Structural Practices

practical knowledge beyond the textbook

Observing Deficient Façade Repairs

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The present condition of a façade is often the result of its aging as well as of the period when it was constructed, as façade solutions are generally specific to periods of time and the profession's position on the learning curve. The author argues that repair and remediation solutions, evident in any existing façade, are also marked by the level of knowledge prevalent at the time of the repair.

Repair methods have evolved over time. Many first attempts were not adequate, and there have been several cases where repairs failed shortly after completion. The issue of prior repairs creates a dilemma for façade inspectors. This article illustrates this dilemma using examples of repair solutions for exterior corners of transitional masonry façades in New York City.

New Façade Solutions

The advent of skeleton construction led to the abandonment of bearing wall structural systems and the development of new façade designs for high-rise buildings. During the period between 1900 and 1950, the typical high-rise façade design used the perimeter steel frame to support the weight of the façade at each floor. These façades, referred today as "transitional," were allowed to be thinner because the masonry had lost its vertical load bearing function. They still had to resist out of plane wind pressures from floor to floor and, in many cases, they were relied upon to contribute to the building's stability as shear walls. However, fire protection concerns set a limit to the reduction in thickness. These walls were, in many cases, assemblies that consisted of face brick furred (backed) with terracotta blocks. With the incorporation of several additional materials, such as steel structural shapes and anchors, bricks, terracotta blocks, and more, the façade led to the loss of tried and trusted details of construction and the diminution of the traditional role of masonry artisans. The typical details for the transitional façades were disseminated mostly by means of manufacturer brochures and trade pamphlets. It took many years to fully understand the problems resulting from incorporating steel into the façade fabric; the painting of steel, required by the building code, had proved to offer poor long-term protection against corrosion.

The introduction of a new solution without fully understanding its long-term reliability was not particular to the transitional façades. It was just the result of the fact that the evaluation of the assemblies was being done primarily by observing "in service" performance.

For a couple of years following their introduction, new solutions might give the impression of success, but many serious defects would take years to surface and be recognized as systemic. Deficiencies related to weathering, especially corrosion, take a long time to develop; the formation of noticeable scale from corrosion might take 30 years. This time lag allows some systems to take hold for long periods of time. Occasionally, during these periods, the industry would discover weaknesses and would develop improved solutions.

For example, around 1900, the use of terra cotta in façades became very popular. The industry published a detailing manual, *Terra Cotta Standard Construction* in 1914. At that time, terra cotta installations were believed to be highly impervious to water. Following a number of failures due to water penetration and subsequent corrosion of terra-cotta anchorages, the standard was revised in 1927 with the authors noting that the changes were the result of a "*careful study of the behavior and weathering properties of exterior building materials*."

When inspecting a terra-cotta façade element, it is thus useful to know whether it was installed incorporating the more prudent details of the 1927 manual. The recognition of corrosion of perimeter steel in transitional façades followed

Figure 1. Cavity wall from the early 1960s. Different brick colors indicate various repair campaigns.

Figure 2. Cavity brick face collapse. The corroded tie does not engage the face brick anymore.

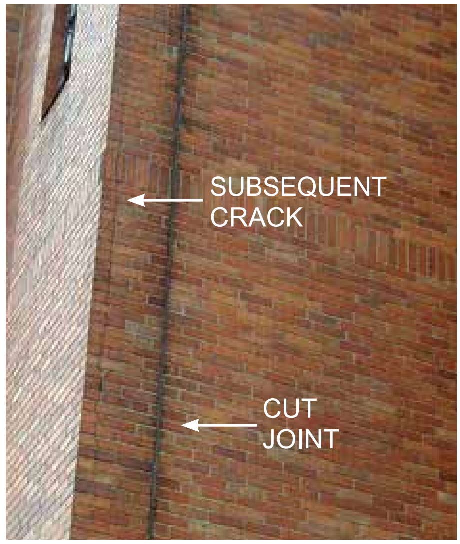

Figure 3. Ineffective repair. The vertical joint was cut without cleaning steel – a new crack appeared.

Figure 4. Bearing masonry corner repair.

the same pattern and timeline. The significant length of time can also be explained by the fact that the first generation skeleton frames used wrought iron and some types of steel alloys that were less prone to corrosion.

Around the 1950s, cavity walls started to replace transitional envelopes in high-rise buildings. The idea of the cavity wall was derived from hollow wall systems, a solution that had proven successful over time. Following some positive fire and structural tests near the end of the 1950s, most local codes permitted such construction types. The first generation lacked sufficient joints in the face brick. It took almost twenty years to understand the serious problems posed by the thermal expansion of the face brick or by the water evacuation from the cavity. Almost all façades built during that period had to undergo a major retrofit that included cutting joints and adding or reconstructing flashing (*Figure 1*).

The lessons learned from the first cavity walls helped form the detailing practice of later generations. The identification of some of the various systemic defects of the cavity systems – such as flashing details, maintenance of weep-holes, joints in shelf angles, frame/façade movement compatibility – spread over many years and came in increments. From time to time, trade associations and manufacturers updated their recommendations and produced improved details that eliminated the newly identified deficiencies. Any present day evaluation and repair may benefit when it considers the cavity wall condition in light of the specific stage of understanding existing at the time of the original installation and the subsequent repair.

Several recent collapses of face brick have revealed the lack of sufficient metal ties anchoring the brick veneer. Missing or corroded ties created problems and had been reported by forensic engineers since the 1990s, but they were considered rare or unique cases (*Figure 2*). Because this type of deficiency had not been identified as specific to the first generation cavity walls, remedy efforts may have been limited. Several recent accidents and pressure from the New York City Department of Buildings (NYC DOB) should result in a retrofit campaign to identify and repair this type of defect.

Over-Extending Lessons Learned

Aside from a few historic preservation specialists, there were only a very limited number of professionals with a solid knowledge of past façade systems when the New York City Local Law 10 for periodic façades inspections was enacted in 1980. Repair of façades was the domain of contractors. At that time, the cavity wall was the most common solution for new façades, and the thermal movement of face brick was already accepted as a principal cause of distress. Cutting joints in the face brick was a typical retrofit prescription.

Engineers and architects that entered the field as a result of the local law had few resources from which to gain specialized knowledge. With a lack of better solutions, they adopted and extended to other types of façades the use of joints as a repair method. This might have been a period of over-reliance on joint cutting solutions. Cases exist where façades had horizontal expansion joints cut along steel spandrels or the building's corners (*Figure 3*). In contrast to the jagged cracks that form randomly and that may lead to pieces of brickwork falling, a joint is, in essence, a man-made crack that can be managed. Of course, the technology of joint caulking is far from perfect, and a joint itself might become a source of water penetration. However, cutting joints in the outside wythe of cavity walls proved to be an effective solution for releasing the stresses produced by restraints on the tendency of the face brick to move.

Cutting joints without ensuring that the now separated element is anchored to a backup can lead to accidents. On one occasion, the author investigated a case where the face brick of the cavity wall collapsed soon after joints were cut because metal ties were missing. Similarly, cutting joints close to the corners of unreinforced masonry parapets avoids the formation of dangerous diagonal cracks at the corner. However, such solutions might not take into account the loss of lateral support that is offered by the parapet return. Reinforcing the parapet (with or without creating a joint) might be a more reliable solution.

Corners Cracks at Transitional Façades

Old bricklaying manuals indicate that builders were well aware that masonry corners provided "the main strength of brick buildings." Vertical cracks at bearing masonry corners are rare. When they do occur, they produce a weakening of the load path and might also allow the occurrence of geometric instabilities in the intersecting walls. These potentially dangerous conditions require

Figure 5. Typical corner crack. Cavity wall (left); Transitional façade (right).

Figure 6. Ineffective crack repairs at corners. Elastic compound fill (left); Mortar fill (right).

immediate restoration of continuity. The most common solution uses steel plates anchored into the intersecting walls. This solution is not expensive but is liable to fail (*Figure 4, page 27*). The proper repair should entail reconstruction of the masonry at the corner.

Vertical cracks around building corners represent a typical distress of transitional façades (*Figure 5*). They have occurred in many different face materials: brick, terra cotta, and even stone. In the case of brick faced buildings, long vertical cracks rarely occur at other locations. Masonry cracks at corners of skeleton construction do not necessarily affect the structural stability of the building but might constitute a danger to pedestrians.

The first method that was used for crack repair involved plugging the cracks, with mortar (*Figure 6*). This avoided the danger of brick separating and falling, and reduced the rate of water penetration. However, the cracks started to open again. Placing elastic compounds in the crack was not more effective. These solutions did nothing to arrest the corrosion of the underlying steel.

Figure 7. Collapse at corner. Masonry fill along cut joints.

Studies on cavity walls indicated that corner cracking was the result of the convergence of movement of masonry on both sides of the building corners. An explanation was provided that seemed pertinent to corner cracks at transitional façades. Under the influence of these studies, a typical 1990s corner repair design involved full height vertical cuts placed close to the corner. The masonry was removed to allow cleaning and rust proofing of the exposed sides of the steel column. The brick was replaced in a manner that created joints along the vertical cuts on both sides.

These new joints served the intent to avoid the damaging combination of movement of the perpendicular fronts, but they severed the horizontal continuity of the masonry. Collapses occurred in cases when the repair did not include anchoring the new vertical corner stack to the steel (*Figure 7*). On the positive side, joints on both sides of the corner allowed the new brick to expand when exposed to the weather, without being restrained by the old masonry that had already exhausted its ceramic expansion.

Later studies and reports specific to transitional façades added several other possible causes for cracks, such as the irreversible expansion of fired clay products when exposed to humidity and steel columns restraining the thermal movement of the brick infill. Other causes include incompatibility between the movement of the structural frame and the masonry, and steel spandrel members deflecting and imparting a vertical load to the masonry below.

These explanations are all valid, but they only describe the original cause of cracking. Today, almost one hundred years later, the visible cracks are the expression of steel column corrosion. Under the conditions of the New York City climate, a crack will enlarge under repeated cycles of icing and the masonry will not revert to its initial shape whatever the initial cause. The cracks facilitate increased water penetration and, when present, the subsequent corrosion of the steel. Once steel begins to corrode, rust jacking takes over and becomes the main culprit for the evolution of cracks.

While not contesting the validity of any of the wall movement explanations, one needs to consider that the level of façade deterioration is in direct relation to the capacity of exterior water to penetrate the skin and induce steel corrosion. Brick is a porous material that, even in the absence of cracks, allows some water to migrate towards the interior. Obviously, the rate and frequency of this migration are dependent on wall thickness. Numerous visible horizontal cracks, typical in transitional façades, are the consequence of beams and spandrels being protected by only one brick wythe. The fact that the corner steel columns have two sides facing the exterior is a particular liability and might be a major contributor to cracking. When corrosion forms on one of the column's faces, it will lead to the cracking of the perpendicular masonry wall that provides some restraint. In short, issues of expansion and movement might play a role in the initial crack formation and consequent steel corrosion, but the repair solutions should focus on the corrosion protection of the steel. As further proof, one should consider the cases where

Figure 8. Corner repair without cut joints – before and after.

improper rust-proofing led to new cracks forming, despite the introduction of joints.

By 2000, the solution of joints on both sides of the corner of transitional brick walls had run its course; corner repairs involving a single joint or no joint at all were being implemented. These solutions respect the original architectural intent but risk the potential cracking created by the pressure exerted by the new brick's tendency to expand and press on the old bricks. One can avoid such cracks by using soft/low strength mortar and sequencing the toothing between the old and new bricks.

In 2001, the author designed the repair of a 1940 transitional façade that displayed severe cracks, especially at its exterior corners. The design involved removing sufficient bricks to allow the cleaning and rustproofing of the corner steel columns. The removed bricks were replaced with new bricks bonded to the remaining bricks. After 15 years, no cracks can be observed around the corner (*Figure 8*).

Conclusions

This article described how some façade systems and repair solutions have evolved over time. In its beginning, the façade repair industry might have used solutions that were insufficient or created unintended consequences (e.g. the creation of joints destroyed the continuity and weakened the attachment of the façade to the structure). This article also illustrates a particular difficulty faced by façade inspectors that often need to assess the effectiveness of work performed in a previous cycle by a different team of contractors and engineers. In the absence of construction documents and limited to visual data, it may be challenging to differentiate between a retrofit, a repair, or a temporary fix. Looking at a corner that had vertical joints created on both sides, how can one determine if the new corner stack was anchored to the steel column?

Every façade has its particularities, but, in general, a façade is the result of the fashion during the period of construction, the ability of engineers to detail them, and contractors to execute them appropriately. The present condition of the façade also reflects the effect of weathering, and past repair and maintenance efforts. The identification of the façade's unique conditions and the root causes of its distress is the main responsibility of the inspector. As the façade inspection/repair profession has progressed, today one can expect a specialist in this field to be knowledgeable of the different historical systems and be capable of properly selecting appropriate repair recommendations from a variety of solutions.

There has been a steady increase in the number of published articles related to façade issues, but such piecemeal dissemination of knowledge is still far from satisfactory, especially for those entering the profession. To contribute to the development of the façade inspection specialty, the NYC Department of Buildings has published, online, *Façade Conditions – An Illustrated Glossary of Visual Symptoms*. This is the result of the collaboration of a group of respected local practitioners. Professionals that consider entering this field need more than a couple of technical papers or presentations – they need college courses with specialized tracks.■