Figure 1. *Limestone facade of courthouse building in Indiana, with load bearing stone columns and arches that support facade components above.*

Assessment and Repair Considerations with Indiana Limestone

BY TIMOTHY M. CROWE, ALA, SE, PE

Monumental structures like those created by the Egyptians, Ancient Hindus, Chinese, Mayans and Greeks demonstrate the longevity and legacy that can be afforded with stone construction. Early American communities utilized locally available materials for construction, and for more significant buildings, natural stone was selected for its durability. By the early nineteenth century, limestone was a common choice, as the quarries used to obtain stone could also provide lime for the mortar of these assemblies. In the early 1800s, quarries evolved in numerous locations where bedrock deposits were accessible, such as Sussex, Wisconsin; the Joliet-Lemont region of Illinois; the Platteville formation in Minnesota; and Lawrence and Monroe counties of Indiana. By the late 1800s, the railroad improved material availability beyond local regions. These limestone formations (sedimentary rock of calcium carbonate) are quite different from each other, with varied durability and workability for carving. Dolomitic limestone, which has a higher percentage of magnesium, is typically a harder material that can be very durable, but typically does not provide the workability of Indiana limestone. The *Indiana Limestone Handbook* published by the Indiana Limestone Institute of

America, Inc. (ILI) notes that this oolitic limestone, not dolomitic, is a calcite-cemented calcareous stone formed of shells and shell fragments, and is particularly non-crystalline in character. The stone, in buff to gray color ranges, varies in grain size and is characterized as a Type II dimension limestone per ASTM C-568, *Standard Specification for Limestone Dimension Stone*.

Assessment of Indiana limestone used in construction, as with any material, necessitates consideration of the methods, materials and detailing required to maintain and restore these assemblies. This article describes performance issues, discusses treatments that should be avoided, and provides suggestions for longer-term repair approaches.

With the wide array of building conditions and details used in stone construction, there is no single method to remediate deterioration observed in limestone assemblies. Construction detailing and coordinated water shedding strategies must be identified for successful repair and/or maintenance approaches. The following elements need to be addressed when evaluating and/or repairing older systems.

In addition to selecting a proper mortar for repair and repointing, as discussed in prior "Second Chance" articles (*Licensed Architect*, Fall 2014), the masonry needs to be evaluated. Stone conditions are influenced by climate, exposure (for example, different facades will experience different freeze-thaw cycling), construction detailing, and past treatments. How the structure is assembled is key. Stone units, which can weigh several tons, can provide structural supports for other building elements (Figure 1) or merely serve as cladding. Thus, cracks or distress within the units may represent a water infiltration concern, or may also have a larger structural consequence to the building.

Cracks can result from the corrosion of embedded ferrous metal anchors and elements, building settlement, differential movement within adjacent materials, or improper water shedding. Embedded ferrous metal may be remediated with removal of mild steel anchors and installation of non-corrosive anchors (e.g., stainless steel or bronze anchors). Depending upon the unit and size of spalls, stones may then be repaired with dutchmen (partial stone unit replacements) or patched with an appropriate repair mortar. However, as cracking may be attributed to settlement, differential movement, or other concerns, it is necessary to confirm if this movement is still active prior to selecting a repair. Cracks may be addressed with properly detailed sealant or epoxy materials if the stability of the crack is understood. However, if the cause of distress is not understood, repairs may not address underlying issues and can thus provide a false sense of security. An example of this was observed at a courthouse building in Indiana, where stone corbel failures had been reported. A previous corbel repair (Figure 2) utilized epoxy injection along a crack within the stone. Epoxy applications such as this may address water infiltration at this crack, but would have questionable efficacy in strengthening this element and may not be compatible with the adjacent stone because of different material characteristics. This cantilevered stone, which supports a stone balcony, had also been packed with mortar along its full length. The mortar at the corbel projection introduced an unintended load path that could increase stresses in this corbel at the epoxied crack, increasing the risk of corbels falling from the building. A repair approach was developed that removed mortar from portions of this joint, to reduce stresses within the stone and restore the intended load path. In addition, a mechanical connection of the corbel was introduced to further reduce the stresses and demands on the epoxied crack.

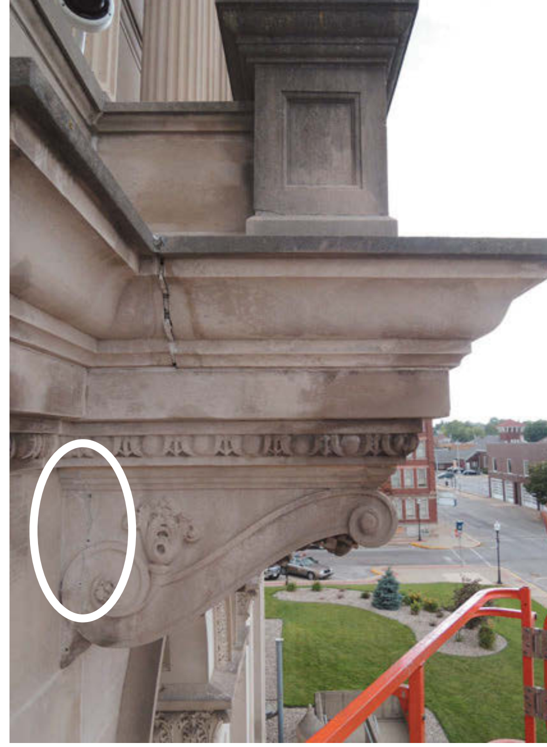

Figure 2. *Epoxy repair at cracked cantilevered corbel.*

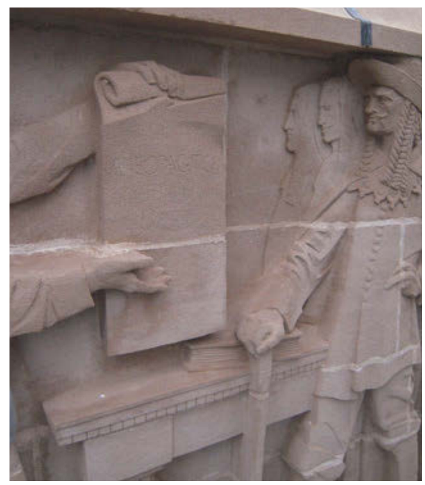

Figure 3. *Example of stone carving on the Nebraska State Capitol that had been damaged by aggressive abrasive cleaning techniques as part of prior building maintenance. Note that the writing on the tablet is nearly gone.*

Additional masonry maintenance concerns, not limited to Indiana limestone, include aggressive cleaning campaigns such as sandblasting or strong chemicals (acids) that can both degrade the stone and damage underlying support systems. In the mid-twentieth century, the unfortunate practice of sandblasting masonry facades as a cleaning practice was common. The end result was usually a loss of carving/detail on the stone (Figure 3), as well as well as rougher surface that ironically is more vulnerable to dirt and biological growth accumulation.

Figure 4. *Spalled limestone fragments attributed to sealer applications that had previously been installed on the limestone.*

Figure 5. *Reconstructed mass masonry walls with Indiana limestone and aged concrete brick back-up masonry.*

Figure 6. *Stone arch reconstruction in progress at the Nebraska State Capitol. Stone grain orientation was normal to the compressive stresses within the voussoirs.*

Proper cleaning of stone necessitates identifying the stain or soiling that is to be removed, which may be dirt or other surface contaminants, efflorescence or minerals from the stone itself, biological growth, or other stains that penetrate into the stone. Past maintenance should be reviewed, as water repellents may have been introduced (Figure 4) that can in some cases trap stains and alter the breathability of the stone surface, leading to material spalling or exfoliation. Each type of soiling may require a different cleaning strategy. Cleaning trials, including microscopic examination of the surface, are recommended to select the most effective cleaning method that does not harm the stone. Maintaining realistic expectations is also important, as cleaning results need to be coordinated with the best approach to preserve the material.

When rebuilding stone elements is necessary, proper anchorage of the exterior masonry to the structure or back-up material is critical to the success of the project. As noted above, ferrous metal anchors can be problematic and result in spalls or other staining issues. There are a number of restoration-type anchors that are available for this purpose, including through-face helical anchors, stainless steel strap and pin assemblies, and other anchors. Connections are also described in greater detail in the ILI handbook and in ASTM C-1242, *Standard Guide for Selection Design and Installation of Dimension Stone Attachment Systems*. Attachments need to be evaluated on a case-by-case basis. An additional consideration is what back-up material would be appropriate for the reconstructed assembly. To avoid long-term expansion concerns of clay brick units, concrete brick back-up may be considered in rebuilt mass wall systems (Figure 5).

Other considerations are the orientation of the rift (natural bedding plane) in the limestone. Recommended practice for stone construction is to have the natural bedding plane of the stone in compression, such as it was in nature. The bedding plane oriented horizontally is likely to be the preferred installation. However, if the reconstructed element is an arch (Figure 6), orientation normal to the voussoirs would be appropriate. Clear specifications and communication with the fabricator, usually via shop drawings, is necessary to ensure the desired bedding plane orientation is achieved.

Proper water shedding characteristics and drainage around the building are necessary to enhance the serviceable life of limestone structures. Water infiltration increases the potential for stone deterioration, contributes to corrosion of mild steel anchorage if present, and can damage interior finishes. Proper treatment of copings, cornices and similar skyward-facing surfaces on these facades typically includes flashings and/or strategically placed sealant joints. Transitions to windows, roofs and other cladding assemblies also require proper attention to enhance the serviceable life of these repairs.

Limestone assemblies are unique, and there is not a one-size-fits-all repair that would be recommended. The considerations noted herein provide a framework and philosophy for issues that need to be addressed with the remediation and restoration of these assemblies. Coupled with appropriate maintenance, proper limestone treatment and restoration efforts must consider material characteristics. Similar to the ancient structures noted above, we can extend the legacy of these buildings.

Timothy M.Crowe, ALA, SE, PE, an Associate Principal with WJE in Northbrook, Illinois, is Co-chair of the Association for Preservation Technology International (APT) Preservation Engineering Technical Committee and specializes in the investigation, and repair of archaic and contemporary structures. He can be reached at tcrowe@wje.com.