Resolving "Sweating" in Open Industrial Concrete Floor Slabs

Problems may be linked to using floors as a casting surface

by Arthur W. McKinney

Although the concrete industry has developed reliable methods for constructing concrete slabs that will carry moisture-sensitive flooring materials,[1] there has been a steady increase in floor moisture problems associated with open industrial floors. In such cases, moisture develops on the exposed surface and produces a persistent wet, slippery condition. This is not a simple transient condensation event. The persistent slippery surface affects foot and vehicular traffic and may also affect moisture-sensitive materials stored directly on the floor.[2] Serviceability and occupant safety are critical concerns.

The floors experiencing these problems share common characteristics: they are in buildings with tilt-up concrete walls constructed within the last 10 years and generally within a relatively well-defined geographic area. This pattern recognition has been useful in trying to understand the underlying causes and developing strategies for avoidance or remediation.

These floors are typically finished by machine troweling; to date, nothing remarkable has been identified in the basic chemistry of the cements or other components of the concrete mixtures.

Common Factors

Certain common factors have been observed where sweating has occurred:

- Sweating can be correlated with specific, predictable changes in ambient humidity; however, in-place measurements indicate that the floor surfaces are typically above the dew point. Geographically, the problem has been concentrated in northern Florida, Georgia, South Carolina, North Carolina, and Texas;
- The projects were built using tilt-up wall construction, and portions of the floor used for casting the wall panels were treated with a liquid-applied, reactive bond breaker to prevent the wall from sticking to the floor when lifted—a requirement unique to tilt-up construction;
- Areas used to cast wall panels sweat, while adjacent floor areas do not;
- In cases where the floor has been cured with a similar reactive product, sweating may be observed over the entire floor, except for secondary areas, such as pourback strips between the erected wall panels and the edge of the slab used as casting surfaces, pourbacks to replace slab sections removed for subsequent utility work, and pourbacks at column blockouts. These secondary areas typically have not been treated after finishing (or they were cured using means other than a reactive product), and they do not exhibit the sweating problem; and
- When drying occurs, white powder, filaments, or crystals may be left on the surface. These have been identified as carbonation products of alkali salts precipitating out of solution. Frequently, such material defines the extent and pattern of tilt-up panels or other components cast on the floor (Fig. 1).

Hypothesis

Reactive bond breakers have been effective in facilitating tilt-up wall construction. Typical reactive compounds contain components to produce a gel or film of crude soap by reacting with calcium hydroxide in the concrete surface. Such products may be applied as a curing compound for the casting surface and possibly to other areas of the floor slab. Multiple coats are applied in the casting area as a bond breaker.

Effects of both the application and the application rate of the reactive compounds are clearly discernible. The residual gel or film and its effect remain persistent over time.

One effect is similar to sealing a concrete surface, causing a redistribution of the moisture profile (from the wetter bottom of the slab to the drier top). This can draw deliquescent materials to the surface, resulting in the powder, filament, or crystal deposits. Observation suggests that the persistence of the problem is exacerbated by the absence of a vapor-retarding sheet under the slab. This allows free movement of water vapor from the subgrade into the slab.

It appears that, unless residual products can be completely removed, their presence and the transport of deliquescent materials to the surface create the persistent wet, slippery surface conditions observed. Adverse chemistry at the floor surface is the root problem.

However, it is also clear that weather does play a role. Floors do not typically exhibit sweating except under specific weather conditions related to relatively rapid changes in relative humidity.

Our analysis suggests that simply cleaning the floor surface could remediate or at least substantially attenuate the problem. This should be coupled with reasonable management of the building ventilation system.

Remedial Approaches

Two remedial approaches have generally been attempted:

- Clean the floor surface to remove any residual or deliquescent materials brought to the surface. The effects of cleaning can be evaluated as a change in the absorption rate at the surface; and
- Manage the building ventilation system to minimize the introduction of outside air (attenuate the rate of change in ambient interior conditions). Ceiling-mounted, high-volume, low-velocity (HVLV) fans can be used to improve air movement. Such fans can move warmer air near the ceiling down to the floor, warming the surface and moving it further off the theoretical dew point.

Normal cleaning procedures have been shown to temporarily resolve the problem. Aggressive cleaning can severely damage the traffic surface, leading to serviceability problems such as tire wear. Numerous protocols have been proposed and field tested over the last several years with limited success. It became clear that a workable deep-cleaning process needed to be developed.

Remediation by deep cleaning

Where the project reflects the conditions described, deep cleaning of the slab surface to effectively remove residual materials may be the best choice. Recent success with this approach has been encouraging, as it directly addressed the root cause. One issue with such cleaning has been to determine the correct materials and protocols for remediating the problem without damaging the slab surface.

A sequence for an effective deep-cleaning protocol is set out in the sidebar on "Cleaning Regime." Experience has shown that both the specific sequence and dwell time within each step are very important.

If deep cleaning does not fully resolve the problem, the weather side of "sweating" may be addressed. Events can be anticipated and attenuated by managing the building ventilation system.

Fig. 1: In many cases, surface moisture problems are associated with the formation of a powder or crystalline residue in areas where tilt-up wall panels were cast: (a) general view of casting area on floor slab; and (b) close-up of crystals

Cleaning Regime

A small test area should be used to confirm the adequacy of the materials, protocol, and timing. When cleaning large areas, results should be checked against the test area at each step. The general outline for testing the procedure is as follows:

1. Check the floor for water penetration. If water sprayed on the surface beads up, proceed with the following steps.
2. Spray alkaline degreaser (at full strength or at a dilution rate recommended by the supplier) in front of a ride-on floor scrubber. The ride-on unit should be configured to agitate the degreaser with its leading brooms, followed by scrubbing and continuous vacuuming.
3. Rinse using a spray of clean water in front of the scrubber, again agitating, scrubbing, and vacuuming continuously.
4. Spray acidic cleaner in front of the scrubber, agitating with the unit's brooms and scrubbing but without vacuuming. The scrubber should leave a trail of bubbles on the floor.
5. Vacuum the floor.
6. Repeat Steps 4 and 5 to increase the absorption of the floor.
7. Fill the clean water tank with neutralizing solution and scrub the floor with neutralizer and without vacuuming. The scrubber should leave a trail of bubbles on the floor.
8. After the complete work area has been treated with the neutralizer, rinse with clean water and vacuum.
9. After each step, test the floor for water penetration and compare the results with the test area. In recent tests, Rilem tubes have been tried to assess relative improvements in surface absorption. The tubes were sealed to the floor and evaluated over a 2-hour period (Fig. 2). Rilem tubes on concrete can produce erratic results, but multiple tests suggest significant improvement after cleaning.
10. Allow to dry or revacuum.

Each agitation and power-scrubbing step may take 15 to 20 minutes based on a 10,000 ft^2 (930 m^2) effort. Keep the work area uniformly wetted through each step. Dwell time is very important. The cleaning products should likely contain surfactants and chelating components. It may take some trial and error to achieve a process that deeply removes the targeted materials without damaging the floor surface. The developed process can then be applied to larger floor areas.

After deep cleaning, application of a surface densifier might be considered (to date, the presence or absence of a silicate densifier has not been shown to be a factor in either causation or remediation).

Fig. 2: Testing for relative absorption using Rilem tubes. In this case, four tubes were used at each test site/cycle

Remediation by managing ventilation

Managing the building ventilation system to limit or avoid moisture events has become better understood as the problem has affected an ever-larger geographical area and, thus, more projects. This solution is, basically, living with the problem. The strategy is as follows:

1. Identify and track the problematic weather events;
2. Keep the floor clean;
3. Avoid negative air pressure in the building;
4. Under the appropriate conditions, close all exterior doors and shut down ventilation fans and louvers to minimize infiltration; and
5. Supplement air movement from the ceiling area down to the floor using high-volume, low-speed (HVLS) fans. These prevent stratification and warm the slab.

Steps 4 and 5 must be activated prior to the weather change. With proper timing, events can be substantially curtailed. Bad timing can make the problem worse.

Such "air movement only" solutions do not require additional heat energy or mechanical dehumidification. Evaporation, per se, is simply not effective unless the air is dehumidified. The perceptible air movement from HVLS fans reduces occupant stress during problematic events.

General Avoidance and Design Considerations

Current understanding of the moisture problem leads to two approaches that should be considered for new open industrial floors, particularly in those geographic locations subject to sweating events:

- Use reactive bond breakers only in areas used for casting and use them in strict accordance with the manufacturer's printed instructions. Avoid direct contact with the floor surface. In the casting areas, cure the floor with a suitable water-based styrene acrylic compound. Again, follow the manufacturer's instructions. Using the curing compound will help ensure that the reactive component in the bond breaker will interact with the materials in the wall panel—not the materials in the floor. This is an approach that is used in stack casting. After casting operations, completely remove the residual materials from the floor surface; and
- Limit sources of moisture by the design and management of the building ventilation system and by requiring a competent vapor-retarding sheet under the entire floor.

Summary

Sweating floors are the result of a combination of adverse transient weather and adverse floor surface chemistry. The problem can be substantially remediated by deep cleaning of the floor surface.

For open industrial floors, the moisture issue represents a growing concern. The indicated strategies will affect the design and overall methods and materials required for a project. This will impart costs that may push pricing outside local market norms.

References

1. ACI Committee 302, "Guide for Concrete Slabs that Receive Moisture-Sensitive Flooring Materials (ACI 302.2R-06)," American Concrete Institute, Farmington Hills, MI, 2006, 42 pp.

2. ACI Committee 360, "Guide to Design of Slabs-on-Ground (ACI 360R-10)," American Concrete Institute, Farmington Hills, MI, 2010, 72 pp.

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