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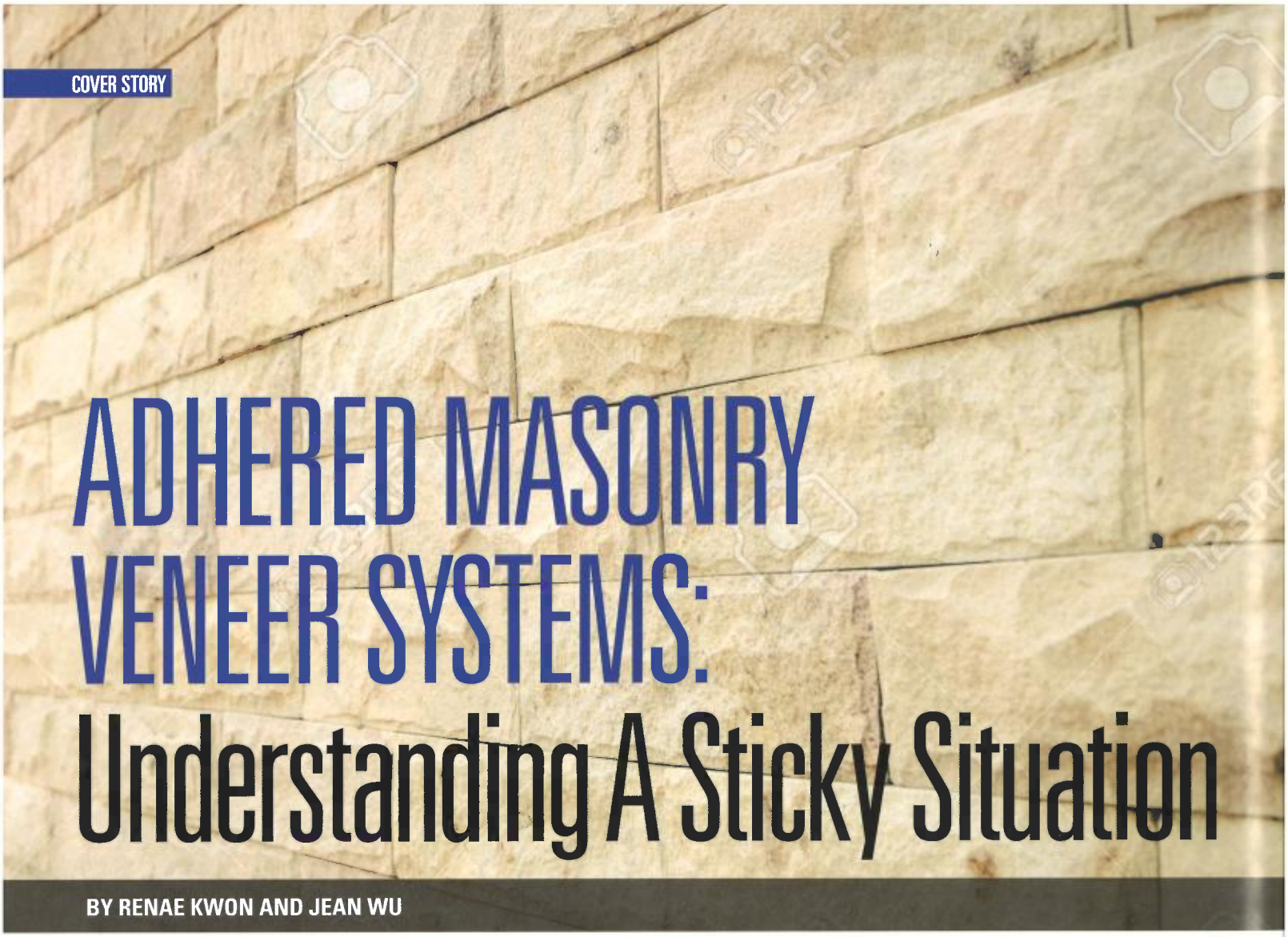

ADHERED MASONRY VENEER SYSTEMS: Understanding A Sticky Situation

BY RENAE KWON AND JEAN WU

Adhered masonry veneer (AMV) systems are being constructed in all climates across the United States in increased frequency. Today, this type of construction is not only seen on high-end residential buildings, but is becoming a common facade element on educational institutions, hospitals, healthcare facilities, airports, museums, and other types of commercial buildings. The AMV systems, also sometimes known as "lick and stick," have been commonly, and perhaps erroneously in some cases, perceived as easier and faster to install than the traditional anchored masonry veneer cavity walls. With the increase in popularity of AMV systems, the variety of assembly options, including weather resistive barriers, insulation, drainage, cladding materials, and even installation techniques, have also expanded. Due to the increased diversity of AMV systems, coupled with the lack of well-known or understood code requirements and industry standards, the design and installation of these systems can be challenging. Additionally, due to the system's heavy reliance on workmanship, these systems can be vulnerable to failure, especially in freeze-thaw climates that can tax the system.

By exploring some of the more critical design considerations and workmanship issues, along with quality control measures and methods for testing the adhesion of these AMV systems, we hope to better inform the readers on the ins and outs of this popular cladding system.

Typical Assembly

An AMV wall system is defined as "masonry veneer secured to and supported by the backing through adhesion." The components of an AMV wall system can vary; however, the typical components of AMV is similar to a stucco system. They include: the backup (i.e., stud framing with exterior sheathing, concrete masonry, or concrete backup), weather resistive barrier (required for stud framing with exterior sheathing backup), scratch coat with embedded metal lath (metal lath is optional for a concrete or concrete masonry backup), adhesive mortar, and veneer units (manufactured or natural stone). Also, omitted mortar joints, commonly referred to as "dry stacked," has become a popular AMV feature. Figure 1 shows a diagram of a typical AMV system assembly .

Additional components such as continuous insulation, drainage layer, and/or an additional air and water barrier for increased energy performance, drainage capability, and added moisture protection can also be included in an AMV system. These components are more common with systems installed in commercial application and can significantly improve the performance of an AMV. However, they typically increase the cost and installation time, which may make a rain screen or traditional cavity wall system a more practical consideration due to its superiority in terms of water management and mechanical anchorage.

Aesthetically, an AMV system has the appearance of a traditional mass masonry wall or masonry veneer cavity wall; however, from a water management and anchorage perspective, they are significantly different. The typical AMV has minimal drainage capability, and therefore methods for limiting water penetration are critical, especially when constructed in a freeze-thaw environment where expansion of freezing water increases the rate of deterioration or even lead to bond failure of the masonry veneer cladding. Additionally, anchorage of the cladding relies solely on the adhesion of the scratch coat and adhesive mortar since, by definition of the system, mechanical anchorage is typically not provided. If adhesion fails, there is nothing to keep the masonry veneer units from falling off the wall.

The following items are some critical design considerations that should be carefully considered when designing and installing an adhered masonry veneer system.

Water Resistive Barrier

Masonry, both manufactured stone and nature stone to a lesser extent, is a naturally absorptive material and must be detailed to manage water penetration. According to Section 1405.10 of the International Building Code , two layers of a continuous water resistive barrier (WRB) are required over stud framed walls and sheathing. It is critical that the WRB be integrated and detailed at all rough openings, cladding transitions, and flashings.

Adhesive Mortar

The adhesive mortar bonds the cladding unit to the scratch coat; in situations where metal lath is not required, the adhesive mortar and the scratch coat can be one and the same. The most common types of adhesive mortar are Type N or Type S mortars. Bonding agents, such as a polymer additives, are often added to increase the bond, and many of the proprietary adhesive mortar include polymer additives for this reason. While the use of a polymer modified mortar is generally recommended, its use does not guarantee that bond failures will not occur. Polymer modifiers, however, cannot compensate for careless mortar proportioning, inadequate surface preparation, or poor AMV installation practices. We have had first-hand involvement in bond failure investigations in which a polymer modified mortar was installed. Additionally, care must be taken when using a bonding agent since mortar dropping can be difficult to remove after curing.

Per ACI 530.1, *Specification for Masonry Structures*[3], the thickness of the mortar behind the veneer unit shall not be less than 3/8 inch nor more than 1-1/4 inches. Per ASTM C1242, *Standard Guide for Selection, Design, and Installation of Dimension Stone Attachment Systems*[4], minimum coverage of the cladding unit included 100% coverage at the four-inch perimeter and 95% coverage at the remaining center. Due to the size of the typical veneer units, this often leads to full coverage at the back of the units, which is required by IBC. Sufficient coverage of the bonding surface with the adhesive mortar is a critical step. Many failures have been attributed to insufficient coverage. This is discussed further in the later part of this article. By code, an AMV system must have a minimum 50 psi (pounds per square inch) shear bond strength.

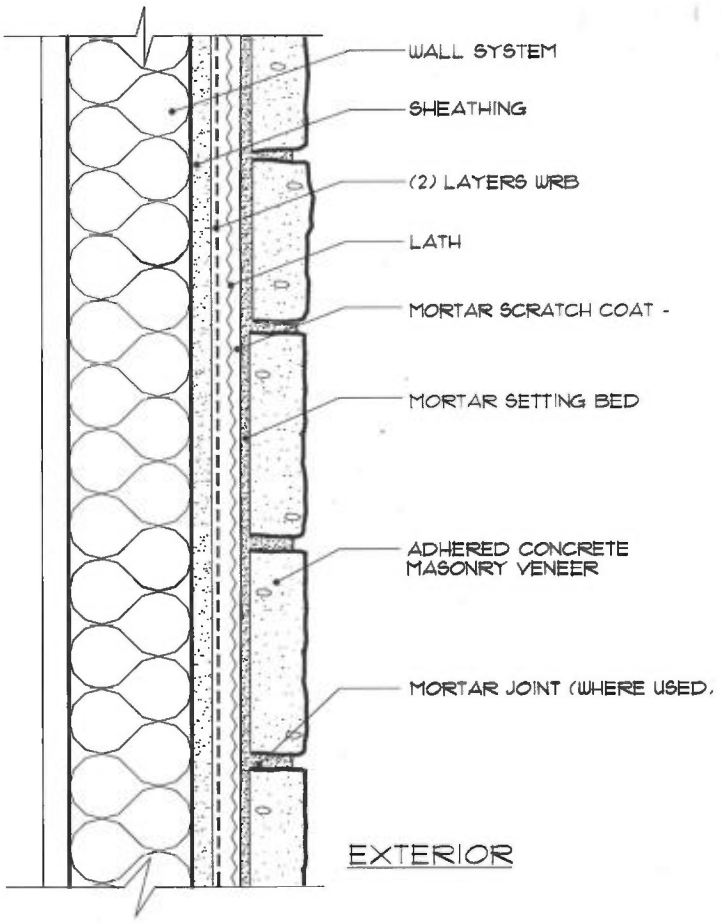

Figure 1: Typical adhered masonry veneer system assembly

Figure 2: Spalls can occur when veins in natural stone are oriented parallel to the wall surface.

Veneer Units

The two most common types of veneer units are manufactured stone and natural stone. Manufactured stone is defined as a non-load bearing unit that is made from a concrete mix (i.e., cement, aggregates and water) that is cast and colored to simulate natural cut stone. ASTM C1670, *Standard Specification for Adhered Manufactured Stone Masonry Veneer Units*[5], establishes minimum product requirements for manufactured stone. Natural stone is typically quarried from the earth and fabricated into veneer units to meet the size and weight requirements of an AMV system. The most common types of adhered natural stone units are sandstone, limestone, marble, and granite.

When comparing manufactured stone and natural stone, the following physical properties should be noted.

NATURAL AND MANUFACTURED STONE PROPERTY COMPARISON		
	Manufactured Stone	Natural Stone
Water Absorption	13% to 29%	0.2% to 12%
Typical compressive strength	1,500 psi	0.2% to 12%

Installations using natural stone can be more susceptible to bond failures if the material has a low absorption and/or a smooth cut surface, which can reduce bond of the adhesive mortar. The orientation of the naturally occurring veins in the natural stone can also be a factor, where separation within the natural stone at these veins can occur if the plane of the veins is parallel to the wall surface (Figure 2).

Bond problems with manufactured stone typically occur less frequently since the absorption rate is higher and manufactured stone is often fabricated with grooves or irregularities at the backside to key in the adhesive mortar.

The ACI 530/ASCE 5/TMS 402 codes specify the following sizing and weight limits for adhered masonry units: not exceed 2-5/8 inch in thickness, not exceed 36 inches in any face dimension, no more than 5 square feet in total face area, and not weigh more than 15 psf (pounds per square feet). ASTM C1242 also limits the height of the AMV system to thirty feet above grade.

Deflection

A steel or wood stud framed wall with exterior sheathing is a common backup construction for AMV systems. An AMV system is a rigid system with limited ability to accommodate deflections. Standards and industry guidelines vary significantly regarding the deflection limit for AMV systems; however, the majority of technical references recommend limiting deflection to anywhere from L/600 (outlined in ACI 530) to L/1000 (outlined in ASTM C1242), where L denotes "span length." Tighter spacing of the framing or stiffer framing members may be necessary to achieve this range of deflection.

Mortar Joint Profile

An AMV system can be finished by either filling the joints with mortar or leaving the joints open (i.e., "dry stack"). From a water management perspective, filling the joints

Figure 3: A large void behind an adhered masonry veneer unit.

between the veneer units will reduce moisture penetration. A concave joint that is properly compacted is the optimal profile, whereas a raked joint can hold water on the exposed ledge of the units and allow increased moisture penetration. A "dry stack" installation is often desired for its aesthetic character; however, this installation can be much more susceptible to moisture penetration and subsequent freeze-thaw deterioration and failure. The open joints between the veneer units act as ledges that can collect water and allow water to travel to the adhesive mortar layer behind the veneer units. Overall, it is the authors' opinion that a "dry stack" installation is prone to failure in freeze-thaw environments. Although a "dry stack" installation is allowed by code, the technical guide *Adhered Natural Stone Veneer Installation Guide*[7] recommends against its use in freeze-thaw climates.

Installation and Workmanship

As previously discussed, an AMV system contains many components. Proper installation and quality workmanship are critical to the success of a multi-component system that does not have the redundancy of other traditional wall systems. With so many failures being attributed to poor AMV installation, detailed attention to workmanship and implementing quality control measures and testing are highly recommended. The following industry standards and guidelines are available for reference regarding installation best practices.

- *ASTM C1780, Standard Practice for Installation Method for Adhered manufactured Stone Masonry Veneer*[8]
- *Installation Guide and Detailing Options for Compliance with ASTM C1780 for Adhered Manufactured Stone Veneer produced* by Masonry Veneer Manufacturers Association (MVMA)[9]
- *Adhered Natural Stone Veneer Installation Guide* produced by Building Stone Institute (BSI) and Rocky Mountain Masonry Institute[10]

Based on these installation guidelines and lessons learned from investigations performed by the authors, below is a summary of some of the key points of installation and workmanship.

1. Two separate layers of WRB are generally required by code. Proper installation of the WRB, which includes sealing all penetrations, proper overlap and integration with flashings, is critical to protecting water sensitive material within the wall system.

2. The galvanized lath must be securely fastened to the backup at the required spacing with approved fasteners. The scratch coat should fully encapsulate the lath and have a scored surface. Reference standards vary on the recommended cure time for the scratch coat; however, 24 to 48 hours is the most commonly recommended time frame.

3. Setting the cladding units with mortar is generally performed by one of two methods: back buttering the unit with mortar and setting onto the scratch coat; or applying a trowel application of the adhesive mortar to the scratch coat with additional back buttering of the unit prior to setting. With either approach, pressing and working the unit into place is critical to achieving the required bond strength. Setting the unit slightly above its final position and sliding it into place while firmly pressing and working the unit is another useful installation technique.

4. The adhesive mortar should completely cover the backside of the veneer units without any voids. ACI 530.1 Specification for Masonry Structures states that "sufficient mortar shall be used to create a slight excess to be forced out between the edges of the veneer units." The fact that it is common during failure investigations of AMV systems to find a large void at the center of the veneer units (Figure 3) proves that the somewhat common belief that buttering only the perimeter and leaving a void at the center of the unit will create a "suction" effect is categorically false.

5. Wetting either the scratch coat and/or adhered masonry cladding unit may be a good practice. However, over-wetting the unit or the presence of free water on the scratch coat or unit, especially on a dense natural stone with low absorption, can lead to failures. During failure investigations of AMV systems, this condition is typically indicated by a "frothy" appearance (Figure 4) in the adhesive mortar at the failure plane, which is usually between the veneer unit and the adhesive mortar.

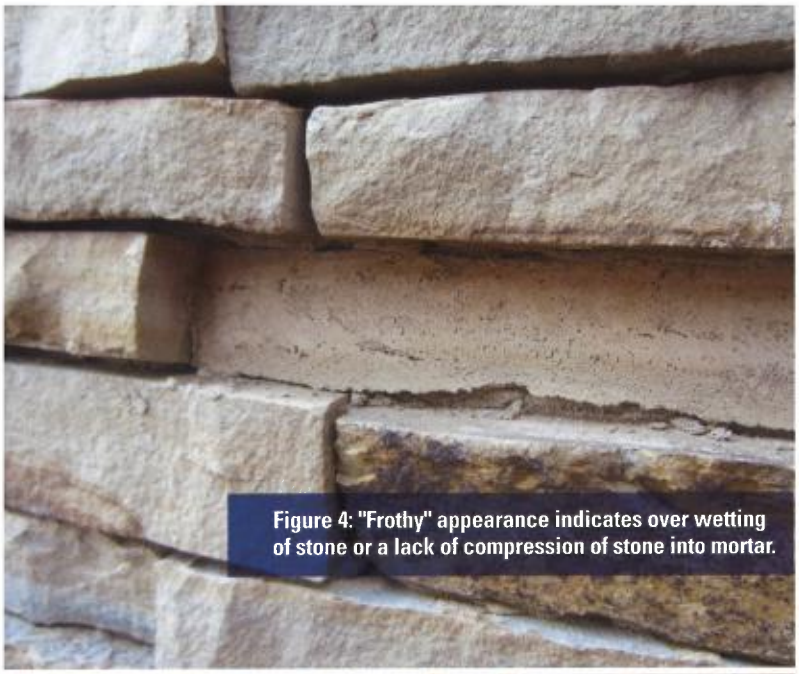

Figure 4: "Frothy" appearance indicates over wetting of stone or a lack of compression of stone into mortar.

Figure 5: Test apparatus for field test of shear bond strength of AMV units.

6. Filling the joints in lieu of a "dry stack" installation is recommended in freeze-thaw environments. The adhesive mortar should be "thumb-print hard" prior to pointing the joints. Installing a joint that is concave and properly compacted will provide the best protection against water penetration.

Quality Control and Testing

Due to its heavy reliance on workmanship, quality control during AMV installation is critical. Adhesive mortar extruded from around the perimeter of the veneer unit is visual evidence of sufficient application of mortar, and of the installer working the veneer unit into the backup. However, since the veneer units are adhered, it is impossible to verify full coverage of the adhesive mortar behind the veneer units without removing them. It is therefore recommended that periodic removal of the veneer units be performed to "spot check" the workmanship during installation. This method is typically recommended by manufacturers of the adhesive mortar as well as the masonry veneer units.

A mockup of the AMV system at the beginning of the project can be invaluable. This is an opportunity to verify installation procedures, workmanship issues, and aesthetics. This is also an opportunity for the installer to work out the kinks and establish an installation standard. The mockup can be stand-alone, and is used as a reference for the rest of the project.

Testing of the installed AMV system can be performed to verify adhesion. As mentioned earlier, the code requires that the AMV system achieves a minimum shear bond strength of 50 psi. While a published field test standard for the shear bond strength of the AMV system does not exist, one is currently being developed by ASTM Committee C18 on Dimension Stone. The application of shear load at the veneer unit/adhesive mortar interface is similar to the laboratory test method prescribed in ASTM C482, *Standard Test Method for Bond Strength of Ceramic Tile to Portland Cement Paste*. However, the tests differ in that, rather than solely evaluating the shear strength between the mortar and unit as in ASTM C482, this adapted field test also evaluates the shear strength between the mortar and substrate. The test involves testing the assembly to failure and measuring the shear load applied at the time of the failure (Figures 5 and 6). If this number is at or higher than 50 psi, the system is deemed to have sufficient bond strength to meet the code. However, it is important to note that the effect of freeze-thaw, which can degrade the AMV bond over time, cannot be evaluated with this test method. Performing additional testing after at least one winter season may be warranted.

An alternate test to verify adhesion of the AMV system is the tensile bond test. This test measures the pull-out

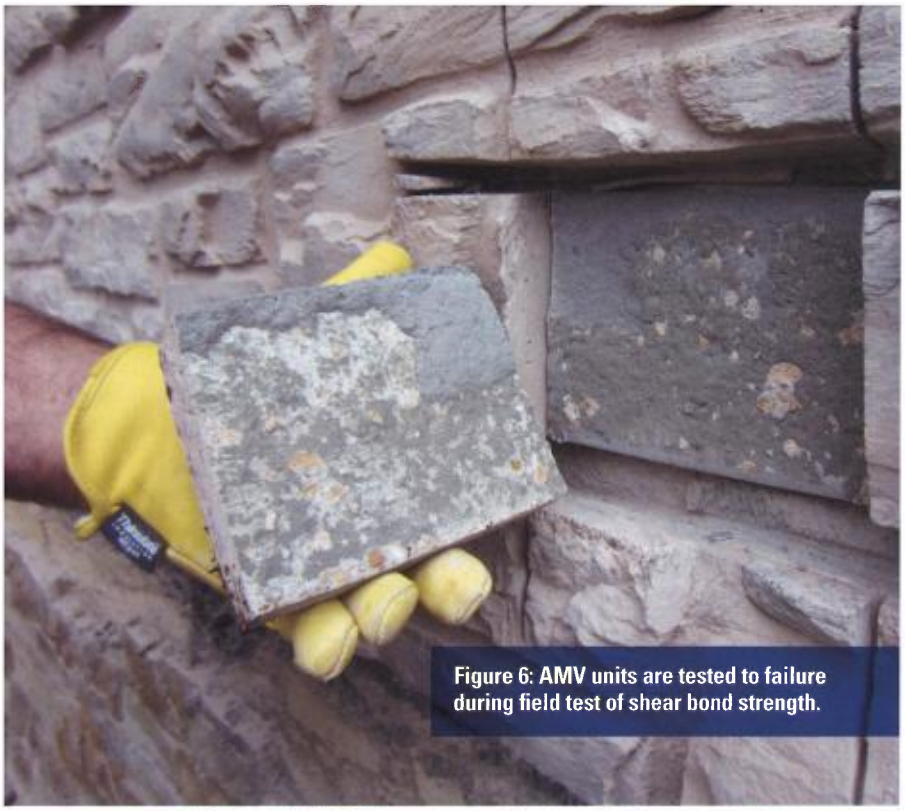

Figure 6: AMV units are tested to failure during field test of shear bond strength.

Figure 7: Test apparatus for field test of tensile bond strength of AMV units.

strength of the AMV system by coring a two-inch diameter section the full depth of the AMV and pulling the cored section from the substrate (Figures 7 and 8). Compared to the shear bond strength testing mentioned above, the tensile bond testing has a smaller scale apparatus that allows for faster setup and is less destructive. This often leads to testing many more locations than shear bond strength tests in the same amount of time. While tensile bond strength does not directly correspond to shear bond strength and there is currently no specific tensile bond strength requirement stated in the codes or published guidelines, in our experience, 50 psi is often considered a sufficient tensile bond strength. However, every project and load condition is different; actual bond strength value should be determined on a project by project basis. It is essential to note that the reliability of an AMV installation is determined more by the variability of the strength test data than any individual bond strength values. A system that has high bond strength at some areas but low bond strength at others is less reliable than a system that has acceptable but consistent bond strength values.

Conclusion

Successful installation of adhered masonry veneer systems requires careful attention to both design and workmanship. Installation with natural stone, smooth surfaces, and dry stack application can make the system particularly vulnerable to bond failures in freeze-thaw environment. Water/moisture management and protection of water sensitive wall components is critical to the success of the installation. Mockups and quality control testing is strongly recommended with possible additional review of installation and testing after the system has been exposed to at least one winter season.

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Figure 8: AMV units are tested to failure during field test of tensile bond strength.

References

[1] Diagram reprinted from "Installation Guide And Detailing Options for Compliance with ASTM C1780 for Adhered Manufactured Stone Veneer" published by Masonry Veneer Manufacturers Association (MVMA), 4th Edition 3rd Printing.

[2] *2015 International Building Code*. Country Club Hills, Ill.: ICC, 2014.

[3] *ACI 530.1-13/ASCE 6-13/TMS 602-13, Specifications for Masonry Structures*. American Concrete Institute (ACI); Structural Engineering Institute of ASCE (SEI); The Masonry Society (TMS).

[4] *ASTM Standard C1242, 2015, Standard Guide for Selection, Design, and Installation of Dimension Stone Attachment Systems*. ASTM International, West Conshohocken, PA, 2015, www.astm.org.

[5] *ASTM Standard C1670, 2016, Standard Specification for Adhered Manufactured Stone Masonry Veneer Units*. ASTM International, West Conshohocken, PA, 2016, www.astm.org.

[6] *ACI 530-13/ASCE 5-13/TMS 402-13, Building Code Requirements for Masonry Structures*. American Concrete Institute (ACI); Structural Engineering Institute of ASCE (SEI); The Masonry Society (TMS).

[7] *Adhered Natural Stone Veneer Installation Guide, Updated Edition June 2010*. Building Stone Institute; Rocky Mountain Masonry Institute.

[8] *ASTM Standard C1780, 2015, Standard Practice for Installation Method for Adhered manufactured Stone Masonry Veneer*. ASTM International, West Conshohocken, PA, 2015, www.astm.org.

[9] *Installation Guide and Detailing Options for Compliance with ASTM C1780 for Adhered Manufactured Stone Veneer, 4th Edition 3rd Printing*. Masonry Veneer Manufacturer's Association (MVMA), Herndon, VA, www.masonryveneer.org.

[10] *Adhered Natural Stone Veneer Installation Guide, Updated Edition June 2010*. Building Stone Institute (BSI); Rocky Mountain Masonry Institute•