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Engineer conducting façade inspection via industrial rope access. Eight story hospital in San Francisco, CA.

Building Façade Inspection

Part 1: Considerations

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Structural engineers with varied experience in the areas of design, forensics, water and damp proofing, and construction are the best qualified professionals to conduct façade inspections. They have knowledge of how materials behave when subjected to imposed loads and movements. Determining the root cause of a deficiency can be very challenging, though not impossible if you understand how façades and building superstructures are constructed, how they behave when subjected to movement and load, and the possible failure mechanisms involved. This article discusses some of the important considerations that motivate building façade inspections; a subsequent one will describe the actual inspection and documentation process.

Background

A building's façade serves three roles:

- Structural resistance to wind, seismic, and gravity loads.
- Environmental protection from the elements, including moisture and temperature.
- Architectural appearance and aesthetics.

Façades are either load-bearing or curtain wall type and can also be a part of a solid or cavity wall. A solid wall is likely load-bearing and only has one moisture barrier. A cavity wall has the additional benefit of two moisture barriers separated by an air space.

With age, façades may experience degradation as a result of normal wear and tear and chemical exposure. Moisture, either penetrating the exterior or escaping the interior of a building, can cause rust and deteriorate supports. Water vapor pressure trapped within the veneer, along with freeze/thaw action, can result in cracks and spalls. Building movement in the form of shortening, caused by creep and shrinkage, and foundation settlement can cause cracks, spalls, and buckling of the façade. Differential expansion and contraction, caused by temperature and moisture changes, can also lead to similar failures. As one can imagine, northern climates experience more severe façade degradation compared to southern climates due to the colder temperatures, significant snowfall, extended periods of below freezing temperatures, and larger seasonal temperature changes.

Thirty or more years ago, not much was known about the effects of moisture changes and building movements on façades. Consequently, buildings constructed in this era lack modern detailing, including expansion and contraction joints and flexible connections, which address these effects. It is estimated that a piece of masonry falls off of a building in the United States once every three weeks. Unfortunately, it has taken front page news of personal injuries, deaths, and property damage to prompt governmental authorities and large private property owners to impose restrictions.

In 1976, Chicago instituted a façade ordinance to protect citizens and property from falling façade debris. Since then, major cities such as Boston, Columbus, Detroit, Milwaukee, New York, Pittsburgh, Philadelphia and St Louis have also adopted façade ordinances. The variability of these laws, ranging from visual inspection only to both visual inspection and close-up physical examination, led to the development of ASTM E 2270, *Standard Practice for Periodic Inspection of Building Façades for Unsafe Conditions*. This standard is intended for adoption by model building codes and local municipalities, as well as owners of multiple buildings. The adopting authority has only to define which buildings within their jurisdiction require inspection based on height, age, and occupancy.

Movement of Materials

While façades can degrade locally through environmental exposure to chemicals and moisture pressure and freezing, most deterioration can be traced to differential movements within the façade and supporting structure. Using multiple materials in combination often leads to such movement. If not accommodated by frequent horizontal and vertical expansion joints and flexible interconnections parallel to the plane of the façade, internal stresses can develop, resulting in façade cracks, spalls, and deformation. The following movements are known to occur.

Thermal

All materials expand and contract with changes in temperature. Fired clay, such as brick and terra cotta, and some stone products, such as granite and limestone, have thermal expansion coefficients similar to that of concrete masonry (CMU). Marble and steel have coefficients higher than that of CMU. Aluminum, often used in window and curtain wall framing, has a thermal expansion coefficient approximately three times that of CMU. Exterior cavity walls have the insulating value of an air space and thus will experience a larger temperature differential between the interior wythe, which is exposed to conditioned air, and the exterior wythe, which is exposed to the atmosphere, than a solid un-insulated wall. This can be greatest on a dark–colored, south-facing wall, where surface temperatures can be as much as 40°F above ambient. An insulated 4-inch veneer will have an average temperature roughly equal to the exterior surface temperature. A solid, uninsulated wall will have a lower mean temperature than the exterior surface due to the competing interior and exterior temperatures.

Moisture

With the exception of metal, most materials will expand and contract with changes in moisture content. However, fired clay products will not contract by drying; they are the smallest size when they cool after leaving the kiln and will continue to absorb moisture from that point, with most of the expansion occurring in the first few weeks followed by a much slower rate of expansion for several years. This expansion is partially offset by drying shrinkage in the mortar joints. Moisture absorption of concrete masonry, like cast-in-place concrete, is the largest after casting. Both shrink as they cure, but expand when exposed to moisture. The combined movements typically result in a net shrinkage.

Wood will shrink as it seasons until the moisture content is in equilibrium with the environment. Wood will continue to shrink and swell with changes in moisture content. Wood properties are anisotropic, so shrinkage and swell is greatest tangentially (parallel to the growth rings), half as much radially (perpendicular to the growth rings), and much less parallel to the grain in the long direction of lumber. A four story wood frame building may shrink as much as ¾ of an inch or more as the wood dries out. It is important to isolate different materials so that the shrinkage and swelling of one material does not impart stresses onto an adjacent material.

Elastic Deformation

Building materials will deform elastically with changes in stress. This deformation is reversible and is a function of the stress level within the material. All forces applied to a building must be considered, including gravity and lateral loads. In curtain wall construction, the exterior veneer is exposed primarily to lateral loads such as wind and seismic; the only gravity load should be the weight of the façade material above, which can be reduced by horizontal relief angles with integral expansion joints, often installed at floor levels. The supporting building structure will be subjected to all of the gravity and lateral loads, and will deform accordingly. Therefore, it is important to use expansion joints and flexible connections to accommodate these movements and ensure that structure loads are not shared by the veneer. Solid composite exterior walls are often load-bearing, and the materials that make up the wall will deform together. It is important that the component materials of a solid wall either have similar properties or incorporate detailing to offset the difference in material properties or minimize their impact.

Creep

Creep is the long term deformation of materials subjected to loads or stress. Creep in cast-in-place concrete, concrete masonry, and mortar is irreversible, starts immediately upon the application of load, and continues at a decreasing rate. In high-rise buildings, combined elastic, inelastic creep, and shrinkage shortening of columns and walls may be as much as 1 inch in 80 feet of height. Creep in lumber can range from 0.5 to 1 times the dead load deflection, with half of the creep deflection being irreversible.

Corrosion

Steel embedded in masonry and concrete includes reinforcing bars, joint reinforcing, ties, anchor bolts, shelf angles, and lintels. Rusted steel embeds that have lost 25% or more of their cross sectional area are typically considered to be no longer structurally effective. Additionally, rust requires up to six times more volume than that of the steel from which it was formed. This increased volume results in internal pressures that lead to cracks and spalls in the concrete or masonry in which it is embedded. It is important that steel embeds be coated with a material to prevent rust, the use of corrosion-accelerating chlorides in concrete and mortar be minimized, and water be diverted away from concrete and masonry.

Cracked corner brick resulting from a lack of expansion joints in the brick veneer.

Unstable Soils

Unstable or expansive soil can result in differential settlement of foundations that support building façades and their superstructure backup. It is important to design foundations for uniform settlement to avoid the consequences of differential movement.

Conclusion

Façade inspection is as much of an art as a science and forces structural engineers to think outside the box. No matter how unique and challenging a deficiency seems to be, experience and persistence will lead to the root cause. With roughly only 15,000 buildings subject to façade ordinances in nine cities across the nation, there are a lot of other possible time bombs out there requiring inspection and remedial action. Hopefully, other municipalities will adopt ASTM E 2270 before the harmful effects of not doing so are felt.▪

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