Hot-applied rubberized asphalt (HRA) is a monolithic, reinforced, asphaltic waterproofing membrane typically used on concrete roofs or plaza decks in a protected-membrane roof configuration. HRA membranes covered with overburden on sloped concrete substrates have demonstrated success ful performance for several decades. The advantages of HRA include seamless composition, single-component installation, broad installer familiarity, and an ability to accommodate and conform to irregular substrate profiles.1

HRA’s robust and continuous bond to concrete substrates provides dimensional stability for the membrane and limits the potential for water to migrate away from membrane breaches. These properties are important for the increasingly popular uses of HRA where overburden materials are significantly more invasive and more costly to remove than utility pavers or gravel ballast. For a continuous mechanical bond to form between HRA and concrete, the concrete must be free of dust and debris, have a textured surface profile, and be “sufficiently dry.” The HRA manufacturers’ requirements vary, but they typically reference a minimum 14- or 28-day waiting period after concrete placement. However, on a construction site, achieving a “sufficiently dry” concrete substrate can be a formidable challenge and may ultimately take weeks or months. Installing HRA on insufficiently dry concrete may affect not only the initial HRA bond but also the long-term bond, as the concrete moisture-vapor drive has the potential to reduce adhesion or debond membranes over time. The roofing industry is well aware of these risks and continues to advance studies on the effects of moisture in concrete decks.2

HRA remains a good choice for many

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applications, but increasingly tight construction schedules may not afford the time needed to sufficiently dry concrete decks for HRA application. To accelerate substrate readiness for HRA, some construction teams have begun applying epoxy moisture mitigation coatings (MMCs) to the concrete substrate prior to applying HRA. The intent is to retard concrete moisture vapor emission and provide a substrate that can be ready for HRA faster than bare concrete would be. These topical treatments are traditionally used in the context of interior floor coverings, but similar treatments are used as a primer for cold fluid-applied waterproofing membranes in exterior applications with a reasonable track record. This approach has been reported to prepare the coated surface of the concrete for HRA application in as few as six days after concrete placement.

Despite the added labor and cost of MMCS, the promise of an accelerated schedule is attractive to contractors and project stakeholders. As with any innovation in construction technology; however, vetting is necessary to assess the merits and drawbacks of this new approach. We developed and executed the testing program described in this paper to support the roofing industry’s vetting of this approach. Specifically, our primary objectives included exploring the following questions:

• How does the adhesion of HRA to MMC products compare with HRA adhesion to uncoated concrete?
• Does broadcasting sand into MMC improve HRA-to-MMC adhesion relative to the otherwise smooth cured MMC surface?
• Is the adhesion of HRA to MMC affected by the dry time of the concrete under the MMC (such as, at 7 days versus 14 days)?
• Does the adhesion of HRA to MMC change over time (such as, from initial installation to 18 months after installation)?

TEST PROGRAM METHODOLOGY
Test Program Features
To isolate variables and start to answer our research questions, we created an HRA-to-MMC adhesion test program. Unless otherwise noted, the sample preparation and testing were performed by Simpson Gumpertz & Heger Inc. (SGH) personnel or laboratory technicians at the authors’ headquarters in Waltham, Massachusetts.

The test program included the following features:

• Two, nearly identical, 4 ft × 8 ft × 5.5 in. (1.2 m × 2.4 m × 140 mm) normal weight concrete slabs with reinforcing bars and underlying polyethylene sheet vapor retarder. Both slabs were wet-cured in general accordance with the American Concrete Institute’s ACI 308.1-11, Specification for Curing Concrete; prepared with surface roughness of concrete surface profile (CSP) 3 with the assistance of an independent subcontractor, in accordance with International Concrete Repair Institute Technical Guideline 310.02; and stored indoors in a temperature-controlled warehouse to reduce potential environmental effects on the testing (Fig. 1 and 2). The only variation between the two slabs was the concrete dry time allowed before the MMC and HRA installation: Slab 1 served as the 7-day-dried sample, and Slab 2 served as the 14-day-dried sample. These durations are shorter than the typical HRA manufacturer’s requirements of 14 to 28 days for normal weight structural concrete. This
variance from the 14- to 28-day range was intentional and part of the test program objective.
• Three MMC products prevalent in the interior floor-covering market. Two of the MMC products were installed on the concrete slabs in sanded and unsanded sample areas in accordance with the individual manufacturer’s requirements; the third MMC product was installed in an unsanded area only. The three MMCs were installed on equally sized sample areas on each slab, and each slab had a control sample area for HRA applied directly to the concrete. The MMC products and slab layouts were as follows (Fig. 3):
  — MMC1: A one-coat epoxy MMC
  — MMC1 with sand: A one-coat epoxy MMC with a sand broadcast into the MMC
  — MMC2: A one-coat epoxy MMC
  — MMC2 with sand: A two-coat epoxy MMC with a sand broadcast into the second MMC coat
  — MMC3: A one-coat epoxy MMC
  — Control: Control sample area for HRA to be applied directly to primed concrete
• One reinforced HRA product applied in accordance with the HRA manufacturer’s requirements. The HRA product was applied to Slab 1 eight days after concrete placement and to Slab 2 fifteen days after concrete placement. In other words, the HRA product was applied to each slab approximately one day after its respective MMC substrate was applied, allowing the MMCs to cure and be covered within the time ranges required by the MMC manufacturers (Fig. 4).
• Six HRA pull-off adhesion tests at the following intervals after the initial HRA application: 1 day (3 hours following HRA application), 3 days, 1 week, 6 months, 12 months, and 18 months (Fig. 5).

**Adhesion Test Method**

The roofing industry continues to examine HRA adhesion test methods, including laboratory and field procedures, and no standardized consensus method had been reached at the time that this paper was written. Various test methods have been studied by the authors, our colleagues,6 and other roofing practitioners. HRA manufacturers do not publish quantitative acceptance criteria for initial adhesion, and the roofing industry has not conclusively studied the relationship between initial adhesion and long-term adhesion. Despite this uncertainty, the known fundamentals and track record of HRA are such that most roofing practitioners will conclude that the initial bond is adequate if the adhesive bond of the HRA to its substrate exceeds the HRA’s internal cohesive bond. This criterion, in concept, is typically supported by the HRA manufacturers. The authors find that the most practical and reliable method to evaluate this criterion (both for field and laboratory applications) is to perform a qualitative pull-off adhesion test on a reinforced tab of HRA and review the failure mode or modes.7

For this program, at each pull-off adhesion test location, we prepared the test using a box cutter and straight edge to cut three sides of a 2 in. wide × 4 in. long (50 mm wide × 100 mm long) tab of the reinforced HRA. We used a multipurpose painter’s tool with a scraper blade edge to lift approximately ½ in. (13
mm) of the tab from the substrate and clamp a duckbill vice grip to the lifted tab edge. We connected a fish scale (a digital force gauge) to the vice grip, and the vice grip to the short side of the tab, pulled on the sample parallel with the long dimension of the tab and at approximately 45 degrees from horizontal, and we documented the mode of failure (adhesive or cohesive) for each tab (Fig. 6). We used the fish scale to facilitate pulling on the HRA sample with a consistent force. Note: The term “failure” is used in this context to mean the condition of adhesive separation from the substrate and/or cohesive separation within the HRA material; this condition does not itself assess performance. For clarity, we use the terms “adhesive separation” and “cohesive separation” in the remainder of this paper.

The primary data point we recorded for each pull test was our visual assessment of the material separation mode in estimated 5% surface area increments of cohesive versus adhesive separation within each tab (Fig. 7).

RESULTS AND DISCUSSION

The tests described above produced results that we discuss in the following sections. We have organized this section by the primary questions that the authors sought to better understand by undertaking this program.

How does the adhesion of HRA to MMC products compare with HRA adhesion to uncoated concrete?

The pull-off adhesion test findings suggest that the adhesion of HRA to an MMC is generally comparable to HRA adhesion to concrete, with the clear exception of MMC1 with sand.

The HRA adhesion to MMC1 with sand on both slabs was consistently and noticeably worse than all the other HRA-to-substrate combinations. We summarize our impressions of HRA adhesion performance for each substrate as follows:

- **MMC1**: On the 7-day dried slab, the 1- and 3-day HRA pull-off tests showed...
poor adhesion. The pull-off test results began improving with the 1-week tests and continued improving until the 18-month tests, when a strong bond was found. Notably, for the same MMC on the 14-day dried slab, the 3-day pull-off tests showed strong adhesion, but subsequently (through the 18-month interval) the pull-off test results varied slightly, with a generally decreasing trend. We therefore categorize HRA adhesion to MMC1, in the context of this program, as inconclusive.

- **MMC1 with sand**: On both the 7-day dried slab and the 14-day dried slab, the pull-off tests showed weak adhesion.
- **MMC2 and MMC2 with sand**: These MMC samples showed relatively similar results with and without the sand broadcast. On the 7-day dried slab, the pull-off test results showed moderate adhesion at the earlier intervals (for example, the 3-day tests) and trended toward strong adhesion at the 18-month interval. On the 14-day dried slab, the pull-off tests began with, and generally remained at, strong adhesion.
- **MMC3**: On the 7-day dried slab, this MMC showed strong adhesion starting with the 3-day HRA pull-off tests and continuing throughout the 18-month interval. However, on the 14-day dried slab, adhesion began (at the 1-day, 3-day, and 1-week intervals) as strong; then, starting at the 6-month interval (and continuing through the 18-month interval), the adhesion significantly declined. We therefore categorize HRA adhesion to MMC3, in the context of this program, as inconclusive.

**Does broadcasting sand into MMC improve HRA-to-MMC adhesion relative to the otherwise smooth cured surface of MMC?**

This program’s findings suggest that the answer to this question is no. Furthermore, depending on the MMC product, broadcasting sand can apparently be detrimental to HRA adhesion. For MMC2, broadcasting sand did not appear to have a substantive impact, for better or worse, on HRA adhesion. For MMC1, however, broadcasting sand generally reduced the HRA adhesion.

This was one of the more interesting findings that we derived from the program. Based on our experience that HRA benefits from a mechanical bond to CSP-3 concrete, we had hypothesized that broadcasting sand would improve HRAs’ mechanical engagement with the MMC substrate which is otherwise a smooth, almost glass-like surface.

**Is the adhesion of HRA to MMC affected by concrete dry time (at 7 days versus 14 days)?**

The dry time of the concrete slab (below the MMC layer) at the time of HRA application did not have a uniform effect on HRA adhesion. The concrete control samples on the 7- and 14-day slabs resulted in generally comparable HRA adhesion for each of the 1-day through 18-month pull-off test intervals.

**Does the adhesion of HRA to MMC change over time (from initial installation to 18 months after installation)?**

When reviewing HRA pull-off adhesion test results with a focus on potential trends across the test intervals (from 1 day through 18 months), we did not find a consistent correlation between HRA-to-MMC adhesion and time.

Notably, however, the concrete control samples provided interesting results in this regard. For HRA directly applied to the primed concrete control sample on both slabs, HRA adhesion improved across the 1-, 3-, and 7-day intervals, but began to decline across the 6-, 12-, and 18-month intervals. We were not surprised to find this decrease in HRA adhesion to concrete over time, but the fact that it occurred so soon (at 6 months) is notable and warrants further study (see “Closing Remarks”). In contrast to the HRA-to-concrete decrease in adhesion over time, the HRA-to-MMC test results for MMC2 showed that that MMC product either maintained bond strength (on the 14-day slab) or increased bond strength (on the 7-day slab) over time.

**CLOSING REMARKS**

Among contemporary options, properly designed and installed HRA remains a good choice for roofing and waterproofing practitioners seeking HRAs’ benefits. However, our experiments suggest that using MMcs as a substrate for HRA does not seem to be a panacea for those seeking to shorten construction schedules without affecting the efficacy of HRA. In fact, in this limited study, which used one common HRA product and three common MMC products, establishing clear-cut trends about HRA adhesion on the MMC products proved to be relatively elusive. The value proposition associated with pairing HRAs with MMcs will continue to be examined by project stakeholders. However, when we consider all that is necessary to introduce MMcs into the HRA equation (for example, MMC material cost, labor, application condition prerequisites, substrate preparation requirements), we conclude that the benefits of using MMcs remain unclear and do not appear to outweigh the combination of drawbacks and unknowns.

The finding that HRA-to-concrete bond began decreasing at the 6-month interval, whereas the HRA-to-MMC bond did not uniformly exhibit a similar decrease on the various MMC substrates, is intriguing and leads us to ask whether MMcs may provide better long-term HRA adhesion than bare concrete offers. This and other questions that emerged during this initial program of testing inspire the following commentary on future research opportunities that could benefit the roofing industry:

- **This test program was conducted (except for concrete placement and surface preparation) indoors, in a temperature-controlled warehouse. This was a practical choice given the availability of storage space and our intent of**
promoting apples-to-apples comparisons. Future researchers may elect to perform testing in an outdoor environment to more closely simulate construction-site conditions (such as exposure to precipitation).

- This test program used one HRA product, but physical properties, chemical composition, and adhesion performance can vary among HRA products. Future test programs could test multiple HRA products on multiple MMCs.
- The authors noted that the control sample of HRA on primed concrete declined in adhesion performance starting at the 6-month interval and continuing through the 12- and 18-month intervals. While this finding is not conceptually surprising given the fundamental principles of moisture drive in concrete, it highlights the need for longer-term research similar to the vapor retarder adhesion research performed by our colleagues Doelp and Donlon, who found that styrene butadiene styrene self-adhering vapor retarders commonly used with low-slope roofing systems in a conventional configuration showed a slight downward trend in adhesive strength on concrete between 115 and 637 days (adhesion tests after concrete placement). The industry would benefit from studying HRA adhesion to concrete (with a larger sample of HRA products) over longer durations than were studied in our investigation (for example, two to five years). Moreover, including MMCs in a future longer-term program could identify how the long-term HRA adhesion with MMCs compares with long-term HRA adhesion to concrete.
- As described previously, the roofing industry has typically focused on HRA’s mechanical bond to the substrate (concrete), and thus the requirements for surface texture are promoted by the material manufacturers. Our findings related to the effect of broadcasting sand into MMC draw attention to another important variable related to adhesion: the chemical bond between HRA and MMCs. Notably, the broadcasting of sand (and the surface texture it creates on the surface of an MMC) did not uniformly produce better HRA adhesion relative to the smooth cured surface of MMC, as we might have expected. Accordingly, the roofing industry would benefit from further study of the chemical bond at the HRA-to-MMC interface, especially if the use of MMCs below HRA gains traction on construction projects.

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REFERENCES


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Foundation Lays Groundwork for a Career in Construction

The future construction workers of America can be found among middle school and high school students in Washington, DC, wrote Rachel E. O’Connell in Construction Executive. That’s the where the DC Students Construction Trades Foundation instructs youth in architecture, design, carpentry, electrical, renewable energy, and sustainable buildings through four programs:

- The Academy of Construction and Design internships and work-based learning
- The Build a House, Build a Future homebuilding program
- The DC Apprenticeship Academy
- A National Center for Construction Education and Research (NCCER) Accredited Training sponsor of skilled trades curriculum in adult worker training programs

The foundation is overseen by a board of directors and industry advisory committee, along with several large partner companies.

“Our offerings create a pathway in that, for the younger students, we offer career exploration, so they can find out about careers in the rapidly changing industry,” said Paula Ralph, chief operating officer of the foundation.

O’Connell noted that employer engagement is key to the foundation’s efforts. “The spark of interest is created in middle school, students begin the program and earn the credential in high school, but outreach from employers is crucial to recruiting passionate, would-be industry leaders during a time when many of their peers are beginning the college application cycle,” she wrote.

Source: Construction Executive