THE CONUNDRUM OF WHAT TO DO WITH WET CONCRETE ROOF DECKS

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With the move to tighter and tighter buildings for energy conservation purposes, issues with moisture are becoming more prevalent. Currently, a lot of attention is being given to how to properly seal the building, where to apply vapor barriers/retarders, and where the insulation should be installed. Another issue of import is the moisture contained within the building materials themselves when they are first installed, as well as the moisture that they absorb before the building is “dried in.”

Some of the problems with the moisture content of the materials are exacerbated by how we build structures. One such example that is a real problem for the roofing industry is concrete slabs that are supported/reinforced with unvented steel deck pans. The steel pan prevents the concrete from drying down into the built environment and can only dry up into the roofing materials. For an idea of just how much moisture can exist in some common construction materials, an 8-ft.-long 2x4 stud may contain half a pound of excess water, while concrete can hold 198 pounds of excess water per cubic yard. Taking this into consideration, how are designers accounting for this water, which will be released into the finished building?

I was first exposed to this type of problem with a roof system that had just been finished and was found to have mold growing on the face of the insulation boards. There were no apparent flaws in the system that could account for the moisture. Unfortunately, there was very little documentation of the construction of the roof that might have indicated how the moisture got there. However, there were some hints suggesting it was built into the roof via the moisture stored in the concrete. As you may have guessed, I was involved with litigation concerning this project. Regardless of the outcome of the litigation, I have come to realize that there are few options for the industry to evaluate when roofing products should be installed over a concrete roof deck.

Many of the parties that have suffered losses from moisture problems in roofing systems have implemented plans to attempt to distance themselves from the problem. At least two different manufacturers have technical briefs suggesting the designer of record is required to determine when the concrete roof deck is acceptable for the installation of roofing materials. Most specifications for a building are written in a manner that requires the roofing contractor to make this decision. The construction management firm and the owner are in an awkward position because the specifications and the roofing manufacturer’s requirements are in conflict, and they need to get the structure built and into service. So how does one proceed?

Currently, the roofing industry appears to be pushing for the installation of vapor barriers as a means to resolve the issue with moisture accumulating in the roof system from the concrete deck. In roofing applications, vapor barriers have little to no permeability. If the vapor barrier is truly vapor-impermeable, where does the moisture go? What will be the long-term impact of the moisture being retained in the concrete roof deck? What if there is a flaw in the tie-in of the vapor barrier for the roof to the fenestration system, the rest of the roof system, the water resistive/air barrier system for the wall of the building, or any of the other locations where the roof vapor barrier needs to be tied to some other component of the building? Based on countless studies and investigations throughout the building industry, air laden with moisture being released into another area with different ambient conditions does not have positive results.

As food for thought, mold begins to grow on organic surfaces at a relative humidity (RH) of 75%, densified wood products (e.g., oriented strand board or OSB) can sustain non-recoverable swelling with RH levels greater than 80%, carbon steel starts to corrode within an RH range of 70 to 80%, and concrete can deteriorate as a result of alkali-silica reaction (ASR) with an internal RH greater than 80%. Some of the potential moisture-related problems listed here can have significant impacts on the structural integrity of the building and can be very costly to repair, such as the ASR deterioration of the concrete. High concrete moisture content may have been the catalyst...
Figure 1 – Sample under ambient conditions vs. oven-dried sample.

Figure 2 – Drying time at 50˚C vs. drying time at 77˚C for two different mixes.

for the separation of liquid-applied roofing materials from concrete roof decks due to reverse osmosis that has been reported in the Pacific Northwest. Another problem that could arise from high concrete moisture content is the failure of adhesives used to secure the roofing materials, especially considering that the roofing industry has moved toward water-based adhesives.

Currently, there are very few tests that can be implemented to assess the moisture content of the concrete roof deck. Some of the tests that have been proposed and used include ASTM F2170 (moisture probes), ASTM F1869 (salt dome), and ASTM D4263 (plastic sheet test). There is one major stipulation for these tests that must be considered, which is the ambient conditions must be stable and controlled to get a true assessment of the moisture content of the concrete. The problems with these tests could be further expanded to the investigation of failed roof systems because you cannot isolate the concrete from the moisture-laden insulation, the temperature is not stable because the thickness of the insulation would need to be cut down to accommodate the equipment (F1869), the test duration is not long enough (F2170), and/or there is no comparison of the ambient conditions above the deck as compared to the deck itself.

So what is being done to resolve the issue? At this time, there is a work item for a new ASTM test method and/or guide that is under development to assess the moisture content of concrete. The test method under development utilizes two concrete specimens for comparison’s sake. The control is placed in an oven to determine the amount of moisture that can be released from the concrete. The other sample is to be left in the field to dry under ambient conditions. Based on the comparison of weight between the two samples, one can get an idea of how much moisture may still be contained in the field sample. So long as the field sample has been exposed to the same conditions as the roof slab, one should be able to compare how much moisture may still reside in the concrete roof slab. As an example of how one might use the proposed test method, a 9- x 9-in. (23- x 23-cm) baking pan of standard weight concrete initially weighing 14.5 lbs. (6.6 kg) loses 0.7 lbs. (0.3 kg) of water after oven drying (100% total loss of free moisture). If the field sample has only lost 0.1 lbs. (0.04kg) in the same time needed to dry the lab sample, one could conclude that the concrete still has 85% of its free moisture to be released. This may not give a definitive answer of when the slab is dry enough, but it does provide a tool to understand how much moisture may still be in the concrete.

As a means to keep the test simple and available, the equipment for the test was kept as simple as possible. The equipment for the test includes two sample pans, a typical kitchen oven, and a higher-end kitchen scale (mainly to accommodate the weight of the concrete samples). The test is run with the oven set at the warm setting, which is approximately 170°F (77°C) and goes until the weight of the concrete sample has stabilized. After the weight of the sample has stabilized, it is allowed to cool to ambient conditions. After the sample has cooled, it is submerged in water for 48 hours. After the 48 hours, the sample is placed back in the oven until the weight of the sample has stabilized once again.

Soaking the sample in water was added to the test method to confirm that the oven-drying process did not remove excessive amounts of water that might be needed for the chemical reactions in the concrete. One of the negatives of heating the concrete is that it alters the chemical/physical prop-
erties of the concrete, which does have a slight impact on the weight of the concrete. However, the difference in weight is negligible as compared to the increased time it takes to get all of the free moisture out of the concrete sample.

To date, several trials of the proposed test method have been completed or are underway. The trials have considered different sample thicknesses, concrete samples with different admixtures, samples with different moisture egress paths, and different oven temperatures. The trials for the new test method have been positive.

Based on the trials that have been completed so far, some interesting trends have come to light that really need to be considered in roof construction. One of the most noteworthy findings is that all of the drying efforts made on a concrete substrate can be lost if water is allowed to accumulate on its surface for a short amount of time (i.e., 48 hours). It is also interesting to see that the concrete returns to a weight that is very close to when it was first placed after being submerged in water for 48 hours. As one can see from Figures 1 and 2, the temperature substantially impacts the time needed for the concrete to release its free moisture. The first trial that was undertaken is reflected in Figure 1. After a month, very little change in weight was observed in the concrete sample that was left under ambient conditions. The average outdoor temperature was 52°F (11°C) for April and 66°F (19°C) for May at my home in Ohio. Based on the results, it was believed that there were significant errors in the test method with regard to the oven temperature. However, subsequent independent testing has confirmed that the test method is sound, which can be seen in Figure 2.

As for the litigation case that was mentioned previously, an admixture was added to the concrete because the owner wanted to have the option to add additional floors to the building for future needs. Some of the advertisements for the particular admixture suggest that it impacts the capillary pores in the concrete, which enhances the concrete’s compatibility with different flooring materials. Some of the people involved in the project identified the impact on the capillary pores as a cause for the moisture problems that were observed with the roof system (i.e., the moisture was released from the concrete very slowly). Based on the results of Figure 3, a concrete sample containing the admixture has nearly the same moisture-release characteristics as a concrete sample of the same mix design, but without the admixture. So how did the moisture get in the roof system?

The trial identified in Figure 4 is for the assessment of the moisture release in concrete with regard to different moisture egress paths. The main reason that this trial was performed was to confirm the test results where it is impractical to use full-thickness concrete samples. One of the results for this trial is that if multiple moisture-release paths are designed into the building, the concrete can release its moisture much quicker than with a single path. This can be verified by looking at the curve for the 4-in.-thick sample with two moisture-release paths as compared to the 2-in.-thick sample with a single moisture-release path. As one can see, the curves are almost identical.

So what should be done about moisture contained in a concrete roof deck? That is a very good question that does not have a simple answer. Is the installation of a vapor barrier over the roof deck the solution? Probably not. The main reason why a vapor barrier may not be the answer alone is because it is not possible to predict where
the moisture will be released and the negative impact(s) that the moisture may have on the other components of the building.

Two of the most significant opportunities that design professionals may have at their fingertips to help the moisture problems associated with concrete are to use vented forms/deck pans or to not use concrete roof decks altogether. There may be negatives to not using concrete in a roof deck or not using a vented deck, but again, what are the potential risks for leaving the moisture built into the building? From a structural point of view, a couple of items that have not yet been fully investigated are the long-term corrosion of the steel deck pan (especially at the joints and laps where the alkalinity of the concrete may not be available to stave off corrosion) and the corrosion of the fasteners used to secure the various roof components around the perimeter of the roof.

Roofing professionals can help alleviate the problem by not installing roofing materials over wet concrete decks. There have been many instances where water has been standing on a concrete deck and the contractor comes along with a squeegee, a leaf blower, and/or a propane torch, and magically the roof is dry enough to install a vapor barrier over the surface of the concrete. Unfortunately, these “drying” activities do not remove much of the free moisture deep in the concrete. These practices may remove sufficient amounts of free moisture at the surface of the concrete so that the roof deck will pass the hot asphalt test, but the majority of the free moisture is still in the concrete. Several hours after the drying activities are complete, the moisture in the concrete will be evenly distributed and will not be much different than before the drying activities occurred.

One should note that free moisture from the concrete deck may not be able to enter the roofing assembly because of the installation of a vapor barrier over the concrete, but what about the long-term performance of the fastening system used to secure the vapor barrier and/or roofing system, or the possible degradation of the concrete materials that are susceptible to ASR deterioration?

Another shortfall that has been commonly observed is the installation of wet insulation because it was not properly stored. Having damp or wet insulation significantly impacts its thermal performance. Wet insulation and moisture in the concrete can be resolved or minimized through the due diligence of the roofing contractor. The insulation can be stored in such a manner that air can freely flow around it and water can be shed off of its surface by maintaining the tarpaulins and packaging that it comes in. Keeping the concrete deck dry is significantly more difficult but not impossible to achieve. One solution might be to place tarpaulins over the deck at the end of the day to keep water from the surface, or through the use of large ventilation fans to help circulate air over the surface of the concrete, increasing the drying potential of the concrete. These efforts may be more costly, but so is tearing off a new roof because mold was discovered or because the adhesives securing the insulation or the membrane in place broke down, causing the roofing system to fail.

The owner/construction manager has a major responsibility to help alleviate the moisture problems in the roof assembly. First and foremost, an owner/construction manager can help to alleviate the problem by understanding that the schedule needs to accommodate the weather. He or she must also realize that just because there were only one or two weather delay days during construction, this does not mean that the concrete substrates are ready to be covered with a roof system. Recall how quickly the concrete can become saturated with water as per the figures above. Again, it is understood that the owner/construction manager has a need for the building and that the schedule and budget are important, but the schedule and budget will be more greatly impacted should a roof tear-off be required due to haste.

As for the plans for moving forward with the test method, hopefully some of the trials that have been completed thus far will give credence to the need for the proposed test method. From a research perspective for the proposed test method, it is being used to confirm the performance of admixtures and coatings to help develop means and methods to help keep standing water from being absorbed by the concrete during construction. There are also plans to look at the performance of vented deck pans, the impact of curing agents and sealers on the release of moisture in concrete, and whether the surface finish applied to the concrete impacts moisture release.

Questions or suggestions related to this topic may be directed to the author.

References

1. Reduction of hem-fir stud from 15% to 11% moisture content with a specific gravity of 0.45.

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