricks were manufactured by heating mineral clays to produce a hard weather resistant material to be used for construction. The heating, or firing process, occurred in a large oven called a brick kiln. Firing transformed the clay by fusing the clay particles into a 'glass-like' mass. Because of the type of kilns used and the lower heat produced by early kilns, the heat required to vitrify the surface did not always reach the inner part of the brick. This resulted in a brick that had a vitrified outer skin and a softer inner core.

Early kilns were wood fired and produced a variety of end products, often from the same load of bricks being fired. Historic bricks, in general, have three distinct zones of hardness within their cross-section: the softer 'core' material, a harder 'transition zone' and the exterior surface. The outer surface, invariably, was the hardest part or most vitrified and is referred to as the 'fireskin'. Because bricks were located in different areas of the kiln when they were fired, these zones of hardness often varied within each batch. Sometimes the variation is quite marked.

Because clay materials from a single pit could have a variety of minerals present in different areas of the pit, bricks from the same pit could have different properties and may be different in colour. The surficial clays, being more weathered and oxidized than the deeper clays in a pit, generally produced lighter coloured bricks. If the history of brick production from a single pit is known, it is possible to estimate the approximate period during which the bricks were produced.

To improve the physical properties of bricks, the brick clays were blended with other materials. Silica, in the form of sand, was added to reduce the plasticity, adsorptivity and the shrinkage. Ground portions of bricks from earlier firings were sometimes added to improve the physical properties of the clay. The added ground or crushed brick material was called 'grog'. To promote the vitrification of the clay and sand, fluxes were added to lower the temperature required to provide a harder, more durable, brick. Early brick makers also learned the colour of the finished brick could be changed by adding other minerals to the clay.

The earliest bricks were shaped by hand packing them into wooden brick molds. These molds would hold only one or two bricks. As demand increased, this method was supplanted by the use of horses and metal molds and a dozen or more bricks could molded at one time. To keep up with demand, starting about the middle of the 19th century, bricks were producing from an extruded pug. A rotating wire was used to cut them to length. This is similar to the method used today.

Because of the variability in the physical properties of the finished brick, after being fired and cooled, historic bricks were often hand selected for suitability. Some bricks were underfired and were not as durable and others might be overfired or over vitrified and might be distorted. These were discarded or crushed to make 'grog'. Others bricks may have been too underfired to use in exposed areas might still be useable for interior wythes of exterior walls or for interior partitions, etc. where they did not have to withstand the effects of weather. It is this hand selection process that further complicates the use of bricks from other sources; care must be taken to make sure the bricks have similar physical and chemical properties to those they are replacing, and that they are suitable for the type of exposure intended.

Historic brick is often not of a uniform size. In spite of legal standards developed in the late 18th century to establish uniform brick sizes, there is a considerable variety in the physical dimensions found in historic brickwork. Bricks might have a stretcher face dimension (length) of $8^1/_4$" to 9" and have a header face dimension (width) of between 4" and $4^1/_2$". The height of a brick may vary from $2^1/_8$" to 3".

In addition to the 'standard' brick sizes, special molded bricks for the construction of brick arches and other decorative effects were also produced. Some brick manufactures also produced oversized softer bricks that could be 'rubbed down' to produce special shapes.

Bricks used for restoration should have a similar physical and chemical properties as those being replaced. This is often overlooked in restoration work. One of the problems of restoration of brick masonry is that the selection of the brick being replaced is based only on the colour, texture or size.

Historic Mortar

Mortar and Mortar Joints

The use of mortar in historic brickwork is almost a study unto itself. It is a complex subject and one that is essential for the longevity of the finished brickwork. Historically, proper mortars were the art of the mason and lacked a formal specification.

When formal specifications were available, they were often obscure. The mortar for the Parliamentary Library Building in Ottawa, for example, was specified in two parts. The first part of the specification was for the mortar used for the general bedding of the masonry and the second part of the specification for mortar used for pointing or finishing the joint. The use of a two-part mortar joint was common for early construction. It consisted of a bedding mortar and a finish mortar for tuck pointing. The bedding mortar was to be batched using the "...best fresh burnt brown lime...'. It is not recorded anywhere what 'brown lime' is. In addition to the ambiguous description of the bedding mortar, the pointing mortar was to be batched using "...one part best brown lime, one part sharp forge ashes, and one part iron scales...". It can be seen from this example that batching historic mortars is not a simple matter, even when the constituents are known.

The problem is complicated because early mortars generally used lime alone as a 'plasticizing' and bonding agent for the sand. The early limes had natural impurities or pozzolans that provided them with hydraulic or semi-hydraulic properties. It was a 'spin-off' of these impurities that permitted mortars to harden in a wet or damp condition and not leach out when exposed to water. That some masonry has withstood the ravages of time is often a testament to the better hydraulic properties that some of these early mortars had. Early masons had to be able to source the proper building materials to ensure a long lasting product. This was part of the skill a master of the trade developed.

Pure lime, as available today, is not suitable for mortar without the addition of a hydraulic cement. With the quality control available today, the pure limes available do not have the natural pozzolithic impurities of historic limes and must rely on the addition of Portland Cement or masonry cement to provide this property.

A mortar used for repairing or restoring historic brickwork must have several properties:

- It must be strong enough to bond the wall together and transfer the loads through the brickwork and at the same time be weaker than the bricks themselves. In this manner, repair of the wall is generally limited to repairing or replacing the mortar joints and not the bricks. This allows the mortar to 'give' and by redistribution, minimize the stresses within the brick.
- The mortar must be more permeable than the brick. This allows the bricks to breathe and prevents water from being trapped within them. Early buildings did not provide for vapour barriers and moisture within the building had to escape through the building envelope. The brickwork walls assisted in this process. Increased permeability can be obtained by using air-entrainment and by adding 'grog' to the mortar mix.
- The mortar should have a similar coefficient of thermal expansion as the brick. In addition, the shrinkage and expansion characteristics should be similar to the brick. This minimizes stresses within the wall and increases the longevity of the mortar within the joint.
- The mortar must be 'stiff'. This also minimizes shrinkage stresses and increases the longevity of the mortar joint.
- To increase for freeze thaw resistance, the mortar should have air entrainment. In early mortars, this was achieved by mixing air into the mortar batch. Current practice is to use air entraining admixtures. Information from Parks Canada indicates that this should be in the order of 10% to 15%.
- The mortar should be lime based. To obtain the necessary hydraulic characteristics, using pure lime, this requires the addition of a pozzolan, generally in the form of Portland cement or masonry cement.. The pozzolan used should use a nearly white colour and should be a Type 5 or sulphate resistant cement. Iron is present in many bricks, and using a non-sulphate resistant cement can produce ferrous sulphide which leaves a black stain.
- Colour for the new mortar joints should be obtained by blending the proper coloured sands. In lieu of matching sand colours, the joints can be 'painted' or coloured using special proprietary methods.

For a restoration project, it may be necessary to produce several 'test batches' before a suitable one can be selected. The selection should not only be based on colour but also on the physical properties mentioned earlier.

Bricklaying

With the exception of a single wythe wall, thickness of historic brickwork walls are generally in multiples of the width of the brick plus the thickness of the mortar joint. Although it is common to find walls 9", 13-1/2", or even 18" in thickness, almost any thickness can be encountered. The common term used for describing masonry wall construction is the wythe. This is defined as being the continuous vertical section of masonry wall that is one masonry unit in thickness.

To improve the strength of walls constructed of two or more wythes, the individual wythes making up the wall were connected to each other. This was accomplished by using brick stretcher courses or by using wrought iron or steel ‘S’ hooks embedded into the mortar joints. Occasionally when working with restoration work diagonal stretcher courses are encountered. This was a method of providing a better interconnection of the masonry wythes.

When brick stretcher courses were used to connect two or more wythes together various coursing patterns developed. Common bonding patterns included ‘English’ or ‘Flemish’ bond where the brick courses alternated between a header course and a stretcher course, ‘Liverpool’ bond, where there are three stretcher courses between each header course and ‘American Common’ bond where four or more stretcher courses are located between each header course.

In addition to constructing brick walls as solid with multiple wythes, some brick walls were constructed using a brick inner and outer wythe connected by ‘S’ hooks and the space between these wythes was filled with loose brick rubble or mortar.

Single wythe brick walls were generally used as a ‘veneer’ over a conventional wood framed building.

Deterioration of Historic Brickwork

Historic brickwork generally deteriorates as a result of one of more of the following primary conditions:

- Failure of the roofing, drainage or wall system has allowed water to enter the wall and consequentially, the brick has remained in a saturated state for a long period of time.

  This can cause a myriad of problems. If the brick was underfired it can deteriorate more rapidly. If the mortar is non-hydraulic it can be leached away leaving only the sand. The bricks can deteriorate from freeze-thaw cycles.

  Subflorescence or cryptoflorescence is the growth of crystals below the brick surface caused by salts within the brick or mortar. The pressure exerted by this crystal growth can cause the brick surface to exfoliate.
- A significant increase in the humidity within the building. Early brick buildings were generally constructed without vapour barriers. This worked well because people generally spent little time indoors and processes indoors used little water compared to present time. This has been further aggravated by the installation of new fenestration and doors that are weather tight and block the ingress of dry fresh air.
- The bricks were underfired and over a period of time have deteriorated due to exposure to the elements. This causes crumbling of the wall.
- Because of the loss of the durable ‘fireskin’, the softer less durable core is exposed to the elements. This softer material rapidly deteriorates and produces the same end result as the bricks being underfired.
- The wall is not properly drained, or the drainage has been impaired. If sufficient water is present it can freeze between the wythes and force them apart.
- Another component of the building that the brick relies on for support has failed. This can cause a small local failure or general failure of the entire wall.
- If metal ties have been used and water has been allowed to enter the wall system, these can corrode causing a local failure or general failure of the entire wall. This can be caused by the corrosion of the ties resulting in a loss of lateral support for the masonry wythes or it can be caused by the expansion products of the metal corrosion.
- Surface damage to the brickwork or deterioration of the mortars because of pollution or acid rain.

Considerable latent damage can occur prior to it being observed at the surface. In addition, tardiness in making initial repairs often accounts for a much greater deterioration. People often fail to realize that the rate of deterioration increases dramatically with time.

There are secondary problems that cause deterioration of brickwork. These are caused by a misguided attempt to fix one of the primary problems without understanding of how historic brickwork functions. Some of the secondary problems that cause deterioration of brickwork are as follows:

- Earlier failures of brickwork have been restored using improper materials or methods. Often a lack of attention to the proper brick or type of mortar selected is the main cause of this type of problem. Often, the well intentioned repair utilizes Portland cement mortars that are far stronger than the original leading to failure of not only the mortar joint but also the historic brick.
- To prevent water from entering the wall, a waterproof coating has been applied. The material selected for this may not permit the brickwork to breathe and may precipitate a failure of another kind. Some coatings do not age uniformly and may discolour the brickwork.
- Inappropriate cleaning methods using chemicals may have a deleterious effect on either the masonry or mortar causing staining or deterioration of the brickwork or mortar.
- Inappropriate cleaning methods using mechanical means may remove the 'hard' fireskin of the brickwork exposing the softer core, which will readily deteriorate. This is often the effect of sandblasting an exterior brick masonry wall to remove surface grime or paint..
- The mistaken concept that the interior surface can be mechanically cleaned by sandblasting because it's not exposed to the elements. This approach can compromise the delicate balance of moisture control from within the building.

Restoration of Historic Brickwork

The first step in restoring historic masonry is to do a detailed study of building or area that has failed. It is necessary to obtain a thorough understanding of the building structure and envelope. This investigation and all subsequent work should be well documented. This type of investigation is generally time consuming and costly. Subsequently, government agencies are often the only group that can afford restoration work.

It is important that the individual undertaking the restoration is aware of mechanisms at play to ensure that the manner of remedy does not cause a more severe problem in the future. Extreme care should be exercised in selecting a method that will not prevent future repairs.

While it is generally possible to determine the cause of the failure, some causes of historic brickwork deterioration are obscure; they may be a combination of several mechanisms. Determining the cause is often a complicated and a time consuming process.

Because most deterioration of historic brick is caused by water transmission, restoration is normally a matter of eliminating the source of the problem and repairing any damage that has occurred. Deterioration is generally a chemical process in nature and the underlying chemical processes should be understood. It is sometimes necessary to obtain samples of the original construction materials. These can be subjected to a chemical analysis to determine constituent components.

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