REROOFING PROJECTS FOR HERITAGE BUILDINGS AND DAMAGED MASONRY:

Is There a Connection?

BY PAUL JEFFS

For the past 25 years, my firm has provided concrete and masonry-related consulting services for a variety of projects, many of which resulted in major restoration of heritage masonry structures or older buildings. During this time, it has become obvious that damage occurring to exterior masonry walls has often followed major reroofing work. Sometimes the earlier roof project included replacing slate with slate, sometimes slate was replaced with shingles, and sometimes a metal roofing system was installed. During investigation into the potential cause of the masonry damage, a typical question has been: Was there a connection between the masonry damage and the reroofing project? Unfortunately, to date, this question has often remained unanswered; or, at best, the link was not possible to prove.

It should be made clear at the outset that I am not suggesting the observed damage was directly and only caused by the reroofing work, nor suggesting that damage will typically be caused whenever reroofing work is carried out. Indeed, often the more likely primary causes have been poor architectural detailing of window openings and other design factors; and, sometimes, problems have been caused by the deterioration of the inner portion of foundation walls (more on this later). However, what I am suggesting is that there is a very strong possibility reroofing of older

Figure 1 – Bowing of upper portions of the clerestory walls was first observed about ten years ago.

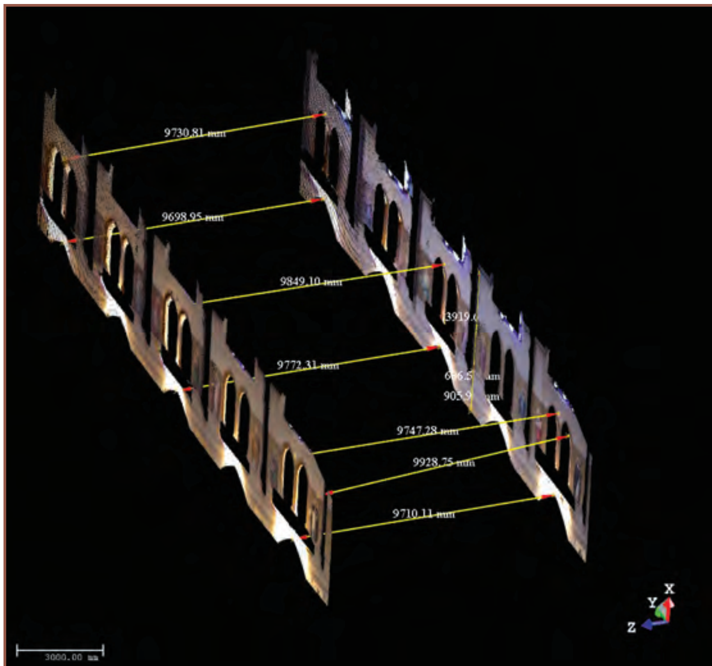


Figure 2 – Computerized illustration of 3-D laser scanning confirming outward bowing.

Figure 3 – The red circle highlights laser dots from two of four lasers (inset).

buildings can contribute to the occurrence of some damage, predominantly in the form of cracks or displacement of masonry; or it can increase the extent of damage that has already occurred or would have occurred had reroofing not otherwise been carried out. The objective, then, of this article is to alert interested parties to the need to at least consider the influence of future reroofing on the stability of traditional mass masonry walls and, particularly, the dynamic changes that could occur when loads are removed and then subsequently replaced.

Unfortunately, there appears to be a dearth of published studies that specifically explore any potential causal link between masonry damage and reroofing. Nor does it seem there are any textbooks that recognize a potential link and advise caution regarding potential damage that could be caused by inappropriate reroofing practices. So, to further explore the question raised in the title of this article, I would like to provide just a few project examples that may serve to illustrate the reasons for concern.

19TH-CENTURY CHURCH

The first example is a 19th-century church in Ontario (*Figure 1*). About ten years ago, cracks were first observed within the interior of the church at the ends of the upper (clerestory) nave walls. Later investigations using 3-D laser scanning techniques from both the interior and the exterior revealed that the center upper portion of the clerestory walls bowed outward some two or three inches (*Figure 2*).

It was not known with any certainty when the cracks were first caused, but the most likely probability is that the outward bowing occurred during the original roof construction, particularly since the "soft" hydrated lime mortar used for masonry construction could have adequately accommodated the movement without necessarily causing visible signs of distress. However, total reslating occurred during the 1950s and once again in the early 1990s; therefore, it is open to conjecture whether or not one of the reroofing projects resulted in the occurrence of the cracks since, after many decades, the lime mortar would have become much more rigid and thereby less accommodating of developing stresses.

The possibility that the bowing of the walls could have been an ongoing progressive phenomenon naturally raised major concerns, particularly since—following an engineering review—it was recommended that consideration be given to reinforcing the walls across the interior. (The retained structural engineer pointed out there was a potential for additional outward bowing that could result in a catastrophic collapse of the roof.) A separate concern was that the 1990s reroofing work had not been successful, and the slate was once more in need of replacement.

Since there was a potential for yet even more bowing to take place during the planned reslating of the roof, it was determined that quantifying dynamic evaluations of the movement should be carried out.

Displacement-measuring lasers were therefore installed at either end of one of the clerestory walls, directed across the nave at the opposite wall, and set to record measurements every four hours to a data-logger (*Figure 3*). A temperature sensor was also installed on the exterior of the church. The data gathering continued over almost one year, after which the results were analyzed (*Figure 4*). These confirmed that, although the walls moved outward at the center a maximum of just over a quarter of an inch between the warmest and coldest times of the year, this movement was fully recovered at similar temperatures.

However, an equally interesting fact was that when measurements were subsequently examined before, during, and after the reroofing work that took place about two years ago, the walls moved outward about another quarter of an inch—but only after the slate was installed, and this displacement was not recovered. It is also interesting to note that the new slate had a more uniform nominal thickness than the slate used in the 1990s, thereby somewhat increasing the load on the walls.

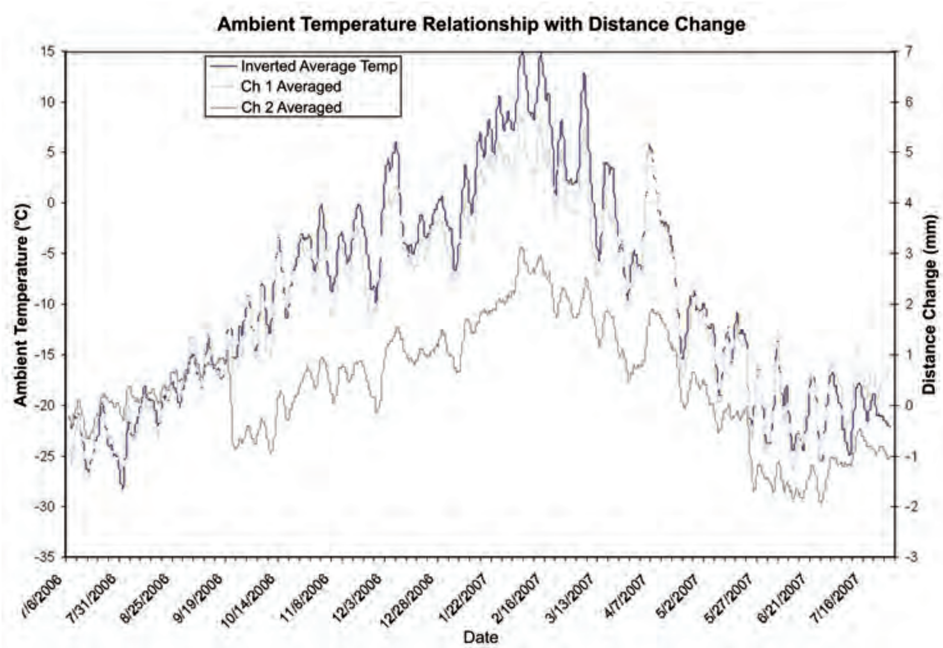


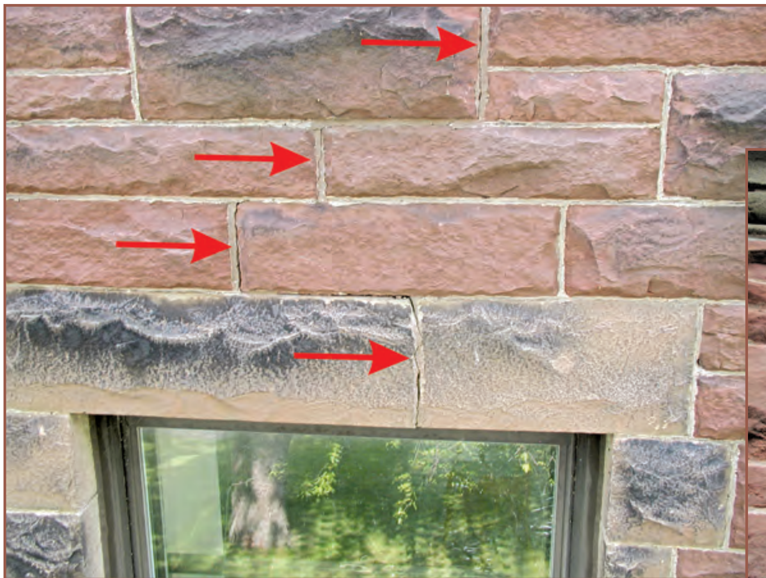
Figure 4 – The data gained over one year confirmed that the bowing of the walls was not progressive.

1870S MUNICIPAL BUILDING

The second example is an 1870s municipal building situated in Eastern Canada that had suffered extensive cracking of its masonry. Over the years, attempts had been made to repair the cracks, but each time they reopened or more cracks had occurred (*Figure 5*). Finally, a comprehensive investigation was carried out to identify the factors likely to have contributed to the damage; a restoration strategy was appropriately developed; and, during 2010 and 2011, phased restoration work was begun.

The earlier investigation included the use of ground-penetrating radar—a nondestructive testing technique that confirmed a considerable number of voids had occurred within the inner core rubble of the traditional mass masonry foundation walls. The voids were considered most likely to have been the result of water infiltration through deteriorated joints—particularly since it was known that flooding of the nearby major river had occurred over the years. In addition, a study of the building's basic design confirmed that the lintels across windows did not extend beyond their jambs, thereby concentrating gravity loads immediately within the masonry on either side of the openings. These two factors most likely

Figure 5 – Example of just one area of cracked masonry, together with a dislodged keystone. Note the failure of the previous repairs.



Figures 6 (left) and 7 (below) – Both of these buildings experienced extensive cracking following reroofing projects. Note the lintels rest only on the jambs. The building in Figure 6 also had hidden voids within its foundation walls.

contributed to the development of overload conditions within the exterior-wythe portion of the masonry, resulting in the cracks.

However, was it just a coincidence that the slate tiles had been removed from the roof some 30 years before and replaced with a metal roofing system? Perhaps a more important question is: Would the cracks have occurred if the building had not been reroofed, even with the existence of the identified deficiencies?

DAMAGE AFTER REROOFING

Two other traditionally constructed buildings in Eastern Canada were also discovered to have similar extensive damage that was determined to have occurred after reroofing had taken place to replace aging slate with asphalt shingles (*Figures 6* and *7*). Although both buildings had lintels that did not extend beyond their window-opening jambs, following ground-penetrating radar investigations,

Figure 8 – In 1971, the roof of this building was removed and replaced with a redesigned structural steel superstructure.

only one was determined to have hidden voids within its foundation walls.

1990S ART GALLERY/MUSEUM

The final example—also in Eastern Canada—is an early 1900s art gallery and museum that underwent total roof reconstruction work during 1971, when its use was changed from a university fine-arts faculty building (*Figure 8*). Later, extensive cracking of columns and masonry units became evident (*Figures 9* and *10*). The damage was unsuccessfully repaired on several occasions over the years, but it was only during recent investigations that the primary cause of the damage was discovered: The steel stub columns connecting the roof structure to the masonry had been located directly over the inner-core portion of the walls (*Figure 11*). As a result of this inappropriate hidden detail, excessive gravity loads had been transferred to the exterior wythe of masonry rather than being uniformly distributed across the full masonry assembly.

In addition to studying the information provided by the project examples, we should also consider the following factors: First, comparatively few buildings are built today with slate roofs; and even fewer, if any, are built using traditional mass masonry assemblies. Second, the typical life of a slate roof ought to be in excess of 40 years. These factors together mean it is highly unlikely there are many experts across North America who have direct experience or expertise regarding the dynamic changes reroofing can have on traditional masonry walls. Third, the differences among the setting, hardening, strength-gaining, and durability properties of traditional hydrated lime mortars and those of modern cement mortars are not widely appreciated.

Also, decades ago, it was not appreciated that the movement accommodation dynamics of the building envelope would change slowly with age, and it was not necessarily perceived that its rigidity would eventually and dramatically increase during the service life of the structure. Therefore, unlike today, it was not usual to specifically design or construct movement-accommodating joints within the masonry assembly or to design for the accommodation of the stresses that could naturally develop during the drying and shrinkage of the roof structure wood components.

These last few factors mean that some older masonry assemblies may be particularly susceptible to damage in any event, even before reroofing work is scheduled. One last factor: Although it would most likely add considerably to the cost of a

Figures 9 and 10 – Extensive cracking occurred after roof reconstruction work and many attempts at repair were carried out.

Figure 11 – The hidden-from-view culprit was found to be the location of the steel stub columns.

reroofing project, I strongly recommend consideration be given to the avoidance or lessening of the dramatic change in gravity load transfer that must occur during the slate removal process and its replacement with whatever system is selected. In particular, when a lighter roof system is selected, the potential reduction in wind uplift resistance and the condition of roof-to-masonry connections should both be considered during the period the slate has been removed and not yet replaced on the opposite side.

CONCLUSION

To conclude on a more positive note, all the damage illustrated by the examples can be effectively repaired and prevented from recurring, provided the primary and contributory causes have been understood and appropriate restoration strategies developed, such as:

- Grouting of voids
- Below-grade waterproofing
- Installation of masonry ties across the masonry
- Installation of small-diameter rods within horizontal mortar joints
- Formation of movement-accommodating joints

It is hoped that this article has provided sufficient background that, during future masonry deterioration investigations and potential cause analysis, greater consideration may be given to the possible adverse influence the connection between the roof superstructure could have had on the supporting masonry assembly. Alternatively, in the event that reroofing work is being considered, a greater awareness of the potential connection may help to avoid the occurrence of further damage to traditional masonry.

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As principal of PJ Materials Consultants Limited, Paul Jeffs specializes in the investigation, cause analysis, and restoration of masonry and concrete structures. Prior to forming his firm in Ontario, Canada, in 1989, he was employed for over 25 years in the construction industry worldwide, the last 18 years with a multinational construction materials group headquartered in the United Kingdom. Jeffs also presents technical courses covering such topics as Conservation of Heritage Structures, Concrete Repair and Protection, and Modern Concrete Materials and Practices.

