Moisture in Lightweight Structural Concrete Roof Decks

Concrete Moisture Presents Challenges for Roofing Contractors

NRCA's Technical Services Section is receiving an increasing number of inquiries relating to the application of roof systems over concrete roof decks. These inquiries can be separated into two general questions: When is a concrete roof deck dry enough to apply a roof covering? And why is a roof system applied over a concrete roof deck showing signs of moisture infiltration when the roof covering isn't leaking?

CONCRETE BASICS

There are three general types of concrete: normal-weight structural concrete, lightweight structural concrete and lightweight insulating concrete.

Normal-weight structural concrete is what most people think of as concrete; it has a density of about 150 pounds per cubic foot (pcf). Lightweight structural concrete has structural load-carrying capabilities similar to normal-weight structural concrete; it has a density in the range of 85 to 120 pcf. Lightweight insulating concrete, which many roofing professionals are familiar with as an insulating, slope-to-drain deck topping, typically has a density in the range from 20 to 40 pcf.

Lightweight structural concrete inherently contains much more water than normal-weight structural concrete

Structural concrete—normal-weight structural concrete and lightweight structural concrete—is produced by mixing large and small aggregates, Portland cement, water and, in some instances, admixtures such as fly ash or various chemical additives. Admixtures can add entrained air to the concrete, accelerate concrete's curing, retain concrete's excess moisture and/or lengthen concrete's finishing time. Use of admixtures typically is not visually identifiable in the field; microscopic analysis usually is needed for post-application identification of admixtures.

The primary difference in the composition of normal-weight structural concrete and lightweight structural concrete is the large aggregates' type. Normal-weight structural concrete contains normal-weight aggregates such as stone or crushed gravel, which are dense and typically will absorb no more moisture than about 2 percent by weight. Lightweight structural concrete uses lightweight, porous aggregates such as expanded shale, which will absorb about 5 to 25 percent moisture by weight. Lightweight aggregate needs to be saturated with moisture—it's often stored in ponds—before mixing. As a result, lightweight structural concrete inherently contains much more water than normal-weight structural concrete.

Lightweight structural concrete is used in roofing-related applications for cast-in-place concrete roof decks using removable forms; composite roof decks where a metal form deck remains in place; and as a deck topping material, such as a concrete topping surface over precast concrete planks or tees.

Once poured, lightweight structural concrete typically cannot be easily distinguished from normal-weight structural concrete. Visual identification is possible using magnification, typically a microscope used by a trained technician.

REPORTED PROBLEMS

The problems reported to NRCA associated with lightweight structural concrete roof decks include the following:

- *Moisture accumulation.* Excessive moisture from a concrete deck can be pressure-differential driven into and condensed within a roof system.
- *Adhesion loss.* The presence of moisture can result in deterioration of moisture-sensitive roofing materials and adhesive bond loss between adhered material layers.
- *Adhesive issues with water-based and low-volatile organic compounds.* Excessive moisture can affect adhesive curing and drying rates. Also, moisture can result in adhesive "rewetting," resulting in bond strength loss.
- *Metal and fastener corrosion.* Excessive moisture can contribute to and accelerate metal components' corrosion, including fastener corrosion.
- *Insulation R-value loss.* The accumulation and presence of moisture in most insulation products will result in reduced thermal performance (lower effective R-value).
- *Microbial growth.* The presence of prolonged high-moisture

contents in contact with organic-based materials, such as wood fiberboard, perlite board and some insulation facer sheets, can support microbial growth.

DETERMINING CONCRETE'S DRYNESS

The roofing industry historically has used rather rudimentary methods for determining concrete roof decks' dryness and suitability for roof system application.

One method is to apply roofing materials to concrete roof decks only after a minimum of 28 days after concrete is placed. For concrete, 28 days is the standard time for testing and evaluating concrete's compressive strength. There is minimal correlation between concrete's compressive strength and its dryness or suitability to be covered by a roof system.

Another method often used is to mop or pour hot bitumen on a concrete's surface and monitor it for splattering or bubbling caused by excessive moisture in the concrete substrate. Experience has shown this method is unreliable, particularly with current generation concrete mix designs because the test only evaluates empirical moisture levels at the concrete's top surface and not moisture levels throughout the concrete's thickness.

NRCA recommends designers not specify lightweight structural concrete for roof decks

A third method involves taping or otherwise sealing the perimeter of a small, transparent sheet or glass pane to the concrete surface and monitoring it over time for developing condensation. This method is standardized as ASTM D4263, "Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method." Experience has shown this method also is unreliable. An airtight seal at the test panel's edges is difficult to achieve, and unless temperatures on the top and bottom sides of the concrete deck are nearly identical, the resulting pressure difference can result in false "dry" indications.

The flooring industry has developed a test method, ASTM F2170, "Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes," that, in NRCA's opinion, holds some promise for the roofing industry to use when determining dryness in concrete roof decks. Using this test method, small moisture probes are drilled, placed and sealed into a concrete roof deck for a minimum of 48 hours. Each probe measures the concrete's internal temperature and relative humidity.

The ASTM F2170 test method does not provide specific pass-fail values for concrete; however, in the flooring industry, manufacturers of resilient and textile floor coverings and coatings establish maximum acceptable humidity levels for their products. Maximum relative humidity values range from 65 to 85 percent depending on the floor covering type and manufacturer; a 75 percent maximum value appears to be the most common.

NRCA has conducted limited ASTM F2170 testing on existing lightweight structural concrete roof decks where roof systems had been installed and moisture-related problems were reported. These roof systems ranged from 4 to 7 years old at the time of testing. Internal concrete relative humidity values ranged from 89 to 99 percent, indicating extremely high moisture levels.

Concrete industry research shows newly placed normal-weight structural concrete will reach internal relative humidity values of 75 percent in less than 90 days under controlled laboratory conditions (no rewetting); lightweight structural concrete will reach this humidity value in about six months.

CONTRACTORS' RESPONSIBILITIES

Project contract, specification or manufacturers' installation requirements often attempt to place the responsibility on roofing contractors for determining structural concrete decks' dryness and suitability to be covered with roofing materials.

NRCA considers the decision of when it is appropriate to cover newly placed concrete substrates with roofing materials to be beyond roofing contractors' control. Because of the numerous variables associated with concrete mix design, placement, curing and drying, roofing contractors are not privy to and may not be knowledgeable of the information necessary to make such a decision.

Also, though a roofing contractor can visually assess the dryness of concrete's uppermost surface, he or she cannot readily assess any remaining free moisture within the concrete and its likely release.

NRCA RECOMMENDATIONS

NRCA recommends the decision of when a newly placed concrete substrate is ready to be covered with a new roof system be made by the building's structural engineer, general contractor, concrete supplier and concrete placement contractor, each of whom likely will have more knowledge than the roofing contractor about the particular concrete's curing and moisture release rates. It also may be useful to consult the building's project or roof system designer and roof system manufacturer.

NRCA's premise and position is consistent with the flooring industry. For resilient tile and textile floor coverings and coatings, floor covering manufacturers generally require quantitative moisture testing be performed before floor covering installation on concrete. ASTM F2170 testing often is used for this purpose.

Furthermore, in new construction, NRCA recommends designers not specify—and construction managers and general contractors not use—lightweight structural concrete for roof decks or as toppings for roof decks. In NRCA's opinion, the risks of moisture-related problems associated with lightweight structural concrete roof decks outweigh the possible benefits.

In the event lightweight structural concrete is used, NRCA recommends designers clearly specify the concrete's drying parameters. ASTM F2170 can be used for this purpose. Until recognized pass-fail criteria applicable for determining concrete's internal humidity

is developed, NRCA suggests a maximum 75 percent relative humidity value be used; lower values may be necessary when using organic-based materials, such as wood fiberboard, perlite board and some insulation facer sheets, as roof system components.

For reroofing situations where the existing roof deck is known to be lightweight structural concrete or where there is evidence of concrete deck-related moisture problems, NRCA recommends two alternative roof system designs be considered.

An above-deck venting design, such as a venting base sheet, using a loosely laid ballasted roof system with perimeter venting may allow release of the concrete deck's moisture without adversely affecting roof system components. Or sealing the concrete's moisture into the deck by using a high-bond strength vapor retarder adhered directly to the deck followed by an adhered roof system is another option. A high-quality, 12- to 15-mil-thick two-part epoxy has successfully been used as a vapor retarder in the flooring industry.

CLOSING THOUGHTS

NRCA remains committed to keeping members informed of further developments relating to moisture-related problems with lightweight structural concrete roof decks and encourages you to notify NRCA's Technical Services Section about moisture-related problems regarding lightweight structural concrete roof decks. Also, we encourage you to share with us any ASTM F2170 testing, relative humidity or moisture content data developed for projects you encounter.

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