

MASONRY FAÇADE ANCHORAGE FAILURES

THE NEED FOR GREATER INVESTIGATION PRIOR TO REPAIR

BY BLAIR E. BATES

Hundreds of thousands of dollars are spent annually on maintaining building envelopes. Unfortunately, many of the building façade repairs are being performed without a complete understanding of the overall condition of the building. In some cases, the existing veneer capacity has been reduced due to deterioration and the system can no longer continue to perform its intended role.

Today's dictionary defines masonry veneer walls as a construction system consisting of a single nonstructural external layer of masonry, typically brick, backed by an air space. The innermost element is usually structural, and may consist of wood, metal framing, concrete, or masonry. Walls constructed in this manner have several advantages over solid masonry, some of which are shared with the cavity wall (where inner and outer layers are both structural), while others are distinct to masonry veneer walls. Anchors are defined as any device that secures something else.

This article explains why masonry façade veneers are failing and what constraints and criteria should be analyzed during the engineer's forensic investigation to properly determine a repair solution.

FORCES AIDING IN FAILURE

Newton's law states: "A body at rest needs to stay at rest unless acted upon by an outside force." So, it is easy to understand that when a masonry veneer fails, there must have been forces acting upon it. Actually, there are multiple forces at work that originate from several primary sources, such as:

- Gravity—This force is vertical in direction and proportional to the mass of the veneer. Gravity applies the same pulling force regardless of the veneer location on the building façade.
- Wind—Wind exerts pressure on the veneer walls of a building via both pushing from the direction of the wind and suction on the backside or sides of the building as the wind wraps around it. Typically, negative or suction forces are greater than the direct prevailing wind forces on a building. Wind loads tend to be greater near corners or other locations of discontinuity of the veneer.
- Seismic—Seismic loads are induced due to the acceleration of the earth during an earthquake or aftershock. Unlike wind loads, seismic loads

can be both perpendicular and parallel to the face of the veneer.

- Vibration—Whether rail traffic, truck traffic, construction nearby, or construction within, the continued vibration of the building façade from the constant pounding of external forces can aid in the disruption of veneer connections.

UNDERSTANDING DESIGN AND DETERIORATION

Load paths—Load paths start with the individual sections of veneer. They accumulate and reach a supporting element, such as a lintel or anchor, which transfers the load into the structural element, such as a column, lintel, or bearing plate. These elements then transfer the load to the building frame. If deteriorated, these items have reduced function.

Façade anchorage devices—Brick ties are the most common type of anchor for holding sections of brick from being pulled away from the façade. Steel lintels transfer the weight of the brick (gravity load) to the building frame.

Veneer assembly deterioration—Brick masonry veneer starts with individual brick units and includes the mortar that either separates the bricks or glues them together. Sections of brick are prevented from rocking or blowing away from the base structure using brick anchors. The mass of brick is occasionally interrupted, using a lintel to transfer the load to the structure. Anchorage devices in the past have typically been made of steel but occasionally have been painted. Most recently, anchorage devices have been galvanized.

Veneer bonding—When veneer construction began, the backup frame was quite often vitrified clay tile (VCT). This material possessed the same thermal coefficient of expansion and creep characteristics as brick masonry. Evolution in building design switched from VCT to backup masonry consisting of concrete masonry units (CMUs). These units have different thermal coefficients and opposite creep characteristics. Bricks tend to expand over time and concrete blocks tend to shrink over time. Most recently, veneer construction is connected to steel studs.

Weep tubes—Air gaps between the veneer and masonry are installed as a thermal break and allow

leaks to be removed by installing weeps. Weep tubes are installed in the masonry veneer or cavity to allow water a path to escape if it enters into the cavity wall. However, in many cases, water running down the face of the building can enter through these weep tubes. This is especially prevalent when there's a negative vacuum within the veneer cavity.

Flashing systems—If a flashing system is installed, verify its integrity, especially at the seams.

Mortar systems—The mortar used in masonry veneers has progressed from low-compressive-strength/high-ductility lime and sand mortars to high-strength/low-ductility mortars that contain portland cement and other proprietary additives. In some cases, the new mortar has higher strength than the surrounding brick units. In Fig. 1, a failure of the brick veneer at the upper parapet wall occurred in a 5-year-old repair area where a stronger mortar than the original was used. An ineffective flashing system also played a role in the failure.

Brick systems—Exterior bricks have now become highly vitrified high-strength bricks with a high degree of initial creep due to their high firing temperatures. Due to the vitrification, these bricks have a low absorption rate.

AGE-RELATED CAUSES FOR FAILURE

Long-term positive creep—Bricks and clay tile are fired components that shrink or get smaller in the firing process. They naturally grow or creep with time after they are introduced into the environment. Therefore, the effects of creep on the masonry structure need to be considered. This is especially important if the veneer consists of long-term positive creep material while the backup structure consists of a long-term negative creep material.

Long-term negative creep—Portland cement-based materials, such as concrete and concrete masonry units, have a creep in the opposite direction of brick. Concrete tends to shrink slightly after casting.

Thermal coefficient of expansion—Materials expand and contract with various temperature fluctuations. Veneers that are located on the exterior of a facility experience a higher range of temperatures and rates of change than the interior back up material subjected to a more controlled environment at the interior of the facility.

Moisture intrusion, positive—Positive moisture intrusion is defined as moisture that originates from the exterior of the building, such as rain or driving rain.

Moisture intrusion, negative—Many buildings have been found to have a negative vacuum at the interior of the building. This is common due to an imbalance in mechanical systems. The building shown in Fig. 2 has a severe negative vacuum at the interior. Thus, moisture is being pulled through building weeps and other void spaces within the veneer,

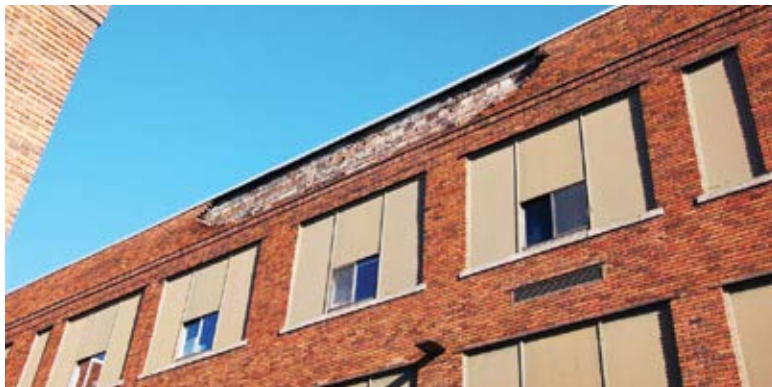


Fig. 1: Brick veneer failure at upper parapet wall of an elementary school, which occurred while school was in session



Fig. 2: Above this vertical shear in the brick masonry, 200 ft (61 m) of jumbo brick wall moved both vertically and horizontally, requiring immediate shoring and investigation for permanent repairs

which has resulted in deterioration. The deterioration is a result of freezing-and-thawing where water has been trapped within the veneer.

Mortar additives—Additives such as latex polymers, bond enhancers, set accelerators, retarders, and freeze preventers have all been used as additives to common mortars. Many of these additives have shown to produce adverse long-term effects to the durability of the veneer unit. Historically, calcium chloride has been added during the winter or cooler weather to speed up the set of mortar. The calcium chloride increases the corrosion potential of the steel within the construction that has contact with the mortar.

Steel corrosion—The expansive forces of corroding structural steel are very large and easily overcome the adhesive bond of the mortar to veneer. As the steel corrodes, the rust pack pushes the mortar and veneer away from the steel. Additionally, the steel loses physical strength due to the reduced steel cross section.

Previous mortar repairs—If previous repairs—such as brick replacement, tuck pointing, and patching—do not match the original mortar and stone or brick characteristics, then the discontinuity in materials affects the behavioral characteristics of the veneer system. Harder and denser tuck pointing mortar reduces the veneer's ability to flex

with thermal movement and allows trapped moisture to evaporate out. Thus, quite often, the deterioration of the parent mortar is accelerated.

Penetrating sealer applications—Penetrating sealers have commonly been applied to the exterior façade to reduce moisture infiltration and theoretically reduce the veneer deterioration. These materials have often been the cause of further accelerated deterioration of the mortar behind the sealer due to the inability for moisture to escape. Any moisture that has found



Fig. 3: Materials of different behavioral properties, including cast stone, clay brick, sand lime brick, terra-cotta tile, and polyurethane joint sealants. Previous leakage through joint sealants has caused deterioration of the brick

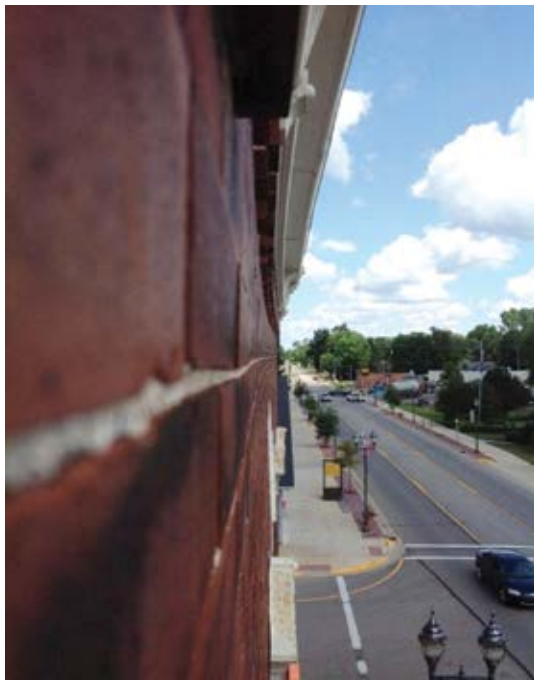


Fig. 4: A 1.5 ft (0.5 m) inner bow not visible from the sidewalk

a way into the system accumulates behind the penetrating sealer and in freezing conditions ruptures the mortar, stone, or brick façade. This moisture accumulation can be from either humidity transfer condensing into liquid water after reaching its dew point or water entering from open cracks or voids.

Joint sealant maintenance—While masonry-clad buildings give the impression of permanence (brick and mortar), the Achilles heel is the sealants at expansion joints or around openings. Until recently, these sealants have typically been urethane with a typical life expectancy of 5 to 7 years. A predictable maintenance schedule is rarely followed after initial construction is complete. Therefore, once the joint sealant deteriorates, water can leak behind the veneer for years prior to corrective action being taken (refer to Fig. 3).

INVESTIGATION AND EVALUATION

There are many observations that one can make while looking at the outside of a building and not disturbing it. But what you see is what you get. If you can't see all the elements and understand how they interact, it makes it extremely difficult to prescribe the proper treatment. Many owners, due to budget restrictions, would prefer that you just look at the building façade and give it a clean bill of health.

Close-up investigation from just a few feet away from the building can provide valuable insight into what is happening at the time of inspection. However, caution must be taken, as areas that have been repaired in the past may be providing a false cover of security.

Checking the vertical and horizontal planes for straightness can give a good indication of stress action on the façade (refer to Fig. 4). If the wall has begun to bow, then the veneer is moving and the anchors are giving way in either the veneer or the substrate.

Original drawings, if they are available, are a good resource of information. However, do not expect that the façade was actually built according to plans.

Some nondestructive test methods may also be used as follows:

- Metal detection—A metal detector can aid in identifying locations and spacing of the original or existing ties and load-transfer devices. However, knowing where an existing brick tie or anchor is located does not tell its condition or load-bearing capacity.
- Thermal imaging—Thermal imaging is extremely helpful in finding abnormalities behind the veneer. Figure 5 shows moisture buildup behind the brick veneer.
- Negative pressure testing—A simple test for negative pressure within the building envelope or cavity of the veneer system is to insert a manometer tube into the weep of the building cavity. Manometer tubes can provide measurable results

that can determine the cause behind water infiltration, including corrosion of the anchorages or freezing-and-thawing deterioration of the mortar and masonry system. If no weeps are provided, a drilled hole is effective. Recommended good practice is to obtain the pressure differential from the exterior to the veneer cavity, and from the exterior face of the backup material on the interior of the building.

Destructive testing can also be performed to assess the façade. Although it sounds like a bad thing, creating a small disturbance is a small price to pay as compared to an “uncontrolled disturbance” (that is, a section falling on its own). Some destructive tests are as follows:

- Borescope—Drilling a small hole into the façade and inserting a borescope provides a limited view behind the veneer. While the view is quite small and isolated to only a single location, the information gained may add to the overall understanding and help determine whether further investigation is required.
- Chloride testing—Simple extraction and testing of the mortar can verify if chlorides were used in the mortar mixture. If taken at various depths, this test can also determine if acid salts are present from inappropriate initial cleaning. However, use caution against drilling too fine of a dust extraction, as too fine of dust will alter the results.
- Mortar and veneer removal—Selective mortar removal allows for visual assessment of the mortar condition and consistency. The mortar on the exterior may visually appear to be good, but if the sample is repointing mortar, the remaining original mortar may not be up to par. If the existing mortar is to be relied on for a tension-holding device (helical anchor), it should be tested for its capacity. Most mortars that are pure lime have low to zero tensile capacity. Figure 6 shows the identification of the backup structural system following brick veneer removal. Figure 7 shows a variety of load-bearing materials used for a 1920 building construction.

DESIGN CONSIDERATIONS

Veneer capacity—Current building code requires brick veneer tie spacing at 2.67 ft² (0.25 m²) or no more than 24 in. (610 mm) on centers. This is based on the veneer’s strength assumption of using code-compliant brick (FBX) and mortar (commonly Type N or S). These have a minimum compressive strength of 4500 psi (31 MPa) for brick and 2500 to 3000 psi (17 to 21 MPa) for the mortar. The existing façade strength capacity needs to be determined to properly design the repair, especially if the façade repair has to meet current code compliance.

Existing load-transfer device condition—The condition of existing transfer devices should be

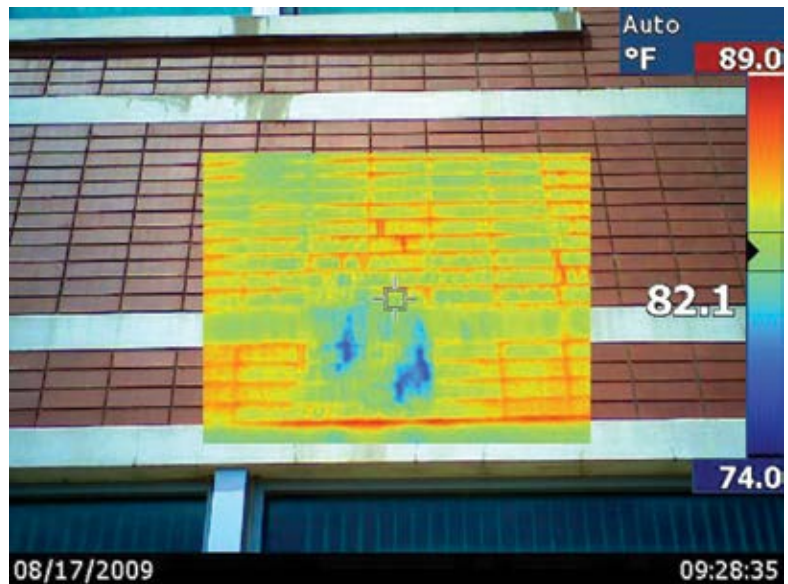


Fig. 5: The dark blue images show water on the surface, while the green areas show moisture behind the brick



Fig. 6: Destructive removals of the veneer system found that the backup structural block system was parge-coated during construction for waterproof integrity. The tie brick was actually inserted into the block wall system



Fig. 7: 1920 construction consisted of a variety of load-bearing materials including cast stone, hard- and low-fired brick, terra-cotta tile, steel, hard dense pointing mortar, and lime sand mortar

evaluated to properly assess deterioration and determine the existing system capacity.

Backup material condition and load-bearing capacity—Identifying the type and condition of the backup material is critical to proper anchor installation. Figure 3 shows the installation of various infill materials. If a new anchor system is selected for a restoration program, the strength of the anchoring device will be limited by what is holding it to the frame.

Mockup testing—Once a method has been determined for a repair, it should be tested in place to determine if the prescribed solution is capable of meeting the requirements of the design. This testing should be performed on both the backup material and the new anchorage device to verify that each element is capable of obtaining the desired strength. Figure 8 shows a pull test being performed on a 1/4 in. (6 mm) stainless steel anchor rod inserted into modified cement, mortar grouted.

Veneer diaphragm testing—The spacing of the original anchors is normally based on the determination of the original strength of the veneer. However, one needs to review the current condition and strength of the veneer. The strength of the veneer, as a plate structure, needs to be analyzed prior to determining the recommended new anchor spacing.

REPAIR CONSIDERATIONS

Surprisingly, many owners are not aware of all of the options available to them for repairing their buildings. An evaluation team should keep the owner informed of all options and their expected longevity, along with the required maintenance plan after the repairs have been performed. Considerations for repair should include the following criteria.

LIFE EXPECTANCY

Short-term immediate needs for life safety—There are times when buildings are reviewed and immediate concerns are discovered that should be



Fig. 8: Anchorage testing—two tests should be performed: one on the backup material and another on the brick or mortar at the exterior veneer surface. Without these two independent tests, verification of the veneer holding system is inadequate

addressed for life safety while on site. These concerns should be reviewed with the owner's representative immediately upon discovery, and followed up in writing immediately thereafter.

Medium-term repairs—A definition of the life expectancy of repairs should be provided to the owner for all options, including concerns on the longevity of repairs. An owner should be given the understanding of life expectations for medium- and long-term repairs; why the original system failed; and what the new repair will provide, along with its life expectancy prior to continuing maintenance.

Long-term repairs—The cause and effect of deterioration mechanisms should always be considered for long-term repairs.

MAINTENANCE PLAN

Once the repair has been made, is it possible to continue a maintenance plan, or has the repair covered up the possibility of observation to the building in the future? This would be the case with exterior insulating finish systems, better known as EIFS or siding systems. Once the repairs are complete, it is strongly suggested that the owner be provided a maintenance or reinspection schedule. Many owners consider repairs as permanent. The engineer needs to protect their liability by ensuring that the owner is aware that repairs are not permanent and the building needs to be maintained.

POST-REPAIR REVIEW

After repairs are complete or even prior to repairs beginning, a review of the structure should be performed to verify that repairs are performing as designed and installed.

TEAMWORK

If the contractor, engineer, and building owner work as a team, building repairs can be performed with greater success and longevity. All parties come to the table with an area of expertise parallel but not similar to one another. If efforts are combined, the greater good is achieved. Consider this the next time a building is in need of repair.



Blair E. Bates is President of Building Restoration, Inc., in Kalamazoo, MI. He is a graduate of the University at Buffalo, the State University of New York, Buffalo, NY. He has over 35 years of experience in the restoration of structures as an owner representative, engineer representative, and contractor. His work experience includes inspection, report writing, specification writing and implementation, and physically performing the work.