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CMHA

CHARACTERISTICS OF CONCRETE MASONRY UNITS WITH INTEGRAL WATER REPELLENT

INTRODUCTION

A concrete masonry unit's characteristics are a function of the properties and proportions of the materials used, as well as the manufacturing processes. The unit characteristics do not singularly define the characteristics and performance attributes of a concrete masonry wall, but they certainly play a significant role in influencing those attributes. When used as part of a breathable exterior wall for an inhabited structure, or as a barrier for any conditioned or protected space, concrete masonry is expected to contribute to the water penetration resistance and moisture control of the wall assembly. Current model building codes include provisions intended to ensure that exterior walls provide adequate weather protection for the building (ref. 1).

Design of concrete masonry walls to mitigate or control moisture migration includes many considerations beyond the characteristics of the concrete masonry unit, such as flashing, weeps, workmanship, mortar or grout characteristics, vents, coatings, vapor barriers, air barriers, temperature differences, and accommodation of differential movement, plumbing and roof leaks, as well as other considerations. The potential for condensation, whether at the wall's interior surface, weather-exposed surface, and/or interior of the wall, should also be considered. Proper design and construction of concrete masonry, considering all of these elements, is critical to the water resistant performance of the wall system. These topics are addressed in References 2 through 7 and in other literature sources.

Mortar joints are especially critical to a wall's water penetration resistance. Achieving good bond between the mortar and the unit surfaces is essential and is largely influenced by the mortar material itself, tooling procedures, and joint profile as well as by the configuration of the concrete masonry unit. Ribbed units, for example, make it difficult to adequately tool the mortar joints. Reducing mortar's absorption characteristic is also important for achieving success in moisture control in a concrete masonry wall. This can be achieved using integral water repellent admixtures in the preparation of the mortar.

While all of the aforementioned aspects significantly affect wall performance, this TEK focuses specifically on evaluating the water penetration resistance characteristics of concrete masonry units and their role in contributing to control of moisture in the wall.

THE ROLE OF CONCRETE MASONRY UNITS

The concrete masonry unit's role and contribution to the concrete masonry wall assembly's water penetration resistance depends in part on how the units are used in the design. The unit characteristic requirements for contributing to success of the exterior wall may vary depending on the design of the masonry wall in which it is used. For example, the role of concrete masonry units is more critical relative to moisture control when they are part of a weather-exposed surface or exterior wall assembly for a protected and conditioned building than if they are used as an interior wall.

There are three primary forces influencing moisture control of a concrete masonry wall: positive or negative air pressures created by the weather or building ventilation systems, internal moisture absorption and/or adsorption through the matrix of the concrete material, and condensation/evaporation. For the purposes of this discussion, absorption is considered to relate to the cementitious material's attraction to or affinity for water at the molecular level. Generally speaking, mortar tends to have a much greater affinity for water than does a concrete masonry unit. Adsorption is the affinity of water at the individual surfaces of the cementitious materials. For instance, capillary pressure creates the tendency for water to migrate into a porous object along the surfaces of the interconnected voids, such as a sponge placed in very shallow water. The same tendency may be observed in a mortar joint or an untreated concrete masonry unit due to interconnected voids.

When units are used on a building exterior, it is desirable to limit moisture migration through the first barrier of defense at the wall surface. Wind driven rain can be a significant cause of water breaching a mortar joint, the front face shell of a single wythe wall, or a veneer unit. These weather-induced positive

pressures can create a challenge to barrier defenses. As a driving force, they are highest at the surface of the masonry and rapidly diminish a few inches into the mortar joint, the unit, or into the cavity of a drainage wall.

Water repellency characteristics of concrete masonry units can be defined by their contribution to barrier defenses at the surface of the wall (which will help limit the effect of the positive pressure of wind driven rain), by their ability to limit the potential for absorbing and adsorbing moisture through their matrix, and by their contribution to controlling condensation.

PERTINENT UNIT CHARACTERISTICS

Barrier defenses in concrete masonry units can be provided at the surface as well as within the mass of the concrete layer. Surface protection can be enhanced by post-applied breathable materials, external coatings and wall coverings. When coatings are used, the most important characteristic of the unit may be its compatibility with the type of coating used. Some clear sealers and certain paints may not be suitable for a particular concrete masonry unit since some coatings may not be able to bridge open pores or fill all surface irregularities or textures. For example, the proper performance of stucco relies on a rougher and more open unit surface texture of the concrete masonry unit to ensure adequate mechanical bonding.

Beyond the unit's exterior surface compatibility with the type of breathable post-applied material, coating or wall covering used, if any, an important consideration is the characteristics of the concrete used to produce the unit. The water penetration resistance of concrete is determined by the characteristics of the matrix and its resistance to absorbing moisture. The properties and proportions of the raw materials used to produce the units and the manufacturing procedures employed influence the water penetration resistance of those units. For example, a greater volume of interconnected voids within the unit may provide an easier path for moisture migration. Alternatively, reducing the volume of voids, such as by increasing the unit compaction, may limit moisture movement through the unit. Aggregate type and gradation, cement to aggregate ratio, mix water content, alkalinity, machine compaction, curing processes, and plasticizing and integral water repellent admixtures are some of the parameters that can have an influence on water repellency characteristics.

INTEGRAL WATER REPELLENTS

Integral water repellent admixtures can be used in the mix design of the concrete masonry unit during production to limit a unit's tendency to absorb moisture through its matrix. Integral water repellent admixtures are usually polymeric products that utilize hydrophobic materials to significantly reduce the absorption characteristics of the concrete. Without these admixtures, even those units with excellent compaction will absorb some moisture through the concrete matrix. Integral water repellents significantly limit absorption by changing the chemistry of the matrix, which may include coating the pores in the concrete with a hydrophobic material that reduces the chemical affinity for water. Thus, concrete masonry units with integral water repellents are positioned to repel water rather than automatically allowing it to migrate through the unit. However, use of integral water repellent admixtures alone does not assure a water-resistant unit. Care must still be taken in production as discussed above to reduce the volume of interconnected voids that will permit moisture migration via other forces, such as wind or gravity.

An advantage of integral water repellent admixtures is that they remain a permanent part of the concrete matrix. Unlike post-applied products, integral water repellent treatments require less maintenance since they are more durable, and they are active throughout the whole concrete matrix and not just at the surface. In addition, integral water repellents can reduce efflorescence by reducing water migration through the concrete masonry (including latent water introduced to the system from grout or mortar).

When integral water repellents are used in concrete masonry units, it is important that the same or a compatible admixture be used in the mortar as well in accordance with manufacturer's recommendations. Failure to use an integral water repellent admixture in the mortar may compromise the water repellency characteristics of the wall.

EVALUATING UNIT WATER REPELLENCY

The water repellency characteristics of a concrete masonry unit can be evaluated using simplistic field methods or more involved laboratory test methods. Three methods are described briefly below, and in more detail in the referenced published industry test methods (refs. 8, 9, 10).

All of these tests are suitable for evaluating units to be used in wall construction. It is important that field testing, if considered necessary, be conducted prior to wall construction since most of these tests can not be accurately performed on a constructed wall surface. For instance, small amounts of mortar left on the surface of a unit even after cleaning, as well as the cleaning techniques themselves, may alter the surface characteristics of the unit relative to its as-delivered condition. Similarly, water introduced into the system from grout or mortar (water of latency) and in turn absorbed into the unit may change the unit's characteristics. Before, after, or during construction, accumulated dust or pollution may also alter the surface characteristics. When water repellency characteristics are evaluated prior to unit placement, any unexpected results from field testing can be addressed in a timely manner using the default laboratory test methods described below.

Water Bottle and Water Droplet Tests

The water bottle and water droplet test methods (ref. 8) can be effective as a first pass evaluations of water repellency. The water droplet method is typically conducted on individual units in a horizontal position as shown in Figure 1 (90 degrees to the "as laid" or construction orientation), but as a variation the water bottle test can also be conducted on units placed in a vertical ("as laid") orientation. Typically, a concrete masonry unit manufactured with an integral water-repellent admixture will be able to support at least three out of the five water droplets for a period of five minutes or more.

At the immediate surface of the concrete masonry unit, the effectiveness of an integral water repellent may diminish over time due to exposure to elements such as dirt, contaminants and UV light. The water repellency characteristics of the concrete just below the surface, however, remain unchanged and provide continuing protection. Therefore, while the water droplet test is rather reliable for identifying a sufficient level of water repellency, it may not be a good indicator of poor water repellency. In other words, if a unit fails to support a droplet of water, the unit should not be considered inadequate, but rather should be taken to a laboratory for further testing using the spray bar and water uptake methods.

If the unit is already installed in the wall, the water bottle test can be used to evaluate the unit. If water applied to the face of the unit is not absorbed immediately, but rather freely runs down the surface of the unit, it likely has sufficient water repellency. Again, if the water is absorbed at the surface, it can not be assumed that the unit does not have sufficient water resistance. Water can be sprayed on a larger wall surface area to determine if isolated units appear to have significantly higher absorption characteristics, since these may appear to have a darker surface color as a result of absorbed water. However, remember that conclusions based upon any field testing, especially on units installed in construction, are not definitive relative to water repellency determinations.

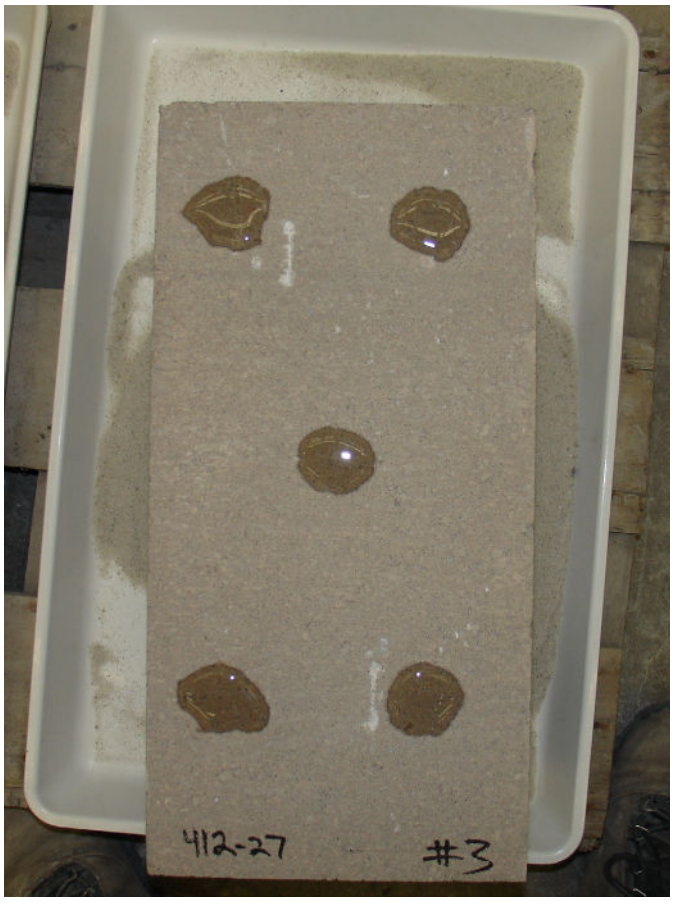

Figure 1—Specimen Undergoing the Water Droplet Test Method

Spray Bar Test

A spray bar test (ref. 9) is a good method to evaluate a unit's ability to limit absorption as well as verify its effectiveness as a barrier against free moisture migrating through pinholes in the unit face. This laboratory test requires relatively inexpensive equipment and can be conducted in a single day. A spray bar is attached to the unit such that it applies a steady stream of water onto its face (see Figure 2). The inside of a hollow unit is visually inspected to assess if and how moisture has migrated through the front face shell.

Moisture may be present on the interior as dampness that can be seen on the inside surface of the front face shell, on the center or end webs, or even on the interior or exterior surfaces of the back face shell. Moisture may also be observed on the inside of the front face shell from "pinholes." Pinholes are locations where water has found a path through the face shell to the interior of the unit. Free water will appear as a droplet and may eventually trickle down the inside of the front face shell. A good water repellent unit will limit moisture migration in both forms: dampness and pinholes. If a unit allows an excessive amount of water to migrate through the unit, the type of failure can give an indication of the corrective action that should be taken by the producer. Excessive dampness, for example, may indicate that additional integral water repellent admixture or process adjustment is needed. Excessive pinholes may indicate that an adjustment to the aggregate blend and/or increased compaction may be necessary to reduce the volume of interconnected voids in the unit.

Figure 2—Specimen Undergoing the Spray Bar Test Method

Water Uptake Test

Another good method for evaluating a unit's resistance to moisture migration is the water uptake test (ref. 10). The test involves placing an oven-dried unit face down (non-split side) in $^1/_8$ in. (3 mm) of water and measuring the water absorption by means of its weight gain over time.

While the water uptake test may be very good at distinguishing between the levels of resistance to absorption uptake, it will not indicate compaction or other flaws that might result in pinholes. Therefore, it is recommended that the results of this test be used to complement the results of the spray bar test and not used exclusively as a means of evaluation.

Figure 3—Specimen Undergoing the Water Uptake Test Method

SPECIFYING WATER REPELLENCY

Most standard unit specifications, such as ASTM C 90 for loadbearing concrete masonry units and ASTM C 1634 for concrete facing brick (refs. 11, 12), do not include performance requirements related to water repellency because these performance characteristics are not necessary in many applications of these products. If desired, water repellency characteristics of the units must be specified separately and identified appropriately in bid packages and purchase orders. When water repellent concrete masonry units are requested, an increase in unit cost should be expected, reflecting the higher material and production expenses required to provide that value-added benefit.

If water repellent concrete masonry units are specified, the following performance criteria and method of assessing that performance is recommended.

- Specification—Water repellency characteristics of concrete masonry units, if desired, should be identified appropriately in project specifications and purchase orders. The specification should state that "water repellent concrete masonry units shall comply with the performance criteria of CMHA TEK 19-7." Any deviations from the information included in this TEK should be clearly articulated.
- Water Bead—Water repellent concrete masonry units delivered to the job site should be able to repel water applied directly to the surface of the unit.
  - o Evaluate the ability for a unit to bead water in strict accordance with CMHA Method CMU-WR1 (ref. 8).
  - o Three units representative of those delivered for use in the construction should be able to support at least three of five water beads (5 ml of water) for a period of five minutes.
    - As a simple preliminary method to determine if a water bead test should be performed, water should not be observed to penetrate readily into a unit when a squirt of water from a water bottle is applied to a vertical surface of a unit. Rather, the water should be observed to fall freely down the unit surface.
  - o In the event that water is repelled, no further evaluation is considered necessary.
  - o In the event that water is not repelled, evaluate a second set of three units in the presence of a representative of the unit manufacturer and other affected parties.
  - o In the event that water is not repelled on the second set of units evaluated, do not draw conclusions as to water repellency characteristics of the unit. Rather perform additional testing in the laboratory using the spray bar test method and/or water uptake method.
- Spray Bar—Water repellent concrete masonry units delivered to the job site should be able to limit the amount of moisture that migrates through the unit.
  - o Evaluate the ability of a unit to limit moisture migration through its matrix in strict accordance with CMHA Method CMU-WR2 (ref. 9).
  - o Three units representative of those delivered for use in the construction should be able to achieve the following after four hours of exposure to a steady spray of water applied directly to its face.
    - Average of 20% or less of the inside surface area on the front face shell for hollow units or 20% or less on the back surface for solid units.
    - For each unit, 5 pinholes or less on the inside surface area on the front face shell for hollow units or 5 pinholes or less on the back surface for solid units.
- Water Uptake—Water repellent concrete masonry units delivered to the job site should be able to limit the capillary pressures within the matrix of the unit and thus limit the initial rate of water absorbed in an uptake test.
  - o Evaluate the ability of three representative units to limit water uptake in strict accordance with CMHA Method CMU-WR3 (ref. 10).
  - o Three units representative of those delivered for use in the construction should be able to achieve the following after partial immersion in water having a depth of $^1/_8$ in. (3 mm).
    - Average twenty-four hour water uptake of 60% or less of the 24-hour total saturation.
- Compliance—In the event that a sample fails to conform to the performance criteria, the unit supplier should be provided the opportunity to remove questionable units from the shipment and retest a second set of three units from the remaining shipment. If the results from a second set of tests performed on representative units remaining in the shipment conform to the criteria, those remaining units should be considered acceptable. If the results from the second set of tests do not conform to the criteria, the remaining portion of the shipment should be considered to not comply with the specified criteria unless a hose stream test onto a sample panel or an agreed-upon portion of the constructed walls shows that the wall assembly demonstrates moisture control to the satisfaction of the owner.

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ABOUT CMHA

The Concrete Masonry & Hardscapes Association (CMHA) represents a unification of the Interlocking Concrete Pavement Institute (ICPI) and National Concrete Masonry Association (NCMA). CMHA is a trade association representing US and Canadian producers and suppliers in the concrete masonry and hardscape industry, as well as contractors of interlocking concrete pavement and segmental retaining walls. CMHA is the authority for segmental concrete products and systems, which are the best value and preferred choice for resilient pavement, structures, and living spaces. CMHA is dedicated to the advancement of these building systems through research, promotion, education, and the development of manufacturing guides, design codes and resources, testing standards, and construction practices.