Slab Moisture Testing: Is It Always Reliable?

When testing concrete slabs for moisture emission before installing impermeable floor toppings, be aware that various environmental and construction factors can affect test results

BY ERIC H. LIDHOLM

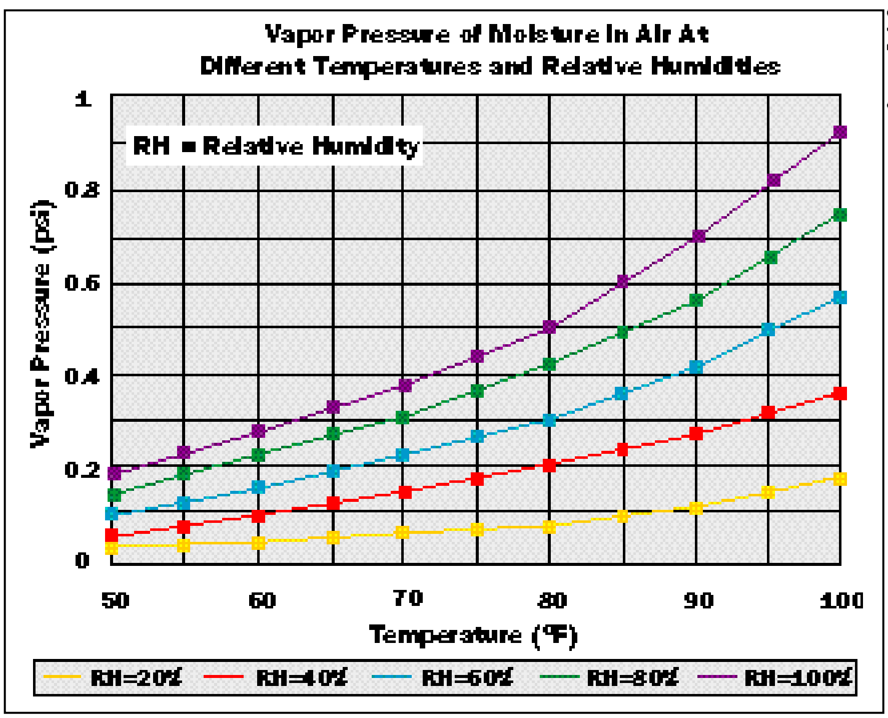
Slab moisture-emission testing is commonly required before contractors can install an impermeable floor topping on concrete slabs on grade. Several tests are available to define whether an excessive slab-moisture condition exists, which can cause debonding of the topping. As the following case history illustrates, however, a slab can pass moisture-emission tests yet still contain too much moisture for adequate performance of an impermeable topping.

The project involved installation of an impermeable epoxy-terrazzo floor topping on a concrete slab that appeared to have been constructed according to project specifications and commonly accepted ACI 302 practices (Ref. 1). Although the slab tested "dry" using accepted slab moisture-emission testing procedures, the floor topping later debonded.

Project Case History

The project, located in the Dallas/Fort Worth area, required installation of more than 10,000 square feet of epoxy-terrazzo topping on the ground floor of a new building. The slab design specified installing a 6-mil vapor barrier on top of a prepared soil subgrade and covering the barrier with a 4-inch-thick layer of select clayey sand at or slightly above optimum moisture content. Crews wetted and compacted the sand, then placed and finished the concrete slab in late December 1993. The concrete was allowed to harden but no curing compounds were used, since they were not required in the project specs.

About six months after floor slab construction, the concrete surface was prepared to receive the epoxy-terrazzo floor topping. Preparation involved grinding and cleaning the floor surface to remove any carbonation and other impurities. After preparing the slab, the terrazzo floor contractor performed mat tests according to procedures out-



Source: Ref. 2

Figure 1. **The driving force for moisture movement through a slab is the differential in vapor pressure between the above-slab and below-slab environments. Use this graph to determine the vapor pressure of moisture in air at different temperatures and relative humidities.**

lined in ASTM D 4263, "Indicating Moisture in Concrete by the Plastic Sheet Method." The slab tested dry. The contractor then installed a test strip of epoxy-terrazzo flooring and allowed it to cure for several days before attempting to remove it with a hammer and chisel. The bond was reported to be excellent, with small bits of the concrete slab adhering to the removed terrazzo flooring.

The epoxy-terrazzo flooring was installed in early August 1994, and the floor performed satisfactorily for about seven weeks. In late September, however, several blisters appeared in the epoxy terrazzo, indicating areas that had debonded from the concrete.

Corrective measures were taken soon after the blisters were noticed. Holes ¼ inch in diameter were drilled on 8- to 10-inch centers through the blistered terrazzo flooring and into the top ¼ inch of the concrete slab in an attempt to dry the concrete flooring and sand layer. But today, more than a year after installation of the holes, moisture continues to seep through many of them, and the flooring continues to deteriorate.

Results of Investigations

Several forensic investigations were also performed soon after the first blisters were noticed. The tests included:

- A petrographic analysis of two concrete cores taken from areas of contrasting epoxy-terrazzo topping performance
- Moisture-content testing of the sand layer and subgrade materials
- Slab moisture-emission testing

The petrographic analysis indicated that the concrete was well-proportioned and had a water-cement ratio of 0.51 to 0.57. The concrete floor slab also met or exceeded the design thickness of 4 inches.

The moisture content of the clayey-sand material was found to be 8% to 11% approximately 15 months after slab construction. The layer also appeared to be relatively dense, and investigators estimated that the sand contained sufficient moisture to be at or slightly less than the optimum moisture content necessary for compaction. The sand seemed to be damp or moist, but not saturated.

During the sand-layer investigations, the position of the vapor barrier on top of the soil subgrade was also assessed. The barrier appeared to be placed somewhat higher than the exterior finish grade, as required by ACI 302.

Site grading around the building was also examined and seemed to be adequate to prevent ponded water. However, a sprinkler system to maintain the lawn area watered up to the building's edge.

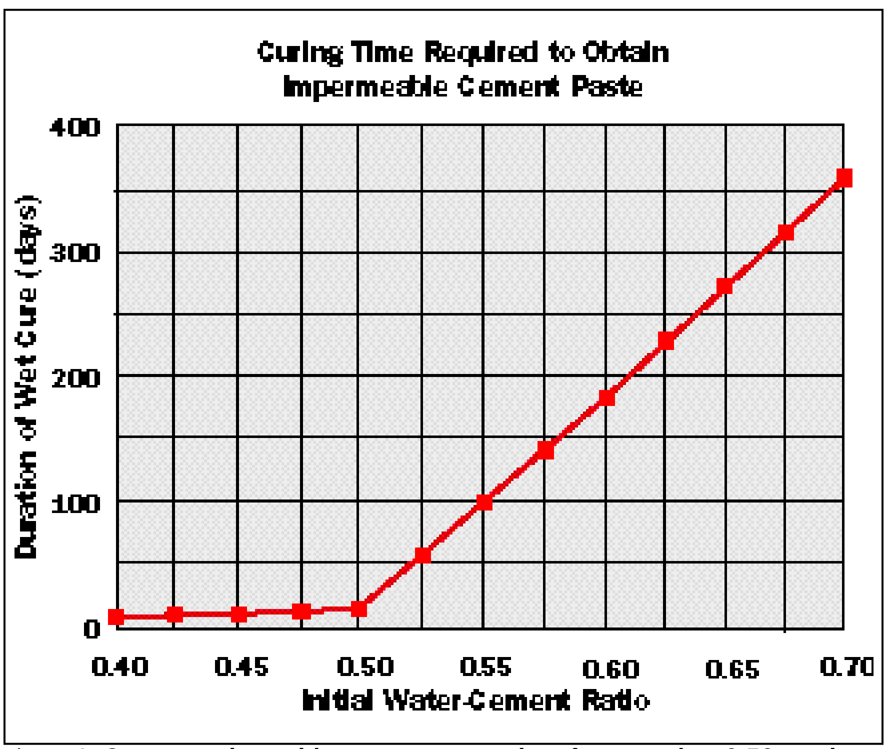
What Went Wrong?

After investigators observed the condition of the epoxy-terrazzo floor topping and compared the design detail to the constructed floor, the question still remained: Why did the terrazzo topping debond from the concrete slab when accepted and widely used construction, design, and testing procedures were followed?

An article on avoiding and repairing slab moisture problems provided the answer (Ref. 2). The article describes the driving force for moisture movement through a slab as the differential in vapor pressure between the above- and below-slab environments. Figure 1 shows the vapor pressure of moisture in air at different temperatures and relative humidities.

When reconstructing the case history for this project, investigators discovered that the slab moisture-emission test performed by the terrazzo contractor occurred during a 24-hour period that broke long-standing temperature records. The low temperature for the period was 77°F and the high was 105°F. The average temperature was about 91°F and the average humidity about 60%.

Since the building was well-ventilated to prepare for installation of the epoxy-terrazzo topping, it's likely that the exterior and interior air temperatures closely matched when the topping was placed. Ac-



Source: Ref. 3

Figure 2. **Concrete mixes with water-cement ratios of greater than 0.50 require longer wet-curing times to obtain a relatively impermeable paste. To avoid moisture problems in slabs on grade, try to use low water-cement ratio mixes and provide adequate curing.**

cording to Figure 1, a temperature of 91°F with a relative humidity of 60% indicates an above-slab air-vapor pressure of 0.44 psi. The underslab temperature at the time of the mat test was estimated to be about 75°F with a relative humidity of about 100%, which also results in a vapor pressure of 0.44 psi. Because little or no differential in pressure existed between the two environments, no vapor transmission occurred. This resulted in a favorable slab moisture-emission test, indicating that the epoxy-terrazzo topping *could* be installed.

After the building's air conditioner was turned on seven weeks later, the interior temperature dropped below 80°F while the relative humidity remained at about 60%. The resulting above-slab vapor pressure was then estimated at 0.27 psi. The climate-control system, therefore, caused a vapor-pressure differential between the above- and below-slab environments of about 0.17 psi. Because pressure differentials are balanced by migration from a high-pressure environment to a low-pressure environment, the moist underslab air migrated to the above-slab environment. This moist air-vapor migration transmitted the damage-causing moisture. More than a year after climate-control of the building interior, the vapor pressure differential is still greater than 0.1 psi.

Compounding the problem is the slab's relatively high water-cement ratio, which was indicated in the petrographic analysis. As Figure 2 shows, significant wet-curing time is needed to obtain a relatively impermeable paste for concrete mixes with water-cement ratios of 0.51 to 0.57 (Ref. 3). Approximately 25 to 135 days of curing is required to obtain a relatively impermeable cement paste. Unfortunately, the contractor did not facilitate curing by applying a curing compound.

The impact of the vapor barrier on the slab's moisture content is unclear. Although the barrier was installed according to ACI 302 recommendations, ACI is vague about the ground moisture conditions requiring vapor-barrier use. Section 302.1R, subsection 2.4.1 states: "Vapor barriers aggravate the problems of plastic and drying shrinkage cracking. Their use should be avoided if ground moisture conditions permit. If ground conditions require their use, a 3-inch layer of approved granular, self-draining, compactible fill over the vapor barrier (and under the concrete) reduces these problems."

It further states: "Where floor coverings, household goods, or equipment must be protected from damage by moist floor conditions, vapor barriers are frequently used under the slab."

It seems that the primary reason for installing a granular fill over a vapor barrier is to minimize plastic shrinkage cracking and to act as a bleedwater blotter.

Conclusions

What can floor contractors learn from this case study? It seems clear that they should take the following precautions when constructing slabs on grade to be covered by impermeable toppings:

- Perform slab moisture-emission tests only when the environmental conditions closely approximate the anticipated in-service conditions. In this case, the slab moisture-emission test performed by the flooring contractor indicated dry conditions; however, it is unlikely that dry conditions would have existed had the building been climate-controlled and the resulting difference in vapor pressure existed.
- Use low water-cement ratio mixes for slabs on grade, since these mixes tend to develop a more impermeable paste.
- Adequately cure slabs on grade, maintaining near-optimum conditions, if possible, to help facilitate the development of a more impermeable cement paste.
- Where impermeable flooring materials are to be used, placing the concrete directly on a vapor barrier appears to be the best method for minimizing moisture transmission.
- Minimize the use of an irrigation system adjacent to a structure having a slab on grade underlaid by a granular layer.
- Repair any damage to a vapor barrier prior to placing the granular layer or concrete.

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References

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2. Thomas K. Butt, "Avoiding and Repairing Moisture Problems in Slabs on Grade," *The Construction Specifier*, December 1992, pp. 107-122.

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