Education institutions can decrease overall chimney repairs by focusing on life-cycle costs instead of short-term maintenance and by establishing a comprehensive preventive-maintenance program.
Photo courtesy of Chad Prior/Structural Group

Stacking Up

A maintenance program for chimneys is necessary to help schools avoid costly repairs later.

By Jim Naylor

Chimneys and stacks appear to be strong and indestructible. But chimneys begin to deteriorate from the moment they are built. Early on, no signs are apparent; but deterioration accelerates in subsequent years, and major repairs are soon needed instead of minor maintenance. With proper attention, most structures can be repaired and continue to serve for years.

Causes and effects

Many factors contribute to deterioration. A chimney's height, slender form and unique function create an environment different from that of

other structures. Degradation is accelerated, and risks are magnified.

Reinforced-concrete chimneys have three major causes of deterioration. The first is from the flue gas itself. Combustion of sulfur-containing coal and oil produces corrosive-forming components that attack the calcium silicate hydrates that strengthen concrete. Gases bleeding into the annular space between the liner and chimney shell condense and form an acidic liquid. If the liquid reaches the reinforcing steel, corrosion-induced cracks, delamination and spalling could result.

When the liner itself begins to deteriorate and the chimney is exposed to hot gases, a second form of deterioration can occur. Metal liners have either an exterior liner insulation or an interior acid-resistant coating. If the insulation becomes damaged or saturated, or the original acid-resistant coating fails, holes will develop in the liner, allowing the process gas to come into contact with the chimney shell. At that point, the stress is chemical and thermal. Thermal stress causes the concrete to crack and spall.

The final form of deterioration relates to carbonation. When the concrete is exposed continually to carbon dioxide, its pH level declines, reducing the protection it offers to the embedded steel reinforcing. In 25 to 30 years, as much as 1.5 inches of concrete will have been carbonated. This is troublesome because the outer curtain ring of reinforcing steel is embedded beneath only 1.5 inches of concrete.

When reinforcing steel rusts, its volume changes, sometimes expanding 12 to 14 times its original size. This causes the concrete to spall and fall off. Carbonation occurs more rapidly at cracks and construction joints, as well as where heat is applied. Some facilities use wet scrubbers to remove sulfur compounds from flue gases. The scrubber residue combines with water to form sulfuric acid, which is corrosive to most metals.

Weather plays a role

Wind, rain and fluctuating ambient temperatures can effect chimneys and stacks.

When wind velocity is greater than zero, an airflow pattern develops around the stack. Aerodynamic volume displacement increases wind velocity around the stack. This produces a zone of negative pressure on the leeward side and draws in the flue gas. Because the external column surface temperature is much lower than that of the emerging flue gas, condensation occurs on the leeward side, leaving yellow, brown or black deposits. These deposits will retain corrosive moisture, which will erode the concrete surface. A suitable coating to the affected surface can stop this damage.

Construction techniques

Another source for chimney deterioration centers on construction techniques. Jump-form construction typically is used to erect reinforced concrete chimney columns. This involves casting in place individual sections (typically 7 feet, 6 inches high) until the specified column height is reached. The resulting cold joints between the individual column sections are referred to as construction joints. No bond is created between the column sections. In many cases, defects in the concrete wall result from inadequate vibration of the concrete during placement. Over time, with continued curing and shrinkage of the concrete, the construction joints will continue to open. Grout used to seal defects in the column surface during construction deteriorates. Both conditions enable corrosive elements to attack reinforcing steel embedded in the concrete wall. Once corrosion damages the reinforcing steel, it compromises the structural integrity of the concrete column.

With metal stacks, which often are designed for a height less than 200 feet, the steel is welded and exterior stiffeners are added. Weld joints can suffer from small cracks caused by wind loads and thermal stresses during construction. Once a crack begins, corrosion soon follows, developing in places hidden from the eye.

Coatings to the rescue

Chimney repair professionals have many coating options available to protect chimneys. These include spe-

Factors contributing to chimney deterioration

Zone 1: Head of the chimney and upper column
- Exhaust gases.
- Thermal variations (sun, freeze/thaw cycles, UV exposure).
- Condensation.
- Fuel ashes.
- Rain.
- Wind.
- Atmospheric and exhaust carbon dioxide.

Zone 2: Middle column
- Exhaust gases.
- Thermal variations.
- Condensation.
- Rain.
- Wind.
- Exhaust from neighboring chimneys.
- Atmospheric carbon dioxide.
- Heightened structural loads.

Zone 3: Lower column
- Industrial atmosphere.
- Atmospheric carbon dioxide.
- Rain.
- Concentrated runoff.

cialized coatings that can withstand a range of chemical and thermal conditions. Concrete chimneys are coated for three reasons: protection against environmental elements, protection against process gases, and compliance with Federal Aviation Administration (FAA) requirements (flashing lights for nighttime and warning paint for daytime).

To select the most appropriate coatings, consult an expert. For example, an acrylic-based aviation warning paint provides sufficient visibility for seven to 10 years. However, some aviation-warning paint does not provide the proper resistive qualities, and does not adequately seal construction joints and other defects in the column surface. This can lead to deterioration and costly repairs. In such cases, a chemical-resistant epoxy coating should be applied to the upper chimney zones, and a less-resistive (and less-expensive) coating would suffice for the lowest zone. Some facility managers apply a resistive coating to the entire chimney because rain flushes corrosive materials from the higher zones.

A chimney's exterior is not the only aspect to consider when selecting coatings. In older chimneys, flue gases run hot, and the liners, typically brick, are installed within inches of the column interior. In this type of chimney, much of the heat carried in the flue gas is transmitted to the concrete column. Condensation forms on internal surfaces. In such cases, it is imperative for the concrete to "breathe." An external coating will allow permeation of the moisture vapor from the interior. If the coating prevents breathing, the trapped moisture corrodes the reinforcing steel. For this purpose, a breathable, elastomeric, acrylic-based coating often is a good solution if it is compatible with the heavier-bodied material used to seal construction joints and other defects. Coating protection also can apply to the chimney flue or liner.

Sometimes specifiers consider only the gas temperature as it exits the boiler or the scrubber. Using only the normal online temperature can be a mistake because the insulated steel liner surface temperature, which normally remains above the dew point, may not behave as expected. Temperatures inside the chimney liner fluctuate,—especially during start-up or shut-down operations—which increases the probability of acid condensation. Take into account other temperatures that could occur along with the chemical composition of the flue gas.

Alternative coatings for metal stacks are available. They have a higher heat resistance for internal and external surfaces, and are made from vinylester and phenolic compounds, as opposed to acrylics and enamels. Another coating "metalizes" the stack's interior by applying a pressurized molten zinc or aluminum alloy, which enhances cathodic protection during high-temperature operations.

Be proactive

What is the best approach to minimize the risk of a costly repair or rebuild? Start by shifting the focus from short-term maintenance to life-cycle costs. Examine the original chimney design and learn what types of stacks, liners and coatings were used.

Maintenance cannot be avoided, nor should it be. But a comprehensive preventive-maintenance program is likely to decrease overall repairs. Establishing a preventive-maintenance program for chimneys should begin with a comprehensive inspection performed by a well-qualified contractor. The frequency of inspections depends on the condition of the chimney. Having accurate data on the chimney's condition will allow for more precise planning and budgeting. Past levels of inspection and maintenance may not be adequate to determine future actions, especially if the previous work was performed by different contractors.

Once a maintenance program is initiated, develop an inspection and maintenance history on the chimney. This will serve as a valuable reference in subsequent years. And when repairs are made, invest the time and resources necessary to determine the best procedures, and ensure that the repairs are performed as specified. ■

What should a chimney assessment report include?

According to the Chimney and Stack Inspection Guidelines, a resource from the American Society of Civil Engineers, a chimney inspection report should include the following information:

- Section 1: Executive summary.
- Section 2: Introduction.
- Section 3: Inspection methodology and procedures.
- Section 4: Structure description.
- Section 5: Inspection findings and engineering review.
- Section 6: General discussion and repair recommendations.
- Section 7: Budget cost estimates.
- Section 8: Appendices: Appendix A (photographs), Appendix B (drawings and sketches), Appendix C (field inspection data forms), Appendix D (laboratory test reports).

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