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INNOVATIVE OPTIONS FOR MASONRY REPAIR

A.J. Deveau, P.Eng., M.A.Sc.[1], and M. Van Dusen, P.Eng., M.Eng.[2]
[1]Shareholder, Halsall Associates Limited, 2300 Yonge St., Suite 2300, Toronto, ON, M4P 1E4, adeveau@halsall.com
[2]Shareholder, Halsall Associates Limited, mvandusen@halsall.com

ABSTRACT

Building Owners have varying needs with respect to exterior masonry wall repair and the extent to which degradation and performance problems are corrected. The best ‘technical’ or typical ‘engineering’ solution to repair distressed masonry is not always appropriate. Factors such as repair duration, cost, aesthetics, impact on building operation, asset planning and leasing should be considered to develop solutions that meet the business needs.

To meet these needs, careful evaluation and innovation are required from the Design Professional. Options need to be carefully evaluated to find a repair that best meets the Owner’s objectives without compromising function or safety.

This paper examines the wide range of masonry repair options that have been applied to meet varying Owner requirements. The options include unconventional patch repair and coating, as well as more conventional targeted repair and replacement programs. Case studies are used to present the repair philosophy, demonstrate how the solution best met Owner needs, and the considerations, risks and drawbacks that needed to be addressed.

KEYWORDS: Infrastructure, Restoration, Repair, Innovation, Ingenuity, Case Study,

INTRODUCTION

Today’s building Owners are faced with a multitude of considerations when determining a course of action to maintain their assets. These considerations include repair duration, cost, aesthetics, impact on building operation, asset planning and leasing. Repair and management strategies must be designed to balance these needs. Where low cost solutions are required, the Design Professional is relied upon to find innovative solutions for building repair and maintenance.

This paper presents three case studies, each using innovative repair philosophies that were tailored to meet individual Owner needs.

CASE STUDY NO. 1: GLAZED BRICK SPALLING

This 1960's vintage 8-storey residential building had extensive brick spalling on the upper floors (Figure 1). The exterior walls consist of exterior glazed brick connected to the back concrete block wall with header bricks. The interior wall finish is plaster-finished foil-faced gypsum board connected to wood strapping placed on concrete block. The pattern of brick damage (primarily at the upper floors) was consistent with high rain wetting areas. There was no evidence to suggest that interior vapour drive through the walls was a significant contributor to spalling.

Figure 1 – East Elevation; Extensive Spalling Of Glazed Bricks

Glazed brick is well known to be spall susceptible, as the vapour impermeable glazed finish traps water within the brick. This trapped water then expands upon freezing, causing spalling of the brick face (Figure 2).

Figure 2 – Close-Up of Glazed Brick Spalls

Previous repair programs had been performed at the building at unknown dates. These repairs consisted of replacing spalled brick with either new glazed brick (similar to the original brick), or with regular clay brick painted white to match the glaze colour. These previous repairs were generally sound. Spalled brick damage generally only affected the outer 6mm to 10mm of the unit. The remaining brick had some surface fractures, but was generally found to be sound and intact when struck with a hammer. Table 1 shows repair options that were presented to the Owner.

Table 1: Spalled Glazed Brick Repair Options

ADVANTAGE(S)	DISADVANTAGE(S)
REPAIR DESCRIPTION	
OPTION NO. 1 - Over-Cladding: This solution involves installing a new cladding system over the existing masonry walls, ideally with additional insulation.	
Reduced Maintenance: Reduced rainwater penetration reduces wetting and subsequent spalling. **Insulation Upgrade**: If insulation is included energy improvements can be achieved and the masonry can be maintained above freezing, thereby further reducing risk for future deterioration. **Renew Appearance**: The new cladding can rejuvenate tired appearances.	**High Cost**: Most costly solution, partially offset by reduced maintenance and energy consumption.
OPTION NO. 2 - Removing and Replacing Spalled Bricks: This is typically the most common means to manage glazed brick walls with localized deterioration.	
Appearance: Maintains the existing building appearance as closely as possible. **Conventional Repair**: Generally accepted as 'normal' industry practice.	**Ongoing Maintenance**: The exterior wall surface needs to be maintained in good condition to limit rain-water ingress and resulting deterioration. This requires promptly replacing spalled brick on an as-needed basis. **Brick Match**: It can be challenging to find new brick that acceptably matches the existing glazed brick appearance and size. Custom brick can be manufactured but require minimum order and long lead time. Coatings including paints and epoxy have also been used to manufacture replacement bricks.
OPTION NO. 3 - Parging and Coating: Non-Traditional Repair: Replacing brick where damage extends beyond 12mm in depth, and parging other spalled brick surfaces, followed by applying breathable coating to restore appearance and protect against further water ingress and the risk of trapping water within the brick.	
Low Cost: This option resulted in a cost savings of approximately 30% from Option No. 2. **Uniform Appearance**: The new coating provides a renewed appearance. **Reduce Rainwater Ingress**: Elastomeric coatings can be selected which limit water penetration and which are flexible and therefore able to seal small moving cracks.	**Ongoing Maintenance**: The coating will require re-application (17 to 25 years depending on the coating quality). This requires promptly replacing spalled brick on an as-needed basis (although at an expected rate below that of Option No. 2 due to reduced water ingress). **Unconventional Repair**: This practice is controversial to some in the industry for fear the coating may trap moisture. Vapour permeable coatings are available to address these concerns.

Owner cost constraints and desire for an improved appearance led to the decision to proceed with Option No. 3. Parge and coat repair has been employed at some buildings with poor success. Poor results are often attributed to parging mortars being too rigid and/or trapping moisture within the brick, both of which can lead to the parging debonding/spalling. In addition, the coating material can lead to failures by either a) not providing adequate protection against rainwater penetration, and/or b) trapping water vapour within the brick.

To reduce the risk associated with this parge and coat repair, a breathable flexible parging material was selected to provide better performance (Figure 3). The parging was allowed to cure before applying the coating, limiting risk of the coating debonding. A breathable (vapour permeable) elastomeric silicone coating was used to assure adequate adhesion to the glazing, lower the risk of water vapour being trapped in the wall and to limit rainwater penetration (Figure 4). This flexible coating also has the ability to bridge small cracks, which further reduces the amount of water ingress (small cracks – debonded mortar joints or cracked bricks – can be the largest source of water infiltration in masonry structures, but it is not possible in practice to maintain a completely crack free wall).

Figure 3 – 'Parge' Repair of Spalled Brick

Figure 4 – Application of Elastomeric Silicone Coating

Figure 5 – Work Proceeding on West Elevation

CASE STUDY NO. 2: INADEQUATE SHELF ANGLE SUPPORT
This 15-storey commercial building was built in approximately 1972. The east elevation exterior wall consists of a clay brick veneer supported at each floor on shelf angles with a cast-in-place concrete back-up wall. The brick veneer was laterally connected to the back-up wall with dove-tail ties.

The Owner had recently purchased the building and had reports identifying extensive problems with the shelf angle supports. These reports called for resecurement and/or replacement of the existing shelf angles at every floor. Replacing shelf angles in existing masonry walls is expensive due to the masonry removals, extensive shoring and/or piecemeal work sequences required (Figure 6). Due to the high estimated repair costs the Owner was looking to revise the scope of work to reduce costs.

(a) (b)

Figure 6 – (a) Temporary Masonry Post Shores in Place while the Inverted Angle Brackets are being Installed; (b) Masonry Being Reinstalled in Sections After the New Shelf Angle has been Installed

Investigative wall openings and probing of the joints below shelf angles confirmed that clear joints had not been provided below the angles. The investigative wall openings also revealed (Figure 7):

- Missing shelf angle anchors;
- Oversized burned holes in shelf angle;
- Loose nuts on shelf angle anchor bolts; and
- Lack of open joint (soft joint) below shelf angles.

The loads being carried by the masonry veneer were evaluated using flatjack testing equipment (as per ASTM D4729-87(1997) Standard Test Method for In Situ Stress and Modulus of Deformation Using the Flatjack Method). If the shelf angles were properly installed and performing as intended, the masonry should have been carrying a maximum load equivalent to the weight of one floor of bricks. The flatjack test results confirmed that the angles were not adequately picking up load because the amount of load found in the masonry was generally much greater than those of one floor.

Figure 7 – Shelf Angle Deficiencies Include Missing Anchor (Blue Arrow), Oversize Burnt Hole (Red Arrow), and Lack of Soft Joint Below Angle.

These extensive problems with the shelf angle supports posed a safety concern, as the only active vertical support of the 11 storeys of masonry veneer was the wall base. Therefore, the masonry veneer was essentially acting as an 11-storey stacked brick wall. The wall was designed to have a maximum of one storey of stacked masonry (with each storey being carried by a shelf angle).

To reduce the costs associated with replacing every angle, new larger shelf angles were designed to carry the masonry loads of three floors (Figure 8). This was possible because the floor slabs had sufficient structurally capacity to carry the additional load, and because the stresses induced in the masonry were acceptable. This reduced the amount of shelf angles requiring replacement by 2/3, which reduced the repair cost by approximately 50% (after accounting for the increased costs for larger shelf angles and increased quantity of retrofit lateral ties).

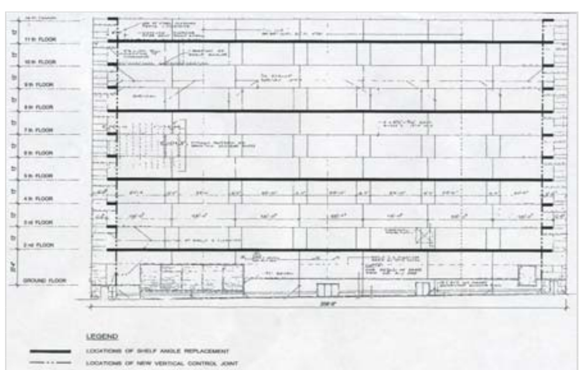

Figure 8 – East Elevation – Heavy Lines Indicate New Shelf Angles to be Installed On Every 3rd Floor (in lieu of every floor as originally installed)

CASE STUDY NO. 3: CORROSION OF STRUCTURAL SUPPORTS

This 16-storey commercial building was built in the 1920's, and is a fine example of art-deco architecture. The lower three storeys and upper two storeys of the south and west elevations are clad with a decorative Roman stone veneer, while the middle storeys have a combination of clay brick and exposed cast-in-place concrete spandrel beams with decorative finish. The masonry back-up generally consists of cast-in-place concrete beams and columns, with local areas of multi- wythe brick piers.

The stone and brick were supported vertically by shelf angles at each floor. Lateral restraint was generally provided by dovetail anchors (which were hooked into the stones). Most of the stone lateral anchors and shelf angle supports had extensive corrosion (Figures 9 and 10). Various repair programs in the 1980's had replaced the majority of the brick shelf angles. The stones had been left in place and were generally re-secured with a series of retrofit anchors, installed by drilling through the stone faces into the cast-in-place concrete structure behind in lieu of replacing the angles. There were minimal records of these repairs – varying types of retrofit anchors were installed over many years. One example of such a repair is shown in Figure 10 where the 3 large threaded stainless steel rods seen were previous retrofit anchors (similar anchor locations can be seen in the face of the adjacent stone to the left). An extremely corroded original shelf angle can be seen directly above the retrofit anchor rods (only portions of the vertical angle leg remain).

Figure 9 – Typical Spall (red arrow) at Corroding Lateral Stone Connection (brick has been removed from above stone).

Figure 10 – 15th floor stones removed. 3 previous retrofit anchors and an extremely corroded original shelf angle shown.

The stones were also extensively spalled and cracked (Figures 9 and 11), generally as a result of the corrosion of the original steel supports and lateral ties. While local repairs were presented as a management option, ongoing and increasing cracking was expected to cause further damage to this historically significant architectural feature. Repair and protection was required to restore structural integrity, to limit water ingress and to correct problems with deterioration. In addition, the stones were very dirty and were in need of cleaning to renew appearance.

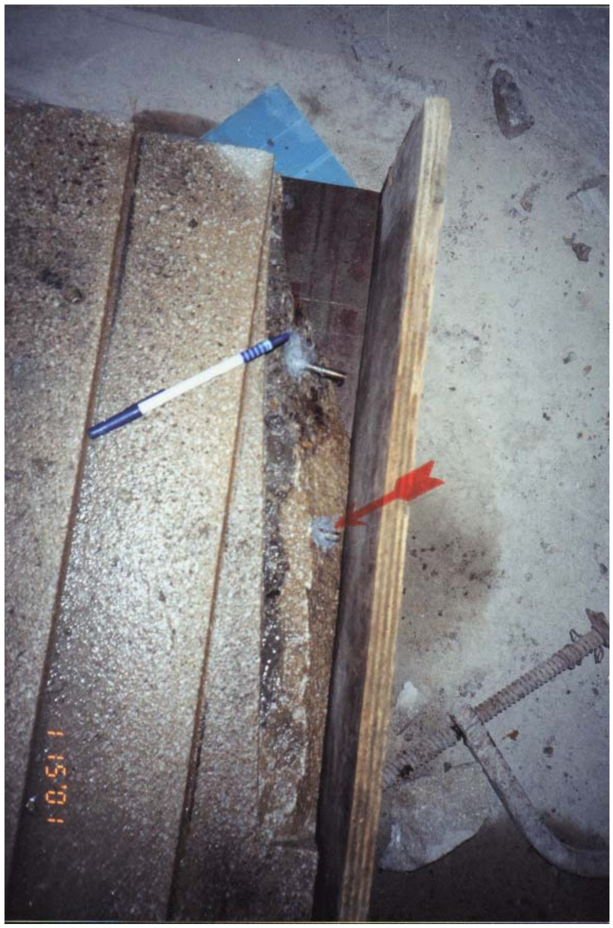

Figure 11 – Cracked Stone (cracked portion removed). New stainless steel dowels installed to 'stitch' the cracked portion back to the stone with epoxy adhesive.

The Owner's goal was to implement a durable repair to preserve the asset, reduce future maintenance repair and risk of disturbing tenants. In addition, the Owner was also in the midst of a general building renewal program to re-position the building and therefore elected for the higher initial cost option of stone removal and reinstatement.

Therefore, the restoration program designed included removing all of the stones, installing new stainless steel supports and reinstalling the stones (Figure 12). The stone spalls and cracks were repaired and the stones were cleaned after they were removed (Figure 11). Upon reinstallation, a sealer was applied to the stones to reduce water infiltration and dirt pick-up. Figure 13 shows before and after photos of the south and east elevations.

Figure 12 – Reinstalled Stone with New Stainless Steel Supports

(a) **(b)**

Figure 13 – (a) South and East Elevations Prior to the Work (note the stone staining), (b) Same Elevations Nearing Completion, after the Stones have been Removed, Cleaned and Reinstalled.

CONCLUSION

The three case studies presented show a wide range of masonry repair solutions, from low-cost unconventional parging repairs to higher cost removal, repair and reinstallation programs. Repair designers should evaluate the building Owner’s needs as part of the building evaluation process so repair and management philosophies can be matched with the Owner’s interests and at the same time ensure safety.