Peeling Back the Layers of Adhered Masonry Veneer Systems

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Adhered masonry veneer (AMV) systems are being constructed in all climates across the United States with 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 institutes, hospitals, healthcare facilities, airports, museums, and other types of commercial buildings.

The AMV systems have been commonly, and perhaps erroneously in some cases, perceived as cheaper 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 air and water resistive barriers, continuous 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 this type of wall assembly.

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 increasingly 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 are similar to a stucco system. They include: the backup (i.e., stud framing with exterior sheathing, concrete masonry, concrete, or cement backer), water 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.[1]

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 are more commonly being included in AMV systems, and in some cases may currently be required by code or will be in the future. These components 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.

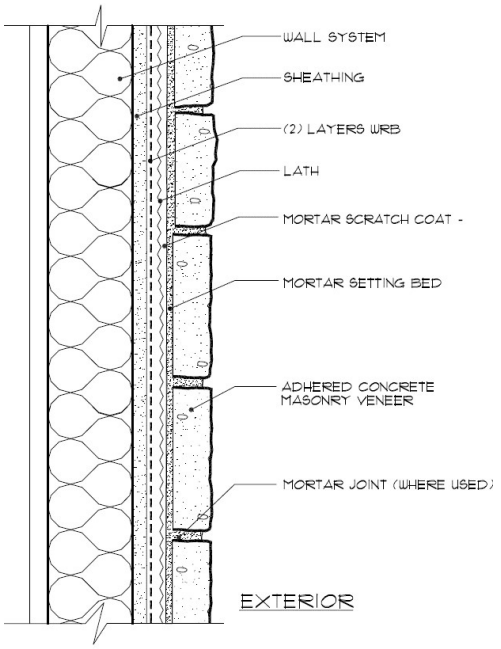

Figure 1. AMV System Assembly

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

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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 no redundancy 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. Recent changes to the International Building Code (IBC) have differentiated the requirements for water resistive barriers (WRB) between Climate Zone B (dry) versus Climate Zone A (moist) and Climate Zone C (marine). Climate zones are geographically defined within 2021 International Energy Conservation Code (IECC). In general, Climate Zone B (dry) includes the western mountain region, Climate Zone A (moist) includes the area between the midwest and eastern coast, and Climate Zone C (marine) includes the western coastline. According to Section 2510.6 of the IBC, the following WRB options, based on climate zone locations, will provide code compliance[2]:

Climate Zone B (dry)

- Two layers of 10-minute Grade D paper or equivalent two layers of WRB complying with ASTM E2556, Type I. Layers installed independently to provide a drainage plane that interfaces with the base flashing.[3]
- One layer of 60-minute Grade D paper or equivalent to one layer of WRB complying with ASTM E2556, Type II. Separate the WRB from scratch coat with nonwater absorbing layer or drainage space.[4]

Climate Zone A (moist) and Climate Zone C (marine)

- In addition to complying with Climate Zone B requirements, provide minimum 3/16 inch drainage space or material on the exterior side of the WRB with a minimum drainage efficiency of 90 percent (per ASTM E2273 or Annex A2 of ASTM E2925).[5]

Regardless of the climate zone or selected WRB product, it is critical that the WRB be integrated and detailed at all rough openings, cladding transitions, and flashings to provide continuity of the moisture barrier.

Figure 2. Corroded Lath

Scratch Coat

The first adhered masonry veneer systems propagated from the stucco industry and borrowed much of the same technology and methods of installation. The scratch coat for a traditional adhered masonry veneer is installed identical to stucco scratch coat and is commonly reinforced with corrosion-resistant lath. Full encapsulation of the lath with the scratch coat is critical to protect the lath from water penetration and potential accelerated corrosion (Figure 2). Per IBC, a nominal ½-inch thick layer of mortar shall encapsulate the lath and the mortar shall be scored horizontally. TMS 402 allows the scratch coat to be comprised of either Type M or S mortar, or polymer modified mortar.[6]

Adhesive Mortar

The adhesive mortar, or setting bed, bonds the veneer 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 given the design considers differential movement between the veneer and the backing if these materials are different. Historically, the most common types of adhesive mortars were Type N or Type S mortars. However, polymer modified mortars, which have superior bond strength compared to Type N and S mortars, have become more common within the industry. The most recent version of the TMS 402/602 code requires the adhesive mortar (i.e., setting bed mortar) of prescriptively designed systems to use polymer modified mortar (meeting ANSI A118.4 or ANSI A118.15). While the use of a polymer modified mortar can greatly increase the bond strength, its use does not guarantee that bond failures will not occur. Based on our first-hand involvement in bond failure investigations, polymer modifiers cannot compensate for careless mortar proportioning, inadequate surface preparation, or poor AMV installation practices. Additionally, care must be taken when using a bonding agent since mortar dropping can be difficult to remove after curing.

The thickness of the adhesive mortar behind the veneer unit can vary, but typically ranges between 3/8-inch and 1-1/4 inches. IBC section 1404.10 indicated veneer units shall be adhered to the mortar scratch coat with nominal ½-inch thick setting bed with full coverage that should result in a nominal 3/8-inch thick setting bed after the veneer units are worked into place. The most recent version of TMS 402-16, *Building Code Requirements for Masonry Structures*, is silent on the thickness of the adhesive mortar, but instead limits the distance between the exterior surface of the adhered masonry veneer unit to the interior surface of the scratch coat or cement backer to 4-5/8 inches to limit eccentric loading.[7] Per ASTM C1242, *Standard Guide for Selection, Design, and Installation of Dimension Stone Attachment Systems*,[8] minimum coverage of the cladding unit included 100 percent coverage at the four-inch perimeter and 95 percent 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 and specified by ACI. 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.

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*, establishes minimum product requirements for manufactured stone.[9], More recently, ASTM C1877, *Standard Specification for Adhered Concrete Masonry Units*, was developed to outline requirements for dry-cast adhered veneer units. 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[10]

	Manufactured Stone	Natural Stone
Water Absorption	13% to 29%	0.2% to 12%
Typical compressive strength	1,500 psi	1,800 to 20,000 psi

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 3). 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 TMS 402[11] code specifies the following sizing and weight limits for adhered masonry units: not exceed 2-5/8 inches in average thickness, bonded surface area of each veneer unit not exceed 720 square inches (bonded surface areas greater than 360 square inches are to be approved by licensed design professional), and not weigh more than 30 psf (pounds per square feet). For prescriptively-designed systems, the height of the AMV system is limited to 60 feet above grade and installed in a vertical application only (not a soffit condition). ASTM C1242 limits the height of the natural stone 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/360 (TMS 402 and the Tile Council of America (TCA)) 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 between the veneer units will reduce moisture penetration.

Figure 3. Delaminated Stone

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 commonly desired for its aesthetic character; however, this installation can be significantly 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* recommends against its use in freeze-thaw climates.[12] Additionally, commentary within TMS 402, section 13.3.1.3 states that dry stack applications should be carefully considered in wet climates that include freeze-thaw conditions.

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 traditional anchored 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. Recent changes within TMS 602 require periodic special inspections for adhered masonry veneers that exceed 60 feet above grade. 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*[13]
- *Installation Guide and Detailing Options for Compliance with ASTM C1780 for Adhered Manufactured Stone Veneer* produced by Masonry Veneer Manufacturers Association (MVMA)[14]
- *Adhered Natural Stone Veneer Installation Guide* produced by Building Stone Institute (BSI) and Rocky Mountain Masonry Institute.[15]
- *Handbook for Ceramic, Glass, and Stone Tile Installation* produced by Tile Council of North America, Inc.[16]

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.

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2. The 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, 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. Achieving full coverage of the unit with adhesive mortar and full contact of the adhesive mortar to the backup substrate are both critical steps to a successful installation (Figure 4). 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. ASTM C1780 states that adhesive mortar should be installed "to achieve setting bed with complete coverage of the back of the unit and full contact between the mortar setting bed, unit, and prepared backing surface". 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 5) 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

Figure 4. Limited Adhesive Coverage

Figure 5. Void in Adhesive Mortar

Figure 6. "Frothy" Appearance

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 6) in the adhesive mortar at the failure plane, which is usually between the veneer unit and the adhesive mortar.

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. Recently published ASTM C1823, *Standard Test Method for Shear Bond Strength of Adhered Dimension Stone*, outlines a procedure for in-situ shear bond testing performed on installed natural stone veneers. This test is applicable to adhered manufactured masonry veneers as well. 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 (Figure 7). 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.

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.

Figure 7. Shear Bond Test

Footnotes

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

[3] ASTM Standard E2556, 2022: Standard Specification for Vapor Permeable Flexible Sheet Water-Resistive Barriers Intended for Mechanical Attachment, *Annual Book of ASTM Standards*, Vol. 04.12, ASTM International, West Conshohocken, PA.

[4] ASTM Standard E2556, 2022.

[5] ASTM Standard E2273, 2022: Standard Test Method for Determining the Drainage Efficiency of Exterior Insulation and Finish Systems (EIFS) Clad Wall Assemblies, *Annual Book of ASTM Standards*, Vol. 04.12, ASTM International, West Conshohocken, PA.

[6] International Code Council, "International Building Code," Falls Church, VA.: International Code Council, 2018; TMS Standard 402/602-16, 2016: Building Code Requirements and Specification for Masonry Structures, The Masonry Society (TMS).

[7] TMS Standard 402/602-16, 2016: Building Code Requirements and Specification for Masonry Structures, The Masonry Society (TMS).

[8] ASTM Standard C1242, 2022: Standard Guide for Selection, Design, and Installation of Dimension Stone Attachment Systems, *Annual Book of ASTM Standards*, Vol 04.07, ASTM International, West Conshohocken, PA.

[9] ASTM Standard C1670, 2021: Standard Specification for Adhered Manufactured Stone Masonry Veneer Units, *Annual Book of ASTM Standards*, Vol 04.05, ASTM International, West Conshohocken, PA.

[10] Building Stone Institute (BSI) and the Rocky Mountain Masonry Institute, *Adhered Natural Stone Veneer Installation Guide, updated edition June 2010*, Chestertown, NY.

[11] TMS Standard 402/602-16, 2016: Building Code Requirements and Specification for Masonry Structures, The Masonry Society (TMS).

[12] Building Stone Institute (BSI) and the Rocky Mountain Masonry Institute, *Adhered Natural Stone Veneer Installation Guide, updated edition June 2010*, Chestertown, NY.

[13] ASTM Standard C1780, 2023, Standard Practice for Installation Method for Adhered manufactured Stone Masonry Veneer, *Annual Book of ASTM Standards*, Vol 04.05, ASTM International, West Conshohocken, PA.

[14] *Installation Guide and Detailing Options for Compliance with ASTM C1780 for Adhered Manufactured Stone Veneer, 5th edition 5th printing*. Masonry Veneer Manufacturer's Association (MVMA), Herndon, VA.

[15] Building Stone Institute (BSI) and the Rocky Mountain Masonry Institute, *Adhered Natural Stone Veneer Installation Guide, updated edition June 2010*, Chestertown, NY.

[16] Tile Council of North America (TCNA), *Handbook for Ceramic, Glass, and Stone Tile Installation*, 2023, Anderson, SC.