POTENTIAL USES FOR POLYMER MODIFIED REPOINTING MORTARS

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ABSTRACT

Water infiltration and saturation of mortar joints in solid masonry walls has always been a concern, especially in northern climates where the action of freeze-thaw cycles is very destructive. The exterior "skin" of a solid masonry wall is the only line of defense against water infiltration. Rarely are there drainage cavities similar to rain screen walls. Areas of high exposure such as cap and plinth stones, cornices, ledges, buttresses, etc. which do not have the benefit of roof eave or flashing protection are particularly vulnerable.

The presentation will discuss the potential benefits of polymer modified repointing mortars. Improved bond, flexural and compressive strengths, reduced water absorption and greater freeze-thaw resistance are a few of the positive points. The significant drawback is the reduced vapour transmission of these mortars, particularly when the polymer/ciment ratio exceeds 10%. This could have a detrimental effect on the existing mortar if any water that may find it's way into the wall cannot escape by evaporation through the joint and is instead forced out through the masonry unit. The result may be a gradual deterioration of the masonry unit depending on the porosity of the unit. The challenge is to develop a polymer modified repointing mortar in which the positive aspects are retained to a sufficient degree and yet maintain an acceptable level of vapour transmission.

Two case studies are presented which explore this question. The first is the 1993 restoration of the head office of the Bank of Montreal, an early 1960's office tower with solid masonry walls in which a polymer modified repointing mortar was used for added bond and flexural strengths. The second is the 1988 and 1998 restorations of St. Patrick's Basilica in Montreal, an 1847 historic monument which has had a long history of repeated failures of the buttress mortar joints. Currently long-term tests are being performed with several mortar mixes, with and without polymer, in order to acquire a better understanding of polymer modified mortars when used for repointing .

Key words: Polymer modified mortars, repointing mortars

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Introduction

This paper is concerned with the use of latex (a stable dispersion of organic polymer particles in an aqueous surfactant solution) as an additive in masonry mortars to improve the long-term durability in areas where traditional mortars have failed. Although considered an additive, latex acts as a binder and is considered as such in the ceramic tile industry where it's use is widespread. In areas of highway, bridge and concrete repair, the use of latex modified concretes and mortars is also fairly extensive. However, in the field of masonry construction and in particular, historic masonry restoration, the use of latex in mortar mixes has not gained popularity. Indeed, to the contrary, the potential for significant long-term damage to the masonry units, and in the case of repointing mortars to the existing mortar, is possible with the inappropriate use of latex. However, there are situations where the benefits may out weight the disadvantages in the use of latex-modified mortars, as will be discussed in the following two case studies.

Case Study I – Bank of Montreal Head Office Tower, Montreal

Fig 1 Head Office of the Bank of Montreal, Envelope restored in 1993

Completed in 1961 and built with a steel frame encased in concrete, the exterior of this 16 story tower is clad with a solid stone and terra-cotta wall. Although modern in appearance, the basic concept for this wall dates back to the early 1900s with no air space or through wall flashings to control water infiltration. Therefore the exterior skin is the only line of defense against the elements.

The assembly of the wall is as follows (from the exterior to the interior): 100mm thick Queenston limestone panels mixed with glazed terra-cotta transom panels attached to 300mm terra-cotta masonry (called speed-tiles). Stainless steel and brass strapping 25mmx3mm of varying lengths in a U shape connect both wythes. The exterior face of the terra-cotta was parged with 12mm of mortar prior to the installation of the limestone, therefore eliminating the air space. The interior face was also parged with 12mm of mortar and finished with an asphaltic coating used as an adhesive for foam glass insulation panels 37mm in thickness. An air space of variable depth and a 100mm parged terra-cotta wall completed the interior finish. The weight of the limestone is entirely carried on shelf angles at each perimeter beam while the terra-cotta backup rests on the beam. The lower edge of the limestone was notched to the thickness of the shelf angle in order for the compression joint to match the width of the mortar joints.

Fortunately the asphaltic coating and foam glass insulation act as excellent vapour barriers, but the connection between the top of the terra-cotta backup wall and the bottom of the ridge beam is not air tight and can allow air movement to occur through the wall.

The need for restoration work became very evident in 1991 (only thirty years after completion) when a piece of glazed terra cotta fell off nearly killing someone. An extensive investigation completed in 1992 confirmed the need for various corrective measures, one of which was a full repointing of the tower since approximately 80% of the mortar joints had failed. The original mortar used to place the stone was very hard and brittle. Although no mortar tests were made, it was believed to be a white portland cement based mix called Stoneset, common at the time of this building's construction.

Failure of the joints typically occurred in one of two fashions. Either a hairline opening at the interface of the mortar and the stone, or sections of mortar which popped out, pieces of which a few centimeters in length were found on the lower roof levels (fig 2). The areas of least mortar deterioration were located on the north and east facades of the elevator core (which protrudes from the east façade) and parts of the east façade office block. These two facades are the least exposed to large temperature changes and wind driven precipitation, therefore less damage from freeze-thaw cycles. Another possible cause for the deterioration of the mortar, although difficult to confirm, is the structural movement of a tall building. Movement induced by wind and building creep (shrinkage) must be absorbed by the caulked horizontal compression joints located below the shelf angle of each floor. Many of these joints had failed either by excessive compression which forced the sealant out of the joints (fig 3), or by excessive tension which split the joint open. In a few instances the compressive forces were so high that the edge of the stone panels spalled off. The lack of the ability of the compression joints to absorb the stress imposed on the cladding resulted in a transfer of the forces to the mortar joints of the stone and glazed terra cotta, which in turn failed.

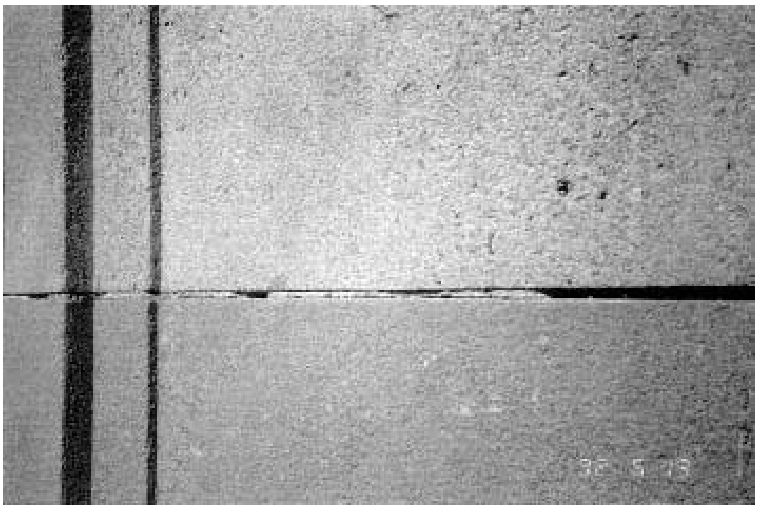

Fig 2 Deteriorated mortar due to excessive compression

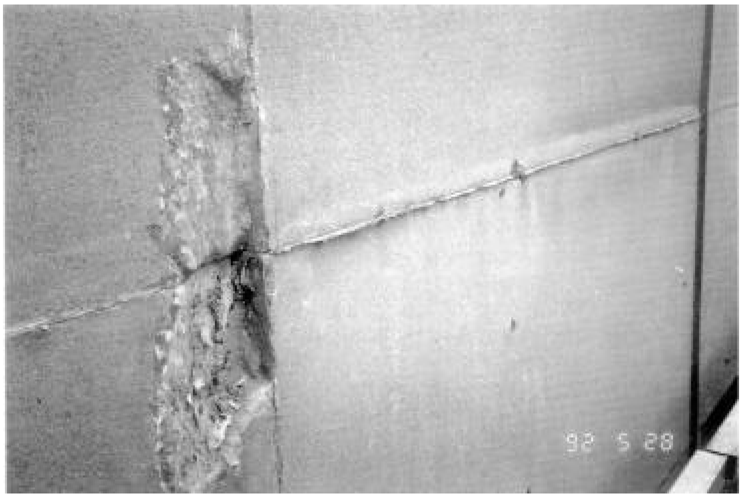

Fig 3 Stone panels spalling at compression joint due to excessive compression

The requirements of the repointing mortar were established as being increased flexibility, greater bond strength, and a high compressive strength in order to better resist the structural and thermal movements of the tower cladding. Our investigation lead to the suggestion to use a latex additive in the mortar mix, however there was very little field data available on its use in this context. The document which proved most useful and conclusive on the properties of latex in a cementious mix was the Transportation Research Board (USA) Synthesis 179 Latex-Modified Concretes and Mortars[1]. Although directed mainly to the area of highway practice, the parallel between masonry mortars and portland cement mortar used in highway repair and construction were sufficient to make the data very usefully. This report is a synthesis of the research and practice in the use of latex in concrete and mortars from Japan, North America and Europe. It compares and resumes the data of 132 books, articles, papers and presentations on the subject. It was the most comprehensive and complete document available to us at the time and proved decisive in our decision to use latex in the repointing mix. The graphs presented in this paper are drawn directly from it.

A type N premixed mortar containing 1 part portland cement, 1part hydrated lime (type S) and 6 parts sand was selected. The latex additive was an acrylic formulation from Laticrete International specifically designed for masonry mortars. The latex was added to the water in a ratio of 1:1. Laboratory tests were performed to determine the compressive resistance of the mix with and without latex. The first results confirmed a compressive strength of approximately 750-psi for both mixes, contrary to what we were expecting. When the curing process was changed from a moist cure to an air cure, the results changed significantly with the latex mix doubling in value to about 1,500 psi and the standard mix remaining the same. This confirmed that the formation of the latex matrix only occurs when the water has been absorbed or evaporated.

The choice of a premixed mortar was made to better control site mixing and facilitate mixing on the scaffolding in small quantities. All joints were repointed to a minimum depth of 25mm (joint width of 9mm). No application, finishing or staining problems were encountered during the installation.

Inspection of the joints on the south side (during a window washing operation) five years after completion (1998) did not detect any anomalies, however a more through inspection would be required to confirm the performance of the repointing mortar.

Case Study II- Saint Patrick’s Basilica, Montreal

Built in 1847 to serve the needs of the rapidly expanding Irish Catholic community of Montreal, St. Patrick’s is an imposing structure. The solid Montreal limestone walls are nearly 2m thick at the foundations reducing to 1m at the top of the 36m tall tower. The exterior is finished with dressed stones while the interior side is a rough cut stone. Lateral stability is provided to the side and apse walls with buttresses centered every 7.6m (25 ft.) raising the full height of the wall,14.5m (48 ft.). At the base, the buttresses are approximately 1m in depth by .75m in width and are stepped three times, each shoulder being capped with a single sloped stone. The projection of the roof edge is such that the buttresses above the second shoulder are sheltered from roof water. Below the second shoulder the buttresses are exposed to constant wetting from rain or melting snow. Over time this configuration has lead to the deterioration of the masonry up to the second shoulder to the point that the dressed stones were completely replaced by 1950. However the damage due to water saturation and freeze-thaw cycles continued requiring repeated repairs. An extensive restoration project, started in 1986 and completed in 1998, saw the repointing and resetting of loose stones of the buttresses in 1988. The mortar mix used at the time was a 1 portland:1 hydrated lime: 6 sand. All joints were fully repointed and the mortar was mixed on site. To help alleviate the problem of water saturation, a siloxane based penetrating sealant was applied from the second shoulder down.

Unfortunately this restoration work did not prove successful in terms of durability. By 1997, water had again saturated the buttresses and many mortar joints had failed (fig 4). Apart from being disturbed by this failure, we established a testing program which set out as an objective to select the most performing mortar for this very demanding condition. Benefiting from the scaffolding required for the replacement of the roof (1998), all buttresses (except the apse) were fully repointed up to the second shoulder. Several mixes were established as follows:

<u>With hydrated lime type S</u>
Mix # 1 1:1: 6
Mix # 2 1:1: 6 with 10% latex
Mix # 3 1:1: 6 with 20% latex
Mix # 4 1:2: 8
Mix # 5 1:2: 8 with 10% latex
<u>With hydraulic lime</u>
Mix # 6 1: 3
Mix # 7 1: 3 with 10% latex

The percent of latex is with respect to the weight of binder (portland + lime).

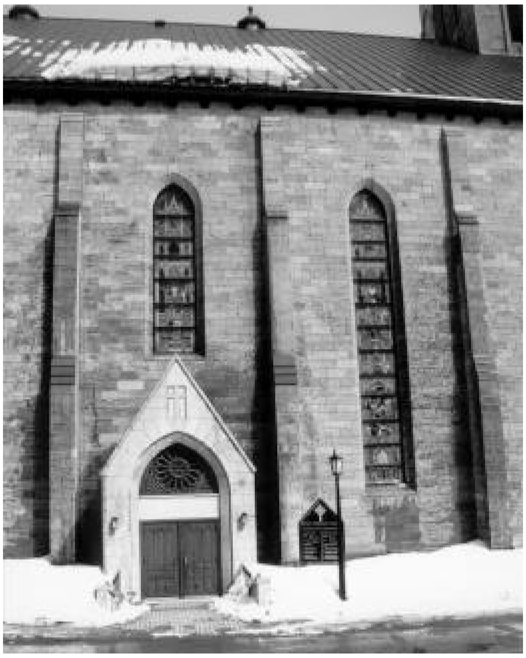

Fig 4 Buttress in 1997
Note ice formation at joints on left

Fig 5 Buttresses 2 years after repairs

A total of four buttresses were repointed with mix #1, two buttresses each for mixes #2, #3, #4, #5, and # 7, one buttress for mix # 6. The mixes were evenly shared between the east and west walls, except for mix #6 which was placed only on the west side. The apse buttresses were not repointed since the roof geometry is such that they receive little roof water, hence were in satisfactory condition. All materials including water for each mix were measured and packaged in the testing laboratory of the mortar manufacturer. The joints were repointed to a depth of approximately 20mm and all cracks and surface fissures were repaired with Jahn M70 restoration mortar. No penetrating sealer was applied but lead shoulder flashings were installed to aid in the deflection of water (fig 5).

Having been completed less than 2.5 years ago, it is still too early to arrive at any conclusions regarding these tests. For the moment, only photographic documentation has been taken to record the progress of the performance of each mix. Steps have also been taken, but yet concluded, to insert temperature and humidity sensors into the joints with remote data loggers. The information obtained could be used to develop charts to compare the water absorption and evaporation rates for each mix with respect to atmospheric data obtained from Environment Canada. This information could then be compared to the rate of visible deterioration of the various mixes and hopefully reach our objective of determining the most appropriate mix for these buttresses as well as obtain a better understanding of how latex-modified mortars perform as repointing mortars. A monitoring program such as is this has been established for the restoration of the Peace Tower, part of the parliamentary buildings in Canada[2] following it's restoration in 1996. It is our intention to monitor the test for a period of ten years and hopefully publish the results at that time. To our knowledge, this is perhaps the only and largest on-site testing program of various mortar mixes, with and without latex, in this country.

Brief Overview of Properties of Latex-Modified Mortars

The decision to proceed with the use of a latex-modified mortar for the repointing of the Bank of Montreal head office, as well as the development of mortar tests on St. Patrick's buttresses, was based on the perceived benefits of the use of latex. Improved bond, flexural and compressive strengths as well as reduced water absorption and greater freeze-thaw resistance are the principal benefits. The tables and charts below, as drawn from the Synthesis of Highway Practice 179[1], clearly show the data to confirm these points. The significant drawback in terms of masonry repointing is that what may be perceived as a benefit is actually a potential problem and may lead to the deterioration of the masonry unit or existing mortar. Examples of this have been noticed on many of our restoration projects where walls originally placed with a lime based mortar were eventually repointed with a dense and too strong portland cement mortar. As a result. there has been either an erosion of the edge of the masonry unit or a deterioration of the mortar within the wall, or both. Too high a compressive strength is not a benefit for a wall with a relatively soft masonry unit (clay brick, some sandstones, etc.). Reduced water absorption has the trade-off of a reduced vapour transmission, a clear disadvantage for the breatheability of a wall.

TABLE 1
PHYSICAL AND STRENGTH PROPERTIES OF ACRYLIC LATEX-MODIFIED MORTARS

Acrylic polymer solids-cement weight ratio	0	0.10	0.15	0.20
Water-cement ratio	0.48	0.40	0.37	0.35
Tensile strength, psi				
28-day air cure	235	530	615	855
28-day wet cure	535			
28-day air cure + 7-day water soak	310	330	350	490
Compressive strength, psi				
28-day air cure	2390	5450	5715	5690
28-day wet cure	5795			
28-day air cure + 7-day water soak	4420	4700	5125	5460
Flexural strength, psi				
28-day air cure	610	1355	1585	1835
28-day wet cure	1070			
28-day air cure + 7-day water soak	735	950	1020	1050
Shear bond adhesion, psi				
28-day air cure	45 (A)	>500 (C)	>650 (C)	>550 (C)
28-day wet cure	185 (A)			
28-day air cure + 7-day water soak	140 (A)	290 (C)	300 (C)	330 (C)
Impact strength, inches/lb				
28-day air cure	6	12	16	22
28-day wet cure	7			
28-day air cure + 7-day water soak	9	11	13	18
Abrasion resistance, % weight loss				
28-day air cure	23.80	1.70	1.15	1.57
28-day wet cure	5.07			

1psi=0.007MPa; 1 inch-lb=0.113Nm

Footnote [4]

Of particular interest to our problem of water saturation of mortar joints is figure 7[3] which shows the rates of water absorption vs water immersion period. The conventional mortar rapidly reached near saturation and after 21 days of drying still had .75% by weight of water present while the acrylic mortar absorbed only 1/3 as much water and was completely dry after the same drying period.

Also of interest and concern is figure 8[3] which shows the rapid rate of reduction in the water vapour transmission when the percentage of latex is increased beyond 5% of the cement content. High polymer content is therefore not recommended.

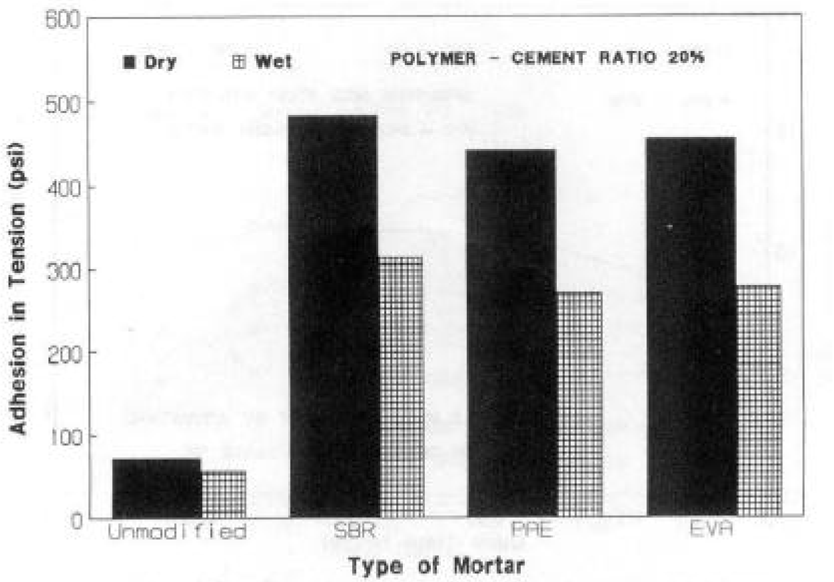

Fig 5 Adhesion in tension of unmodified vs latex-modified mortars[5]

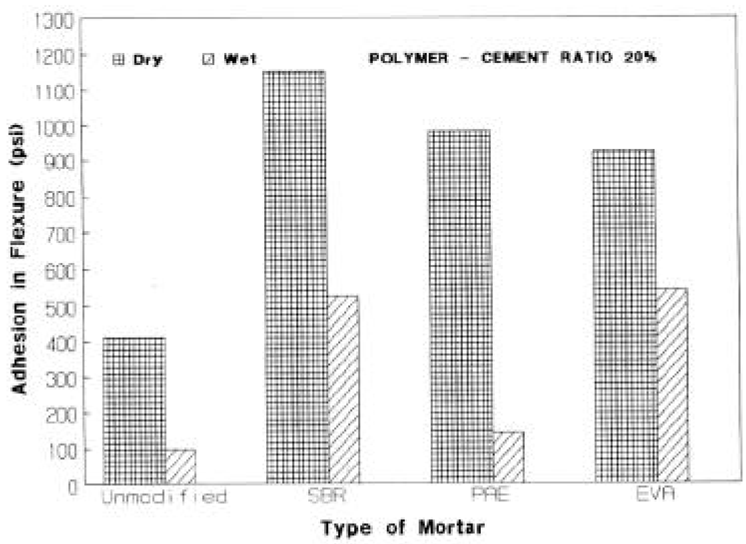

Fig 6 Adhesion in flexure of unmodified vs latex-modified mortars[5]

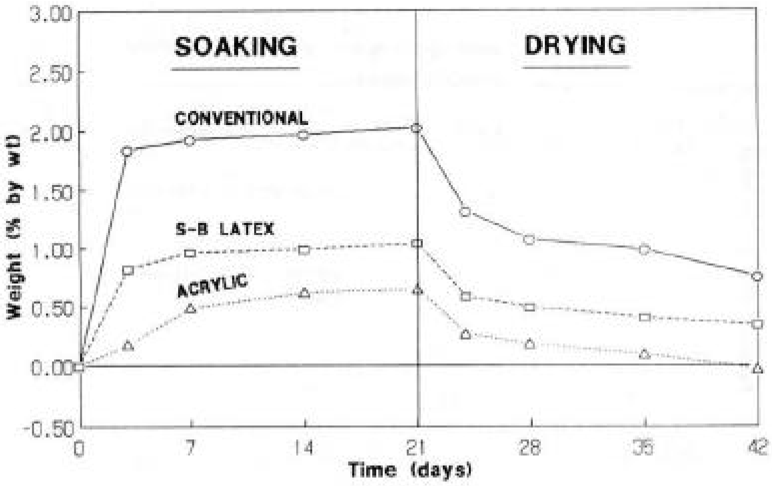

Fig 7 Water absorption vs water immersion period for SBR-modified mortar[3]

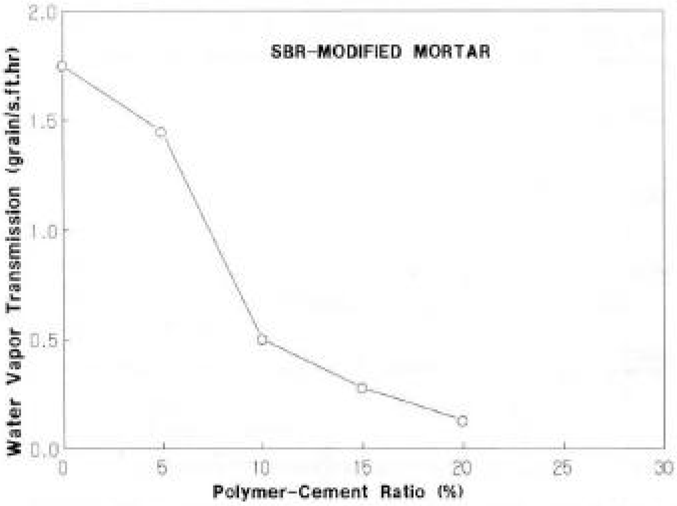

Fig 8 Water vapour transmission in mortar vs polymer content[3]

As with conventional mortars, the properties of latex-modified mortars are dependant on other factors. The type of latex, cements, lime and aggregates used as well as the ratios of the materials and environmental conditions during placement and curing will have a direct effect on the performance of the repointing mortar. These factors must be well controlled in order to achieve the expected results.

CONCLUSION

This paper has presented two case studies where the use of a latex-modified mortar may present a solution where conventional mortars have failed. Areas such as buttresses, cap stones and plinth stones which are exposed to excessive water saturation, as well as walls which are subject to excessive movement, such as on tall buildings, may derive a benefit from the use of a latex-modified mortar. We can also report the successful use of latex in mortars used for the setting of stones on entrance stairs and landings, items in need of repeated repairs in this country. However, the general use of this type of mortar is not recommended due to the disadvantages it could present. Before the decision is made to use a latex-modified mortar as a repointing material, one needs to have a clear understanding of the causes of deterioration, the nature of the existing masonry and mortar, as well as the risks involved. To this end, we encourage further research on this subject.

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