INSIGHT™
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"Insight: to see into and understand; an item of knowledge gained by this power."

Successful dimension stone cladding designs must address aesthetic considerations of stone color, finish, and panel size in conjunction with engineering requirements, including applied loads, material strength, and attachment to the building. RRJ has investigated numerous stone cladding failures rooted in technical misconceptions and erroneous design assumptions. This issue's Tech Tip article discusses one such design issue. Also included is an announcement for a new ASTM Special Technical Publication on dimension stone use in building construction co-edited by RRJ Principal Kurt Hoigard.

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Kurt Hoigard
Co-Chairs ASTM
Symposium on
Dimension Stone

Tech Tip

Stone Cladding Anchorage Stiffness

Modern building facade design concepts consider all cladding materials as nonstructural elements designed to have their weight supported by the building and to transfer all localized lateral loads from wind or seismic activity to the building frame. Dimension stone cladding is comprised of relatively thin slabs of natural stone, such as granite, marble, and limestone, attached to the building via intermediate elements known as anchorages. A common, but flawed, stone cladding design approach is to assume all individual anchors (Eq. A) or all portions of a continuous anchor (Eq. B) will participate equally in supporting the attached stone panel. These assumptions neglect the effects of variations in anchor placement, engagement, and stiffness, as well as stone panel and back-up structure stiffness and load/deformation behavior.

$$\textbf{Anchor Load} = \frac{\textbf{Total Applied Load}}{\textbf{Number of Anchors}} \qquad \textbf{(Eq. A)}$$

$$\frac{\textbf{Anchor Load}}{\textbf{Unit Length}} = \frac{\textbf{Total Applied Load}}{\textbf{Total Kerf Anchor Length}} \qquad \textbf{(Eq. B)}$$

In reality, the determination of actual load distributions within many stone cladding anchorage configurations is a complex exercise not readily performed using hand calculations. A common example involves wind and seismic load design of stone panels integrated into unitized curtain wall systems. Frequently, the stone panels in this type of arrangement are attached to vertically oriented aluminum mullions via full-width aluminum extrusions that engage the stone via slots, known as kerfs, cut into the top and bottom edges (Figure 1). The fallacy of the assumptions inherent in Equation B has been shown to be the root cause of stone kerf failures on several high rise building facades investigated by RRJ. Finite element computer analyses combined with laboratory load testing of as-built stone cladding configurations have demonstrated that instead of providing equal support across the full width of the panels, the flexibility of the aluminum extrusions results in the kerf loads near the panel edges being significantly higher than those at mid-width (Figure 2).

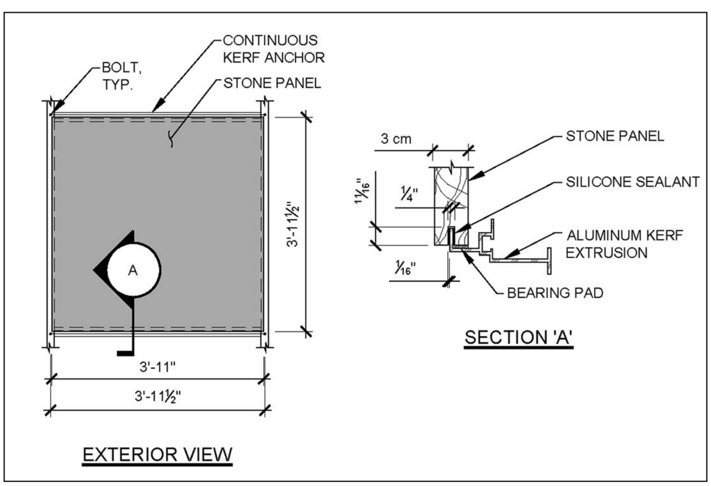


Figure 1— Example of a full-width kerf anchor configuration.

Figure 2—Progressive cracking of a full-width kerf anchor configuration during laboratory testing.

In one building investigated by RRJ, peak kerf loads were more than 10 times higher than the mid-width loads and almost 4 times higher than predicted by Equation B (Figure 3).

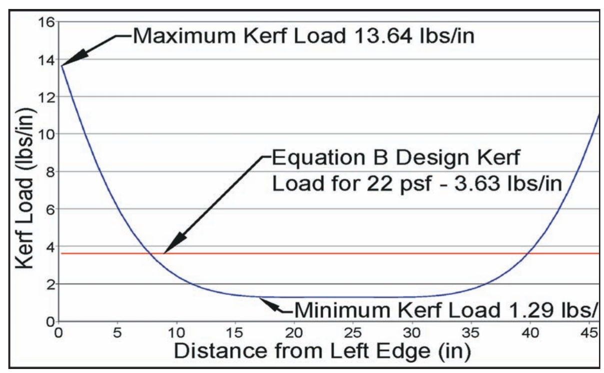


Figure 3—Actual kerf loads compared to calculated loads based on simplified assumptions.

Lessons learned from RRJ's investigations of stone cladding anchorage failures include:

- With the exception of four bi-symmetrically placed anchors, it is easy to create circumstances where the loads carried by individual anchors are not equal.
- Full-width kerf anchors generally do not provide uniform bearing, with kerf forces being greatest near the kerf anchor support points.
- The relative stiffnesses of the stone cladding panels, anchorage components, and back-up structure all affect the distribution of loads within the stone panel and the anchors. In general, the more flexible the back-up structure and anchorage components are, the more likely it is that the loads carried by individual anchors or portions of continuous anchors will vary significantly from those predicted by Equations A and B.

The information presented in this article was excerpted from a paper entitled, "Stiffness Considerations in Dimension Stone Anchorage Design" published by Kevin Conroy and Kurt Hoigard in ASTM STP 1499.

— Kurt R. Hoigard, P.E.

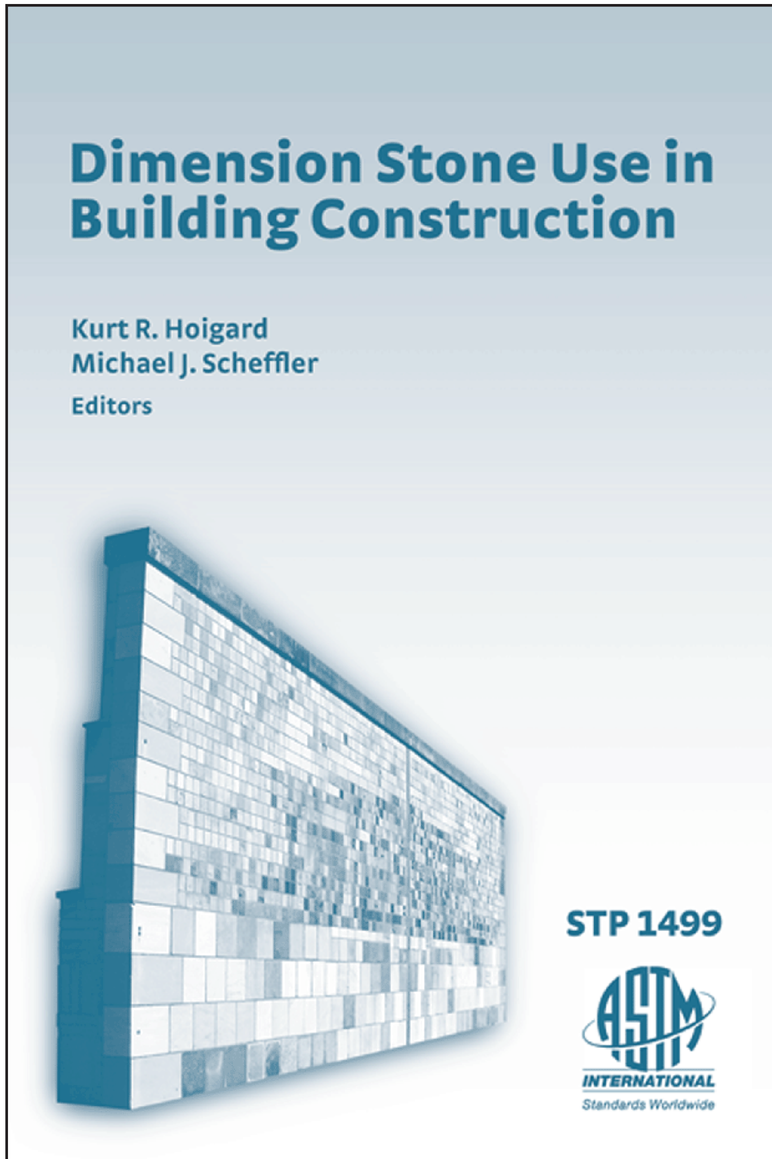
Symposium Publication

Hoigard Co-Chairs ASTM Symposium on Dimension Stone

RRJ has gained national recognition for expertise dealing with the investigation and repair of buildings. In addition to publishing technical articles and making presentations about building leakage, many of our staff are actively involved in professional organizations such as the American Concrete Institute (ACI), the American Institute of Steel Construction (AISC), and ASTM International, which prepares standards, practices, and guides for testing and evaluation procedures.

RRJ Principal Kurt Hoigard has been an active contributor to the revision of existing ASTM dimension stone standards and the development of new ones, including ASTM's first standards for cladding panel and anchorage testing. He recently received the ASTM Award of Merit and the Committee C18 Daniel W. Kessler Award of Meritorious Service for his continuous and outstanding contributions to the work of the committee.

Mr. Hoigard recently co-chaired an ASTM Symposium on Dimension Stone Use in Building Construction. This symposium was the third in a series sponsored by ASTM Committee C18 on Dimension Stone. Presentations were made by specialists from the United States, Europe, and Australia. Topics covered included strength testing, stone durability, paver design, anchorage design, building code issues, failure investigation, and case studies. The symposium presentations were each reviewed by two peers knowledgeable of the subject matter and published by ASTM as STP 1499. This STP, like the others in the series, provides a compilation of technical papers on current thinking and developments in the use of dimension stone in building construction. Two of the papers in this compilation were written by RRJ staff: *Stiffness Considerations in Dimension Stone Anchorage Design,* by Kevin Conroy and Kurt Hoigard, and *Material Strength Considerations in Dimension Stone Anchorage Design,* by Brian Lammert and Kurt Hoigard. Some of the material from the Conroy/Hoigard paper is represented in this issue's *Tech Tip* article. ASTM STP 1499 can be purchased directly from ASTM International at www.astm.org.



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