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PARTNER OF THE DALLAS COWBOYS

May 21, 2020 – Webinar

Understanding the Roofing Industry's Concerns With Moisture in Concrete Roof Decks

presented by

NRCA

Mark S. Graham
Vice President, Technical Services
National Roofing Contractors Association

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Speaker bio.

- Raised in a three-generation family in the construction business
- BS degree in Architectural Engineering
- Roofing contractor
- Consultant and designer (and expert witness)
- Last 27 years at NRCA:
  - Staff lead on Technical Services
  - Codes and standards
  - Problem analysis
  - Contributing editor to *Professional Roofing* magazine

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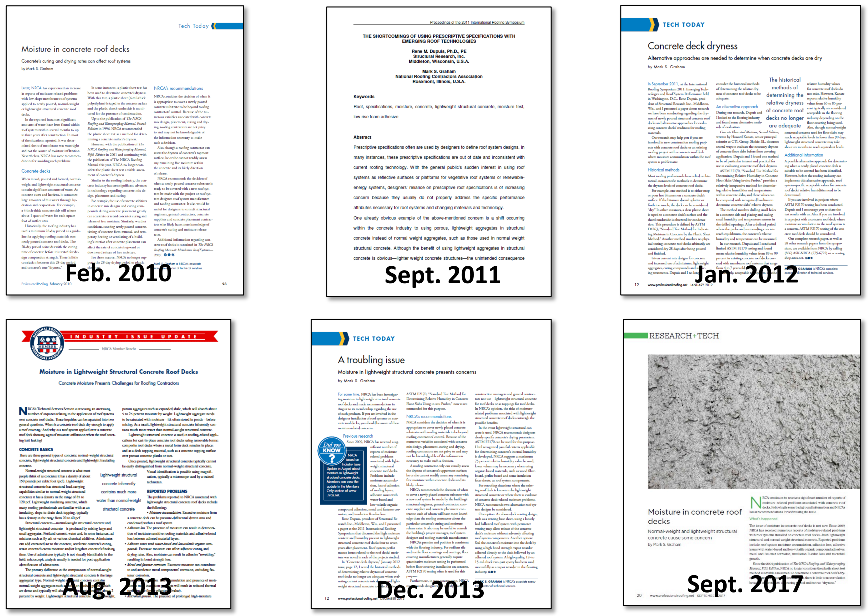
Moisture in concrete roof decks



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Topics

- Reported problems
- Concrete basics
- Traditional dryness evaluation methods
- Historical drying research
- Industry drying research
- Additional research
- NRCA's recommendations
- Questions

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Reported problems

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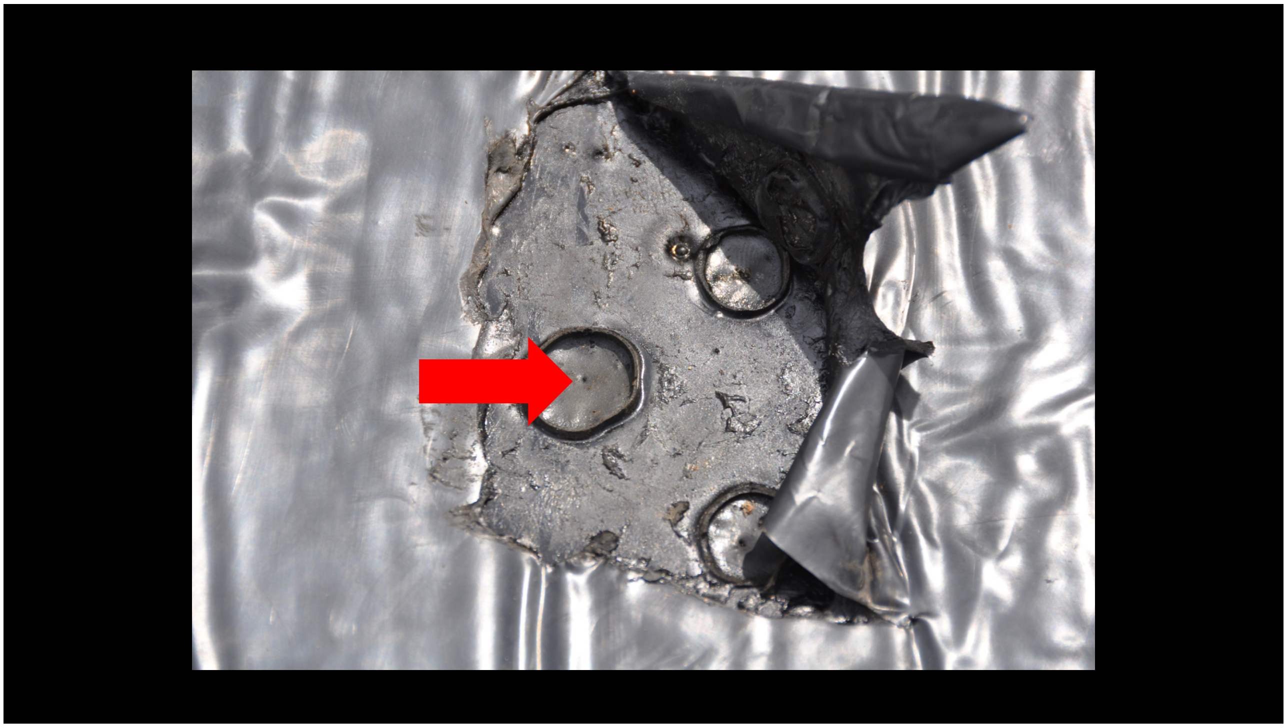

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<u>Concrete deck moisture-related roofing issues</u>

- Moisture accumulation
- Adhesion loss
- Water-based and LVOC adhesives issues
- Material degradation
- Metal and fastener corrosion
- Insulation R-value loss
- Microbial growth

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The issue is concrete deck moisture
in it vapor phase…

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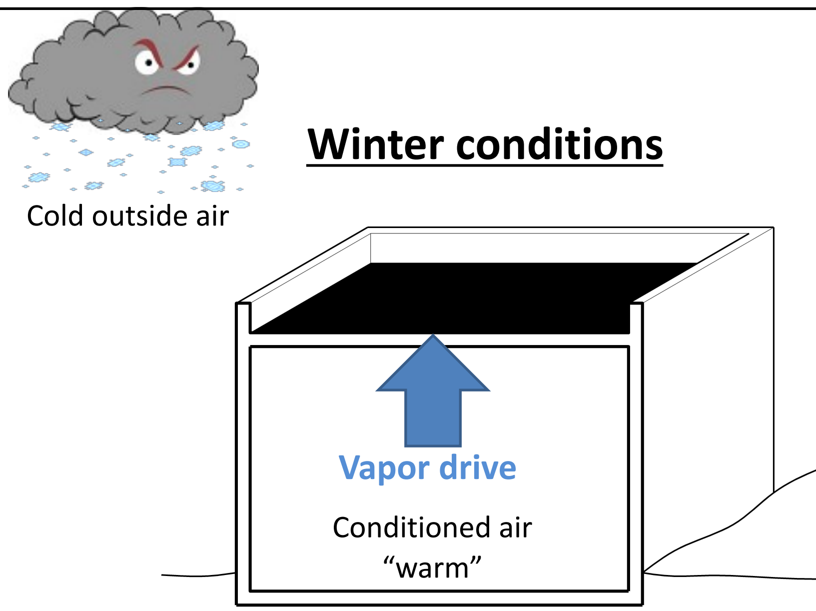
Winter conditions



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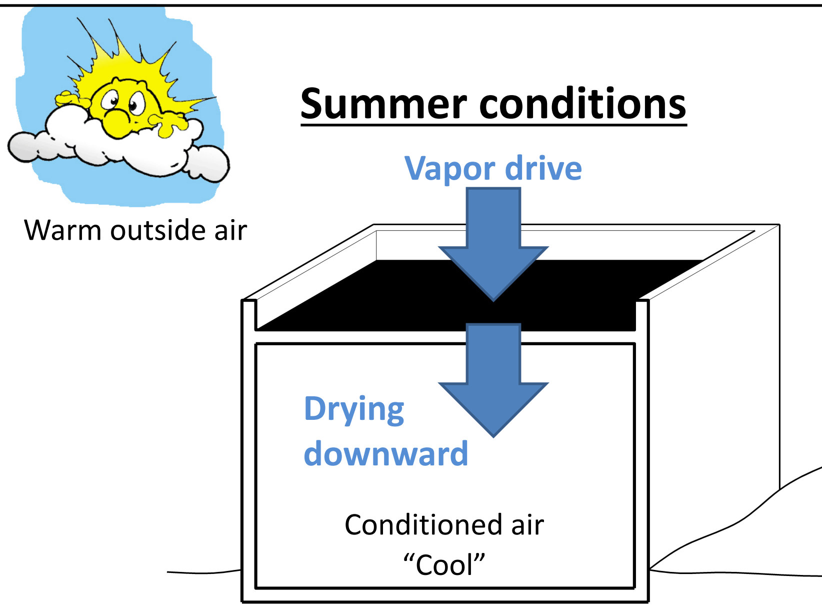
Summer conditions



"Self-drying" roof assembly

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Concrete basics

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Some terminology

- **Structural concrete (normal weight)**
  - 150 lbs/ft^3
- **Lightweight structural concrete**
  - 85–120 lbs/ft^3
- ~~**Lightweight insulating concrete**~~
  - ~~20-40 lbs/ft^3~~

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Concrete mix design

- Aggregate:
  - Large aggregate
  - Fine (small) aggregate
- Portland cement
- Water
- Admixtures:
  - Fly ash
  - Air entrainment
  - Curing compounds
  - Etc.

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Concrete batch

Date 08-Jun-2016 Item Listing Page 1

Item Code	Description	Short Descr	Item Category	Inventory Item Code	Keep in Inventory
96506030	4000 PSI #67 AE	4500 PSI #67 AE	03658 7 B		[ ]

Constituents	Item Code	Short Descr	Quantity	
2	21005000	LAFARGE - CEMENT	520.00	lb
	21009000	FLY ASH - BULK	130.00	lb
	12210000	FINE AGG/CONCRET	1280.00	lb
	16210001	3/4" COARSE AGG/	878.00	lb
	13060000	3/4" LIMESTONE/C	878.00	lb
	20997000	AIR ENTRAINING-F	6.00	oz
	23001000	WATER	29.00	ga

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Concrete Aggregates

60-80% of Concrete Mix Design

- Normal-weight aggregates (stone):
  - Dense
  - Absorb about 2% by weight
- Light-weight aggregates (expanded shale):
  - Porous
  - Absorbs from 5 - 25% by weight

Lightweight structural concrete inherently contains more moisture

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An up-close look

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Uses for lightweight structural concrete

- Cast-in-place roof decks (removable forms)
- Composite roof decks (metal form deck stays in-place)
- Deck topping (e.g., topping over precast concrete)

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What is the appeal?

Water Tower Place (1975)
Chicago, IL
859 feet tall

- Reduced weight:
  - Transportation
  - Pumping
  - Placement
  - In-place (Dead load)
- Similar strength
- Similar workability:
  - Begin finishing earlier
- Sustainability credit:
  - LEED

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Traditional dryness evaluation methods

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When is it OK to roof?

Historical guidelines

- 28 days after placement
- Application of hot bitumen
- Plastic film test
  - ASTM D4263, "Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method"

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Plastic film test

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When is it OK to roof?

Historical guidelines

- 28 days after placement
- Application of hot bitumen
- Plastic film test
  - ASTM D4263, "Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method"

These guidelines are not appropriate for current generations of concrete mixes

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Flooring industry

ASTM Committee F06—Resilient Floor Coverings

- ASTM F1869, "Standard Test Method for Measuring Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride"
- ASTM F2170, "Standard Test Method for Determining Humidity in Concrete Floor Slabs Using In-situ Probes"

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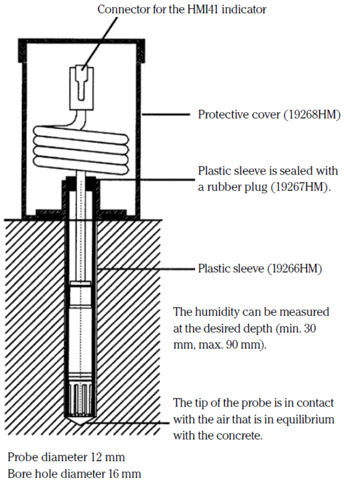
ASTM F2170 apparatus

Measure relative humidity (RH %) and temperature



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Trial ASTM F2170 tests

Existing lightweight structural concrete roof decks

	Roof 1	Roof 2	Roof 3
Roof age (yrs)	4	7	7
Area (ft^2)	13,200	23,840	14,760
Thickness (in.)	6.5	7.5	7.3
No. of readings	13	10	8
High reading	99% RH	99% RH	99% RH
Low reading	63% RH	96% RH	84% RH
Median reading	97% RH	99% RH	99% RH
Mean reading	89% RH	99% RH	95% RH

Values of 65-85% RH are considered acceptable in the flooring industry depending upon the specific floor covering type.

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Historical drying research

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PORTLAND CEMENT ASSOCIATION
RESEARCH AND DEVELOPMENT LABORATORIES
Development Department • Bulletin D89

Table 1 Drying time in days at 73 F and 50% relative Humidity for a 4-inch-thick specimen to reach 3 lbs/1,000 sq. ft./24 hrs.

Water-Cement Ratio	Bottom Sealed	Bottom Exposed to Water Vapor	Bottom in Contact with Water
0.4	46	52	54
0.5	85	144	199
0.6	117	365	>>365
0.7	130	>>365	>>365
0.8	148	>>365	>>365
0.9	166	>>365	>>365
1.0	190	>>365	>>365

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***Concrete Floors and Moisture* (2008)**
Howard Kanare

A concrete slab will reach a 75% RH
- Normal weight structural concrete
  – Less than 90 days
- Lightweight structural concrete
  – Almost 6 months

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Re-think our concept of concrete roof decks

A concrete deck is not a non-breathable, non-absorptive solid

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Re-think our concept of concrete roof decks

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Roofing Industry's concrete dryness research

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Roofing industry research

- Phase 1:
  – Characterization
  – Hygrothermal testing and initial analysis
- Phase 2:
  – Laboratory simulation
  – Computer simulations

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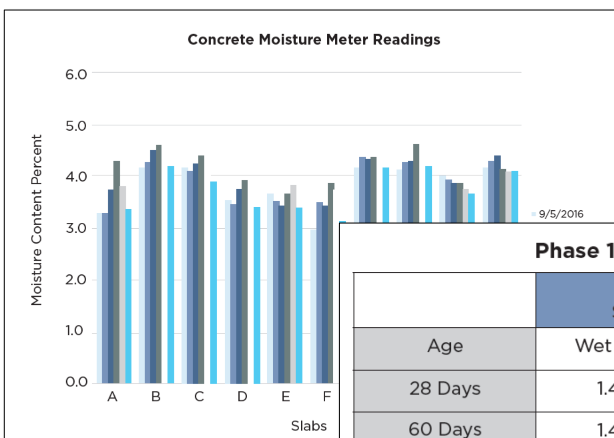
Phase 1 results



Phase 1 - ASTM E96 Calculated Perm-in

	Lightweight Structural Concrete		Normal Weight Structural Concrete	
Age	Wet Cup	Dry Cup	Wet Cup	Dry Cup
28 Days	1.48	0.78	3.42	1.05
60 Days	1.45	0.47	2.03	1.13

Figure 2: Results of ASTM E96 water vapor transmission testing. Note the lightweight structural concrete has about half the permeability of normal weight structural concrete. Considering lightweight structural concrete arrives with more than twice the evaporable water of normal weight structural concrete, this explains why lightweight structural concrete remains moisture laden so long.

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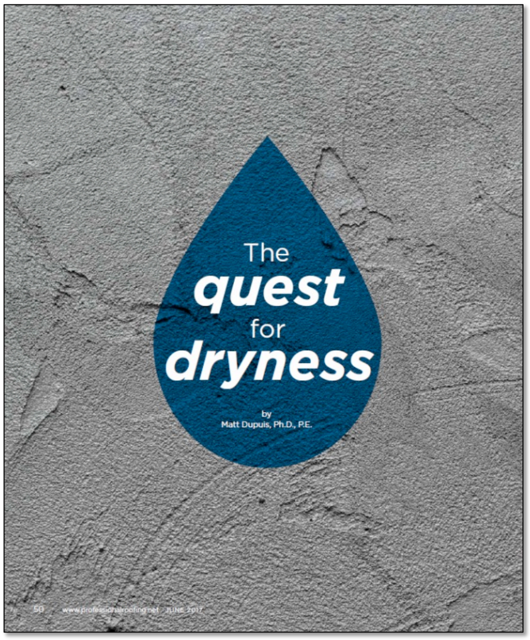

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June 2017

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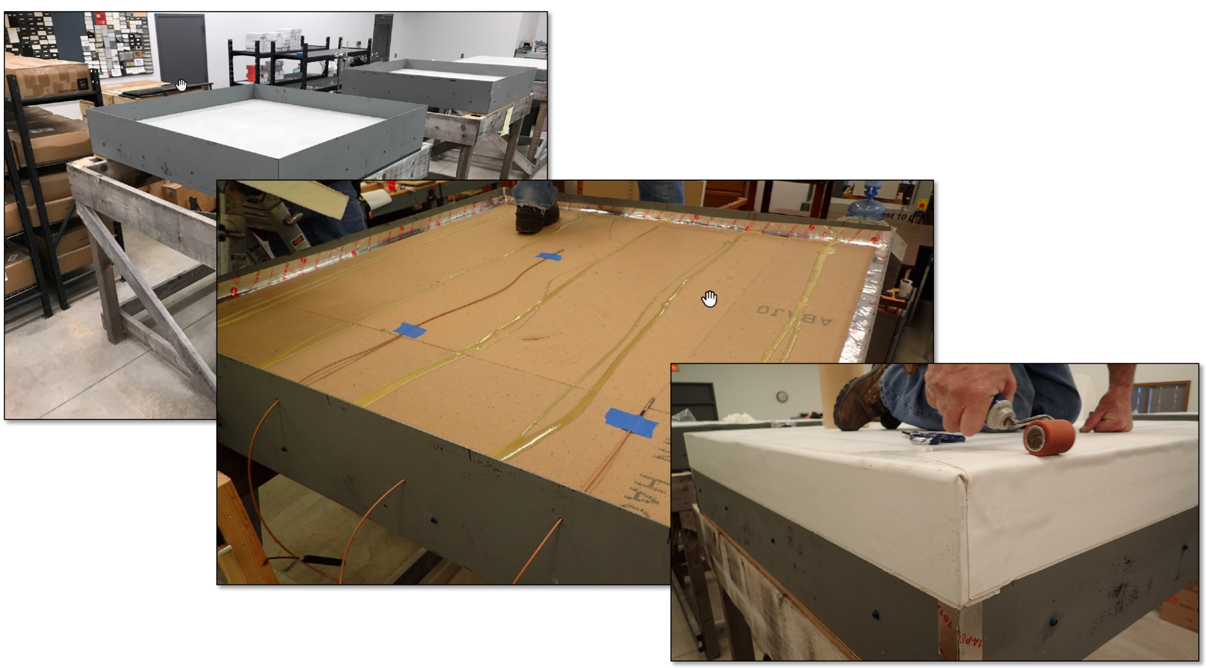

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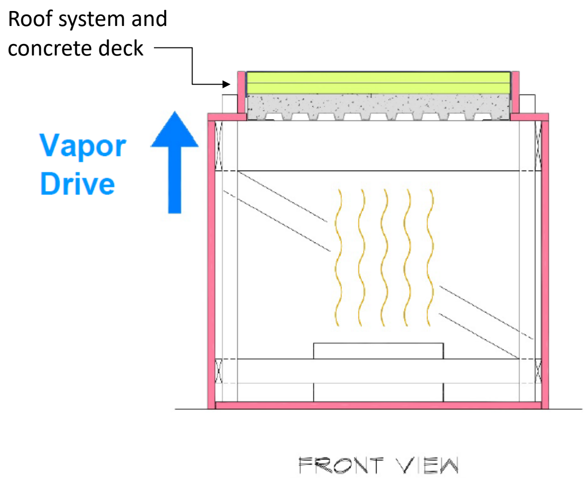

Conditions:

- "Outside": 70 F & 50% RH (lab. cond.)
- "Inside": 90 F & @50% RH

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Phase 2 -Results

	Table 5. Mass For 28 Day Cure Time in Laboratory (Pounds)	
	Lightweight structural concrete	Normal weight concrete
Pour	1627.87	1819.90
28 Days	1568.87	1806.82
Loss	59.00	13.08

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Phase 2 – Results (continued)

	ASHRAE Climate Zone						
	1	2	3	4	5	6	7
	Normal weight concrete slab moisture content at 28 days (lbs./ft^3) – stripped form						
	Miami	Houston	Atlanta	Nashville	Chicago	Minneapolis	Edmonton
Jan	3.88	5.84	4.70	5.38			
Feb	4.14	4.38	3.84	4.26			
Mar	3.38	3.94	4.22	4.10			
Apr	3.40	3.80	4.28	3.48			
May	5.24	3.08	4.24	4.22			
Jun	4.74	3.28	3.54	3.86			
Jul	3.52	3.58	3.82	3.24			
Aug	3.82	3.30	3.38	3.32			
Sep	4.88	3.80	3.76	3.64			
Oct	4.84	3.28	4.08	4.70			
Nov	3.40	4.38	4.74	3.90			
Dec	3.36	4.14	4.88	4.50			

	No Vapor Retarder - Any Facer Peak Moisture Content at Three Years (lbs./ft^3)						
	ASHRAE Climate Zone						
	1	2	3	4	5	6	7
	Normal weight concrete slab – stripped form						
	Miami	Houston	Atlanta	Nashville	Chicago	Minneapolis	Edmonton
Jan	4.29	9.01	15.52	15.82	16.77	16.98	17.78
Feb	4.64	8.93	15.43	15.82	16.67	16.93	17.71
Mar	4.01	9.35	15.89	15.95	16.64	16.86	17.70
Apr	4.08	11.71	16.06	16.01	16.66	16.98	17.69
May	5.66	10.12	16.06	16.02	16.65	16.98	17.72
Jun	5.25	11.98	16.06	16.03	16.65	16.97	17.77
Jul	4.14	12.63	16.08	16.03	16.81	16.99	17.79
Aug	4.43	12.71	16.08	16.04	16.83	17.02	17.77
Sep	5.39	12.91	16.07	15.98	16.84	17.03	17.79
Oct	5.36	12.63	15.91	15.62	16.84	17.02	17.80
Nov	3.95	11.70	15.07	14.83	16.82	17.04	17.75
Dec	3.92	9.29	15.32	15.39	16.82	17.02	17.78
AVG	4.59	11.08	15.80	15.80	16.75	16.99	17.75

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Phase 2 -Conclusion

- A very low perm. vapor retarder is needed to prevent moisture vapor drive from a concrete roof deck into the roof system

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Vapor retarder effectiveness

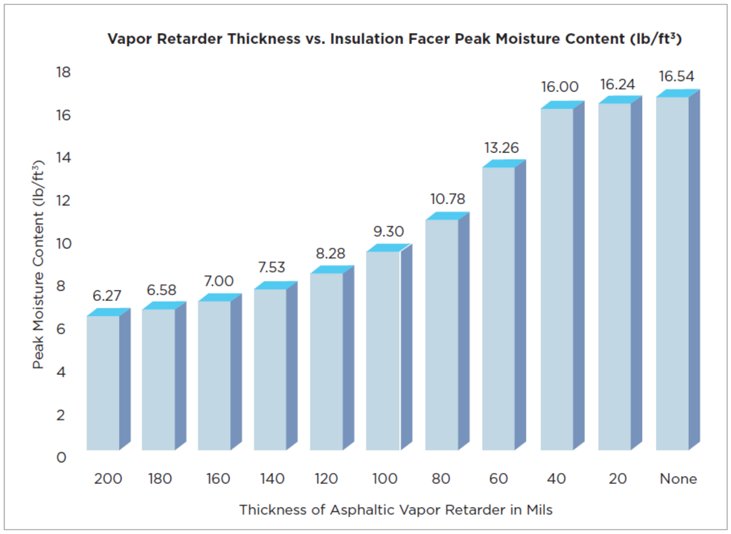

Figure 3: This graph shows simulation results for a roof modeled in Chicago. The results show the peak moisture content over time in a facer in the insulation system. Typically in northern climates, this will be the topmost facer under the roof membrane during the end of the winter season.

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Additional research

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RESEARCH + TECH

Are admixtures the answer?

Moisture in concrete roof decks continues to be problematic

by Mark S. Graham

NRCA's Technical Services Section has been receiving inquiries regarding the use and effectiveness of specific concrete mix additives and topical surface treatments to address moisture release-related concerns with concrete roof decks. Such admixtures broadly are referred to as moisture vapor reduction admixtures (MVRAs) or porosity-inhibiting admixtures. NRCA provides recommendations regarding their use.

MVRAs

Concrete admixtures intended as MVRAs are specific chemicals added during concrete's batching and mixing to provide an additional chemical reaction during the concrete's hydration and curing process. MVRAs use the concrete mix's excess water and chlorides to create a calcium silicate hydrate gel within the concrete. The gel is said to fill the small pores and capillary openings in curing concrete, minimizing the concrete's ability to pass and release moisture vapor. The gel is intended to be permanent and integral throughout the concrete's entire thickness.

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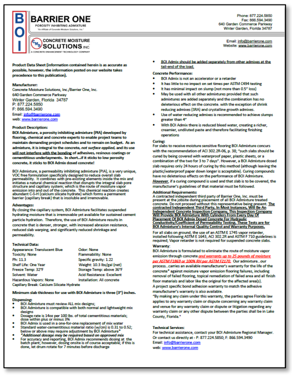
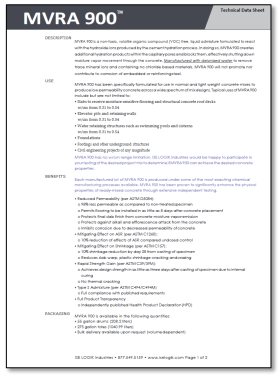
Moisture vapor reduction admixtures (MVRAs)





NRCA still has not seen an MVRA perform successfully in concrete roof deck applications

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ASTM E96 testing of MVRA vs Non-MVRA concrete decks

Figure 1 – Roofing concrete cores without MVRA, samples 6-1 and 6-2

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Figure 2 – Roofing concrete cores with MVRA, samples A-1 and A-2.

Figure 3 – Roofing concrete cores with MVRA, samples B-1 and B-2.

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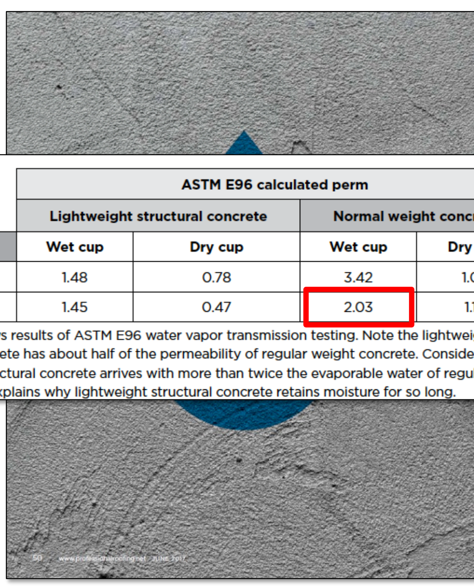

	ASTM E96 calculated perm			
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The figure shows results of ASTM E96 water vapor transmission testing. Note the lightweight structural concrete has about half of the permeability of regular weight concrete. Considering lightweight structural concrete arrives with more than twice the evaporable water of regular weight concrete, this explains why lightweight structural concrete retains moisture for so long.

Professional Roofing, June 2017

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Without an MVRA

With an MVRA

TABLE 2.1 SUMMARY OF AVERAGE WATER VAPOR TRANSMISSION PROPERTIES						
	SAMPLES 6-1 AND 6-2		SAMPLES A-1 AND A-2		SAMPLES B-1 AND B-2	
SAMPLE ID	6-1	6-2	A-1	A-2	B-1	B-2
Perm-in	1.9	1.8	3.7	3.4	3.7	3.8
Permeance for 25.4 mm (ng/Pa*s*m2)	108	101	214	195	210	215
Permeability (ng/Pa*s*m)	2.8	2.6	5.4	4.9	5.3	5.5

The specimens containing an MVRA have tested WVT values about two times (i.e., more "vapor open") more than the specimens without the MVRA

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NRCA's recommendations

Understanding the Roofing Industry's Concerns With Moisture in Concrete Roof Decks

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NRCA's recommendations

Addressing moisture in concrete roof decks

- For structural concrete roof decks in new construction, designers should specify a high bond-strength/well adhered vapor retarder
- For structural concrete roof decks in reroofing where there is evidence vapor migration from the roof deck, designers should consider specifying a high bond-strength/well adhered vapor retarder

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NRCA's recommendations – cont.

Addressing moisture in concrete roof decks

- Experience has shown a 2-ply, hot-applied, built-up membrane applied to a primed concrete deck has performed successfully.
- Designer should include specific details for sealing edges and penetrations in the vapor retarder

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NRCA's recommendations – cont.

Addressing moisture in concrete roof decks

- Designers should specify a roof system type that does not involve the use of insulation or membrane fasteners (that would penetrate the vapor retarder)
  - Use adhered, loose-laid and ballasted or protected-membrane roof systems
  - Avoid mechanically-attached rigid board insulation and mechanically-attached membrane systems

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NRCA's recommendations – cont.

Addressing moisture in concrete roof decks

- Additional design considerations:
  - Consider avoiding moisture-sensitive, organic content roofing products
    - Polyiso. insulation with reinforced cellulosic facers (Type II, Class 1)
    - Perlite board insulation
    - Wood fiberboard insulation

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Deck acceptance

Whose moisture is it in the concrete?

the roofing industry

Why should we take responsibility (or incur liability) for someone else's moisture?

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Roofing contractors do not have the necessary information – and, in most cases, the expertise – to make when to roof decisions over structural concrete roof decks

- Mark S. Graham

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Contract provision addresses installation of roof system over concrete deck

Assessing moisture content in roof deck: Roofing Contractor is not responsible for the effects of moisture migration originating within the roof deck or substrate, including concrete decks, or due to moisture vapor drive from within the building. Residual moisture within the roof deck, particularly structural concrete decks, can adversely affect the properties and performance of roofing materials, regardless of additives or concrete admixtures that may be included in the concrete mix. Roofing Contractor's commencement of roof installation indicates only that the Roofing Contractor has visibly inspected the surface of the deck for visible defects prior to commencement of roofing and the surface of the deck appeared dry. The 28-day concrete curing period does not signify the deck is sufficiently dry.

Roofing Contractor is not responsible to test or assess the moisture content of the deck or evaluate the likelihood of condensation from moisture drive within the building. Roofing contractor recommends that roofing not commence until probes in concrete decks show moisture content is no greater than 75% relative humidity when there is no organic content within the roofing materials. Wood fiberboard, perlite and organic paper facers on polyisocyanurate insulation will generate mold with relative humidity as low as about 65-70%.

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Questions…

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The *quest* for *dryness*

by
Matt Dupuis, Ph.D., P.E.

Roofing contractors have been installing roof systems over new concrete roof decks for decades. In the past, contractors and designers gave little thought to moisture in concrete decks; the only concern was how well a roofing material could adhere to a concrete surface. This was the norm through the 1990s and into this century. However, at the turn of the century, more claims by building owners of roof system failure caused by concrete deck-sourced moisture began to emerge. Photo 1 (on page 52) shows the result of a roof system unknowingly installed over a moisture-laden concrete deck.

The problem quietly simmered for about a decade. Then, the issue was put in front of the roofing industry by several papers published for the 2011 International Roofing Symposium, by the Midwest Roofing Contractors Association and NRCA. The papers focused on extra moisture in the aggregates used in lightweight structural concrete. But these papers and others that followed lacked directions or solutions for how to assess a concrete deck, what moisture levels in concrete are too high and what to do if they are too high.

Why now?

An innocent yet weighty question was asked during the 2017 Chicago Roofing Contractors Association (CRCA) trade show: "We have been roofing over concrete decks for a long time. Why is this happening now?"

The answer is multifaceted, and it relates to the roofing materials the industry uses, specifically the insulation, adhesives and membranes.

The roofing industry is using a great deal of ASTM C1289 Type II, Class 1 polyisocyanurate, which is faced with reinforced cellulosic mat facers. Colloquially known as "paper-faced iso," this product typically works well unless it is exposed to moisture.

Moisture in concrete roof decks is a growing problem that needs to be addressed

Decades ago, there were two choices for adhesive: coal tar or asphalt. Currently, there is a plethora of adhesive choices, including foams, volatile organic compound- (VOC-) based, low VOC, water-based and others. Some adhesives have proved to be more resistant to high moisture levels than others.

The issue with roof membranes has not been so much with membrane types but rather color. Specifically, cool roofs and their high solar reflectivity, which leaves them operating at lower temperatures. Consequently, roofs with lower membrane temperatures are less able to move moisture away and potentially out of a roof system.

Another complicating factor is compressed construction schedules. Any roofing contractor who has worked on new construction knows general contractors are demanding roof systems be installed earlier and earlier in the construction schedule. Our firm has had reports of general contractors demanding roof system installation as little as three days after concrete has been poured—a truly insufferable situation.

These issues combine to explain why we are seeing more moisture problems in roof systems related to concrete decks.

Photo 1: This roof system was installed over a lightweight structural concrete deck in the upper Midwest. The roof had only been in place for a matter of months before wind delaminated the moisture-weakened polyisocyanurate facer at the membrane level. Small amounts of condensed moisture are visible on the concrete surface.

Current testing

Many moisture testing methods available for concrete have been around for decades. The flooring industry has done a great deal of research into these methods and their viability. Flooring industry research has shown some of these tests to be rather unreliable predictors, and most of them generally have been moved to obsolescence; yet they remain in many roofing industry boilerplate and legacy specifications.

The spot test

When you use bitumen (coal tar or asphalt) to adhere insulation, you can conduct a spot test. To do so, heat the bitumen to application temperature and pour about a 1- to 3-foot diameter area of hot bitumen on the concrete. If the bitumen sizzles and creates pinholes (from super-heated water vapor) or a spud bar can pry cooled bitumen from the concrete, the concrete is not ready to receive a roof system. The spot test is subjective and field-improvised. Admittedly, it has served the roofing industry for decades but should be considered a last resort.

ASTM D4263

ASTM D4263, "Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method," is qualitative in nature. A plastic sheet is affixed to the concrete surface for 24 hours, and pass/fail is determined based on whether moisture can be seen between the concrete and plastic film. However, any moisture detected is local to the concrete's surface. Additionally, the test can be heavily influenced by weather conditions. This test generally is considered unreliable and unable to detect moisture located deep in concrete.

ASTM F1869

ASTM F1869, "Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride," uses a small plastic dome placed over the concrete surface with a desiccant inside. The desiccant is weighed before and after exposure; from this, a moisture vapor emission rate is determined. Tests conducted by the concrete and flooring industries have shown this test only measures moisture contained within a fraction of an inch of the concrete surface, leaving the moisture deeper in the slab unmeasured. In short, the flooring industry is abandoning this test method, and similar to the plastic sheet method, the test is affected by weather. As such, it, too, should not be considered viable for concrete roof deck assessment.

Electrical resistance

Electrical resistance testing generally is not seen in North America. It is used in Europe and consists of two holes drilled in a concrete deck a specified distance apart with wire brushes inserted in each. The electrical resistance is measured between the two brushes. This resistance will vary with moisture content. Although this method will reach moisture deep in a slab, concrete experts have reported the resistance of the concrete depends on a great deal of variables other than moisture. This makes a reading from one concrete slab potentially meaningless when compared with a different concrete slab. Therefore, its use as a universal tool for the roofing industry appears limited.

Electrical impedance

Similar to electrical resistance, electrical impedance uses an electrical measurement to correlate to moisture content in concrete. There are several commercially available models from manufacturers of handheld meters. However, experience and research have shown they only measure moisture near the surface of concrete. Although these models may be suitable for determining a "surface dry" condition for concrete, they are unable to measure and/or detect moisture in the core of a slab.

ASTM F2170

ASTM F2170, "Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes," involves drilling into concrete and placing a sensor at a prescribed depth. The sensor returns temperature and humidity readings after remaining in place for 72 hours. The flooring industry has widely adopted this method as part of manufacturer requirements before a flooring system is installed.

This methodology has shown some promise for the roofing industry. However, obtaining appropriate readings generally is confounded by ambient weather conditions. Specifically, the test is specified to be run at room temperatures. There are seldom room temperature conditions on a roof deck. Additionally, research has shown there is a coupled system between the air being measured inside the sensor and the drilled concrete to which it is exposed. The air obeys the psychometric chart, but the exchange of moisture between the air and concrete as temperatures change appears not to. Again, this makes it difficult to use as a universal test.

However, this method still has value forensically for evaluating existing concrete roof decks. The probes, when installed under insulation, achieve room temperature or near room temperature conditions. Therefore, they can be used diagnostically to confirm, deny and quantify in-situ moisture within existing concrete roof decks.

Current research

The numerous roof system failures and concrete moisture test methods as well as lack of research data regarding moisture in concrete roof decks led NRCA; CRCA; the Canadian Roofing Contractors Association; GAF, Parsippany, N.J.; and SOPREMA® Inc., Wadsworth, Ohio, to sponsor research into this topic in 2016.

The initial research was focused on outdoor exposure of concrete slabs, concrete slabs exposed in a controlled laboratory environment, hygrothermal laboratory measurements, instrumentation trials and computer modeling. The research occurred in three phases.

Phase 1

The first phase involved SRI Consultants Inc. constructing test concrete roof slabs and preparing them for instrumentation of temperature and humidity at depth. The slabs were located at SRI Consultants' facility in Middleton, Wis. The slabs were configured for measuring and examining the following variables:

- Aggregate type (regular weight vs. lightweight)
- Surface finish (magnesium float vs. hard steel trowel)
- Rewetting (outdoor vs. laboratory)
- Drying capacity (steel form deck vs. stripped form)
- Moisture level in slabs over time
- Time required for instruments to measure moisture levels

The outdoor slabs were prepared and instrumented for a factorial experiment to evaluate the first five variables and compared against slabs prepared and maintained indoors, in a controlled laboratory environment. Numerous smaller concrete specimen pans were prepared for weekly installation of instrumentation to measure the last three variables; these specimens are outdoors and in a laboratory environment. In all, more than 200 instruments were used with the slabs during this phase. In addition to temperature and humidity measurements, a weather station recorded companion data during this phase. The station was positioned with the outdoor specimens and slabs.

Photo 2 shows the 5- by 5-foot slabs in the lab along with smaller 1- by 1-foot pans. Photo 3 (on page 54) shows the slabs being prepared outdoors for exposure to weather, and Photo 4 (on page 54) shows the completed slabs and pans undergoing weathering.


Photo 2: Concrete slabs and pan specimens, both regular weight and lightweight structural concrete, in SRI Consultants' laboratory in 2016

For links to supporting documentation cited in this article, go to www .professionalroofing.net or download our app.

Photo 3: Exterior concrete slabs being poured at SRI Consultants' facility in July 2016

Photo 4: The poured concrete slabs and pan specimens, both regular weight and lightweight structural concrete, during outdoor weathering

Phase 2

R&D Services Inc., Cookeville, Tenn., provided laboratory measurements of hygrothermal material properties for the concrete used in Phase 1. The samples were cast alongside the slabs and pans. The measured concrete values were targeted at 28 and 60 days. It is believed hygrothermal numbers for such "green" concrete have not been previously determined by others. The hygrothermal material numbers were used in Phase 3 of the work. Photo 5 shows concrete samples prepared for ASTM E96, "Standard Test Methods for Water Vapor Transmission of Materials," vapor transmission testing. Results of the ASTM E96 testing are reported in the figure.

Phase 3

The hygrothermal data from Phase 2 was used with WUFI Pro software. WUFI Pro is a finite element heat and moisture transport modeling program. With this software, an experienced user can simulate the moisture movement to, from and within concrete roof decks. It also can simulate moisture movement in concrete after a roof is placed over it. If properly calibrated, validated and used, these models can be a powerful tool to analyze the moisture problems the roofing industry is experiencing.

Using the WUFI Pro software, hygrothermal simulations were designed and run, with the assistance of JustSmartSolutions, Oak Ridge, Tenn. The simulations were expanded to a matrix of roof system types and locations throughout North America.

What it means

To date, hundreds of computer simulations of moisture movement in concrete decks exposed to historical weather data have been completed. The concrete moisture levels at the end of the bare concrete deck simulation were entered into a new simulation with a hypothetical roof system installed over the concrete deck. The simulations answered several questions and raised new ones.

The specific issue of rewetting concrete was observed in the outdoor instrumenting and was predicted by the computer modeling. This concept is rather fundamental: New concrete roof decks exposed to precipitation, including dew and frost, will absorb moisture. Conversely, dry weather will allow for dry down of the new concrete deck. Therefore, the moisture levels in a new concrete deck is transient and difficult to predict by mere observation of past weather at a specific location.

For example, the simulations showed a roof system using paper-faced polyisocyanurate insulation and no vapor retarder installed over a normal regular weight concrete deck cast in July near Atlanta could be suitable


Photo 5: Concrete specimens prepared for ASTM E96 water vapor transmission testing

for roofing 28 days after it was poured. However, this same roof deck, if cast in December, would need a vapor retarder to keep the paper facers at an acceptable moisture level to function as intended.

Repeat this simulation in Phoenix, and the concrete dries sufficiently 28 days after the pour in any given time of year. As such, in an environment like Phoenix a vapor retarder is most likely not needed.

Now, if one moves the simulation to Edmonton, Alberta, there appears to be no month during which this same roof system could be installed after 28 days without a vapor retarder. Some areas of North America provide easy answers regarding concrete decks while much of the continent seems to fall into an "it depends" category on the use of vapor retarders to protect roof systems from moisture migration out of concrete.

The simulations run to date have focused on regular weight concrete decks. A handful of simulations looked at the effects of utilizing lightweight structural concrete. Of little surprise to those familiar with the extra evaporable water available from lightweight aggregates, the results of these simulations are much worse from a moisture migration standpoint.

The research is ongoing. In 2017, more concrete decks will be cast, and roof systems will be installed over them. The 2017 research will focus on validating the Phase 3 computer modeling.

Preliminary recommendations

The simulations conducted to date answered many questions. Specifically, northern climates are at greater risk of moisture-based failure, specifically with paper polyisocyanurate facers. This occurred with normal weight concrete decks and lightweight structural concrete decks. Therefore, given the currently available research data, I recommend that unless the designer of record states otherwise in writing, a vapor retarder of less than 0.01 perm is necessary over new concrete roof decks. Note this level of vapor retarder (0.01 perm) is relatively stringent and some commonly used vapor retarders may not meet this level.

The only alternative to retarding moisture entry from a concrete roof deck into a roof system is venting the moisture vapor out of the system. To achieve this, designers essentially need to design roof assemblies as if they were roofing over lightweight insulating concrete. Numerous manufacturer and NRCA details are available and adaptable for this type of configuration. In fact, this design recently has been observed in practice and was functioning as intended—keeping the concrete moisture divorced from the roof system.

As the research progresses, more updates and recommendations will become available.

	ASTM E96 calculated perm			
	Lightweight structural concrete		Normal weight concrete	
Age	Wet cup	Dry cup	Wet cup	Dry cup
28 days	1.48	0.78	3.42	1.05
60 days	1.45	0.47	2.03	1.13

The figure shows results of ASTM E96 water vapor transmission testing. Note the lightweight structural concrete has about half of the permeability of regular weight concrete. Considering lightweight structural concrete arrives with more than twice the evaporable water of regular weight concrete, this explains why lightweight structural concrete retains moisture for so long.

MATT DUPUIS, PH.D., P.E., is principal of SRI Consultants Inc., Middleton, Wis.

What we know now

Recent research provides insight into moisture in structural concrete roof decks

by Matt Dupuis, Ph.D., P.E.

Photo 1: Exterior concrete slabs are poured by union concrete finishers. Two separate concrete loads—one normal weight structural concrete and the other lightweight structural concrete—were used.

The roofing industry has been installing roofing materials over structural concrete roof decks for more than a century. For most of this time, hot-applied built-up roofing was the predominate roof system installed over concrete roof decks, and any insulation was almost always adhered in hot asphalt. Using an asphalt-based roof system provided a fairly robust roof system in terms of adhesion and watertight integrity; the mopped asphalt functioned as a relatively good vapor retarder. Because of the asphalt, BUR roofs resist moisture movement and typically remain adhered to the concrete even if moisture intrusion occurs.

However, because of new products entering the market and changing preferences, the roofing industry has shifted away from roof systems adhered in asphalt. Currently, the roofing industry uses adhesives, usually applied in ribbons, to adhere roof systems to concrete. In addition, current energy codes have forced contractors to install more insulation, usually in multiple layers. This insulation typically is polyisocyanurate complying with ASTM C1289, "Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board," Type II, Class 1, with fiberglass-reinforced cellulosic felt facers, commonly known as "paper-faced" polyisocyanurate insulation.

The adhesives currently used, particularly in ribbon form, do not act as any form of a vapor retarder like asphalt once did. Further, previous research identified paper facers on polyisocyanurate insulation are highly susceptible to moisture-based failure. Combine these two factors with accelerated building construction schedules, and the industry has created a moisture minefield for roofing professionals who install roof systems over new concrete decks.

The problems

Concrete roof decks arrive at job sites in liquid form. The concrete mixture is made of coarse aggregates, fine aggregates, Portland Cement, admixtures and water. Once a concrete roof deck is poured, it typically is left exposed to the elements. The effects of weather will vary depending on geography, time of year, typical daily variations and job-site conditions. Regardless, a new concrete roof deck potentially will be exposed to rain, snow, dew and frost in varying amounts. Be aware that this situation is the same for precast concrete decks and precast concrete decks with a poured concrete topping.

This additional environmental moisture can cause the concrete to rewet. In simplest terms, the moisture from the construction environment and weather can be absorbed into the concrete slab. This rewetting can reset the dry down of the slab or even give it more free moisture than it originally held.

So a roofing professional must first contend with the water that arrived in the concrete and then any rewetting that occurs from construction or weather. Combined, these conditions make the dry down and, ultimately, the moisture content in a concrete slab difficult to assess regarding when it is appropriate to begin installing roofing materials. To further complicate the matter, the free moisture in a concrete slab typically is within the slab and is not readily visible from either the top side or bottom side of the slab.

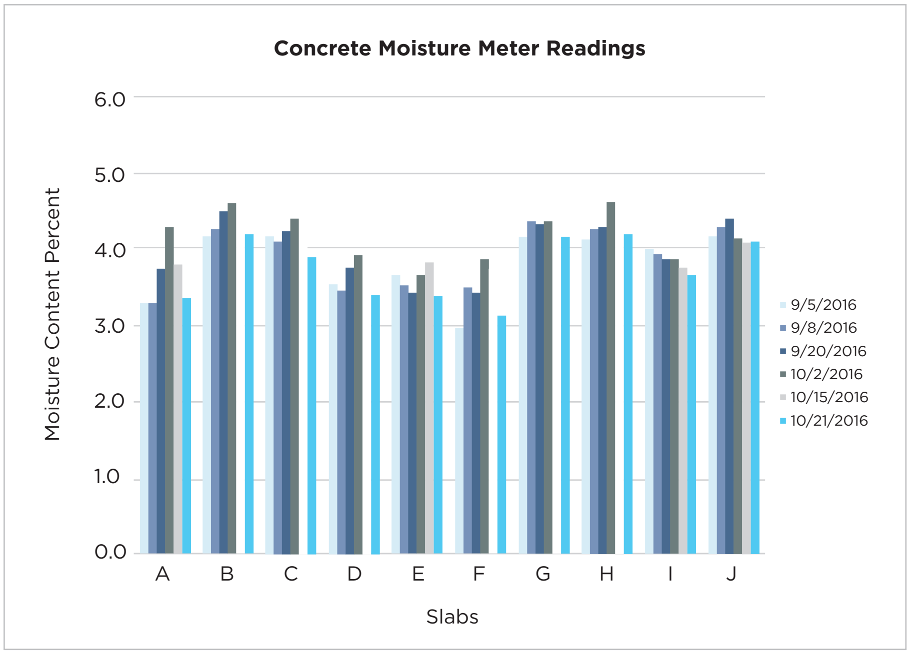

Figure 1: This graph depicts the 10 slabs used in Phase 1. The slabs were read with an electronic moisture meter (Tramex CMEXII) at the beginning of each week. Half are normal weight structural concrete, and half are lightweight structural concrete. Two of the 10 slabs were inside the laboratory. Note how interior/exterior and lightweight/normal weight make no discernable difference. Even after a rain event, the surface readings would spike until drying conditions prevailed and returned to less than 4.5%.

Phase 1 - ASTM E96 Calculated Perm-in

	Lightweight Structural Concrete		Normal Weight Structural Concrete	
Age	Wet Cup	Dry Cup	Wet Cup	Dry Cup
28 Days	1.48	0.78	3.42	1.05
60 Days	1.45	0.47	2.03	1.13

Figure 2: Results of ASTM E96 water vapor transmission testing. Note the lightweight structural concrete has about half the permeability of normal weight structural concrete. Considering lightweight structural concrete arrives with more than twice the evaporable water of normal weight structural concrete, this explains why lightweight structural concrete remains moisture laden so long.

With increasing frequency, roofing contractors have been installing roofing materials over new concrete roof decks that are presumed to be dry by their crews, a general contractor or another party. They come to this conclusion simply because a certain amount of time has passed since the concrete was poured or the concrete visibly appears dry, but, in fact, the slab may have significant free moisture inside.

What tends to happen is a roof system is installed without issue, but months or even years later one of the parties discovers the roof system has become moisture laden. Many times, this moisture is seen as a thin film of water on the surface of the concrete under the roof system. Numerous exchanges of angry letters, insurance claims, warranty claims and lawsuits have resulted from free moisture in concrete slabs intruding into roof systems. Some of the larger claims for damages are for millions of dollars.

In response to this issue, the roofing industry and other organizations provided financial and material support to my company for an in-depth study to better understand moisture in concrete roof decks and provide the industry with data-driven information to help avoid future problems.

Phase 1 (2016-17)

The first portion of the research sought to investigate whether aspects of the concrete affected moisture content over time. Multiple concrete slabs with different types of aggregate (normal weight/lightweight), different surface finishes (hard steel/floated), surfaces available to dry (steel form deck/stripped forms) and environment (outdoor/laboratory) were studied for moisture levels over time with multiple measuring techniques and instruments.

Multiple full-scale slabs were cast in an outdoor test farm. The slabs were configured to explore each of the aspects described. A large union general contractor was retained to construct and finish the concrete slabs. Eight slabs were cast outdoors, and two control slabs were cast inside a laboratory.

In addition to the full-scale slabs, numerous smaller slabs were cast for exposure outdoors with matching companions inside the laboratory. These smaller slabs were small enough to be moved for weekly weighing. All slabs were subjected to drilled-in moisture probes (per ASTM F2170, "Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes"), massing and electronic moisture meters (per ASTM D4263, "Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method").

Photo 1 on page 35 shows the outdoor slabs being poured. These slabs were scheduled for 16 weeks of exposure starting in summer. They were tracked into the fall. During this time, any concrete slab that would begin to dry down would return to a full-scale reading following a rain event.

In addition to the work done with actual concrete slabs, a computer modeling program was used in Phase 1. This hygrothermal modeling program can simulate the movement of heat and moisture through construction materials, including a roof.

To use this program correctly, we needed hygrothermal material data for the materials we simulate. The data exists for materials such as TPO, PVC and EPDM membranes, polyisocyanurate insulation and polyisocyanurate facers. However, the data for the specific concrete in use was not readily available. For this reason, samples of the concrete were prepared and sent to another laboratory for hygrothermal characterization. The concrete samples were tested at 28 days and 60 days. The hygrothermal work proved to be insightful and numerically demonstrated what was observed in the field experiment portion.

The results of Phase 1 included the following findings:

1. Although the indoor control slabs slowly dried down over months, the slabs outdoors remained at high moisture contents. Even if an outdoor slab would begin to dry, rain would cause it to rewet back to a high moisture content. This was true for concrete roof slabs over steel form deck and those cast with removable forms (concrete exposed on the underside). It also was true for slabs made of normal weight structural concrete and lightweight structural concrete.
2. The ASTM F2170 probes used on the outdoor slabs were at or near full scale (100% relative humidity) for the entire testing period or returned to full scale after rewetting.
3. The electronic meters repeatedly were able to determine when the concrete surface was dry (see Figure 1).
4. ASTM E96, "Standard Test Methods for Water Vapor Transmission of Materials," testing showed the vapor permeance of concrete changes over time and normal weight structural concrete allows vapor to move about twice as fast as lightweight structural concrete (see Figure 2).
5. Hygrothermal modeling of the concrete slabs showed great promise in quantitatively predicting transient moisture behavior of concrete slabs.
6. Preliminary predictive modeling of roof systems installed over new concrete roof decks showed a vapor retarder of 0.01 perm was required to successfully moderate vapor movement into the roof in all North American climates.

Phase 2 (2017-19)

Based on the results of the hygrothermal work in Phase 1, numerous discussions with funding partners led to a consensus: The next phase of work would be to validate the hygrothermal model against full-scale roofs and then use the validated model to simulate roof systems installed over new concrete decks throughout North America.

Anytime you do research work with a computer model, even a commercially available one that has been validated in other applications, it is imperative for the credibility of the results that the model be validated for the specific application you are researching. In this case, this

Photo 2: A view of the SBS polymer-modified bitumen base sheet being torched to a primed concrete deck during the roof system installation

+ For an article related to this topic, see **"The quest for dryness,"** June 2017 issue.

was a roof system installed over a new concrete roof deck. As such, great effort was made to validate the computer model against actual measured data.

Concrete roof slabs similar to the Phase 1 slabs were prepared by the same general contractor using the same concrete design mixtures. The design mixes were from a regional concrete supplier. The supplier provided its most commonly supplied normal weight and lightweight structural concrete mixes to commercial construction sites for the local batch plant. In all, 10 concrete slabs were created. Half the slabs were normal weight concrete, and half were lightweight structural concrete. Further, half the slabs were cast over steel form deck, and half were cast using strippable forms. Note that these are two different drying conditions. Once the forms are stripped away, moisture can exit the slab from the top and bottom; with steel form decks, moisture can only exit from the top. The slabs were all cast inside the laboratory and allowed to cure for 28 days.

Note the 28-day period for concrete is a historical value related to the chemical process that helps concrete gain the strength required by structural engineers. It has nothing to do with moisture content.

On day 28, half the concrete slabs received an SBS polymer-modified bitumen sanded base sheet as a vapor retarder installed directly on the concrete deck (see Photo 2 on page 37). The concrete deck was primed with a solvent-based primer that complied with ASTM D41, "Standard Specification for Asphalt Primer Used in Roofing, Dampproofing, and Waterproofing," and the base sheet was torched to the concrete deck.

Then all slabs were roofed using two staggered layers of paper-faced polyisocyanurate adhered in foam ribbons. A 60-mil-thick TPO membrane was installed by directly adhering it to the polyisocyanurate. In all, there were eight experimental slabs. The remaining two slabs, one normal weight and one lightweight structural concrete, were cast on load cells where the moisture loss (dry down) was determined by weight loss over time.

While the roof systems were assembled, miniature hygrometers (which measure temperature and relative humidity) were placed at selected points in the roof assembly's cross section. Photo 3 shows the first layer of insulation and two hygrometers in place. All the instruments were connected to a central computer to collect and store the data.

Once the roof systems were assembled, they were left alone so we could monitor the moisture's movement. With the roof system's temperature being a constant 70 F (the laboratory temperature) throughout the testing period, there would be little driving force for moisture to move. An in-service roof system can see a temperature differential of much more than 100 F between indoor and outdoor temperatures. To simulate this inside-to-outside temperature differential in the laboratory, a regulated and heated environment of 90 F was created below the roof system specimens. This 20-degree differential above and below the roof created a vapor drive from under the slab to the roof membrane and was held constant. The experiment ran for a year.

As with Phase 1, the concrete was hygrothermally characterized, which was the same concrete mix. However, in this case, the concrete samples were cut from a larger block just before testing. It was hypothesized this type of sampling would help avoid edge effects and better represent the concrete within the slab versus just the surface.

When the newest hygrothermal data was entered and modeled against the data collected with the laboratory data, the agreement was exceptionally accurate. Therefore, the model was deemed validated for this application and the final research portion could begin using the model to predict performance in various climates.

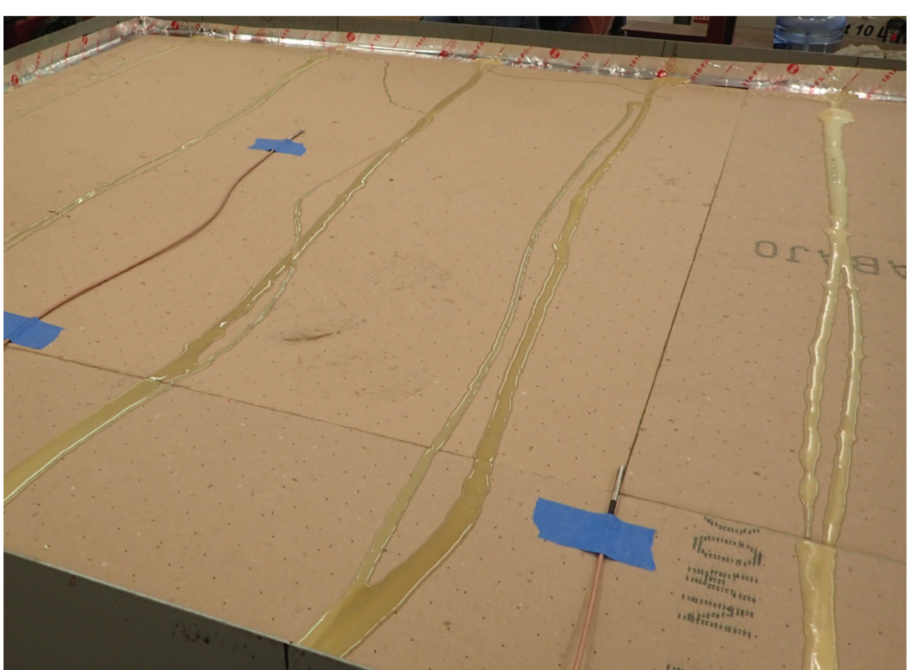

Photo 3: A view of the Phase 2 roof systems being installed over the concrete decks after 28 days. The insulation system was planned for staggered joints and installation placement of the instruments. The ribbon adhesive can be seen rising and blue tape holding the matchstick-sized temperature and humidity sensors in place.

Thousands of simulations were conducted to look at the variables of structural concrete type, use of a vapor retarder, use of forms versus steel form deck, month of installation and ASHRAE climate zone. All roof systems were identical to those experimented within the laboratory. The critical analysis point was the moisture content of the paper facer on the polyisocyanurate insulation. Previous research has shown these facers become significantly weakened above 12% moisture content by weight. In numerous field failure investigations of roof systems over new concrete roof decks, the weakened insulation facer was the primary symptom and source of complaints. Therefore, the moisture content of these facers was the focus of these modeling runs.

An example of the type of data that can be generated from hygrothermal modeling is shown in Figure 3. In this figure, a hypothetical roof system using paper-faced polyisocyanurate is modeled for installation in Chicago. In each successive simulation, the vapor retarder used is made thinner and thinner until no vapor retarder is used. Recall that a moisture content above 12% is detrimental for cohesion within the paper facer.

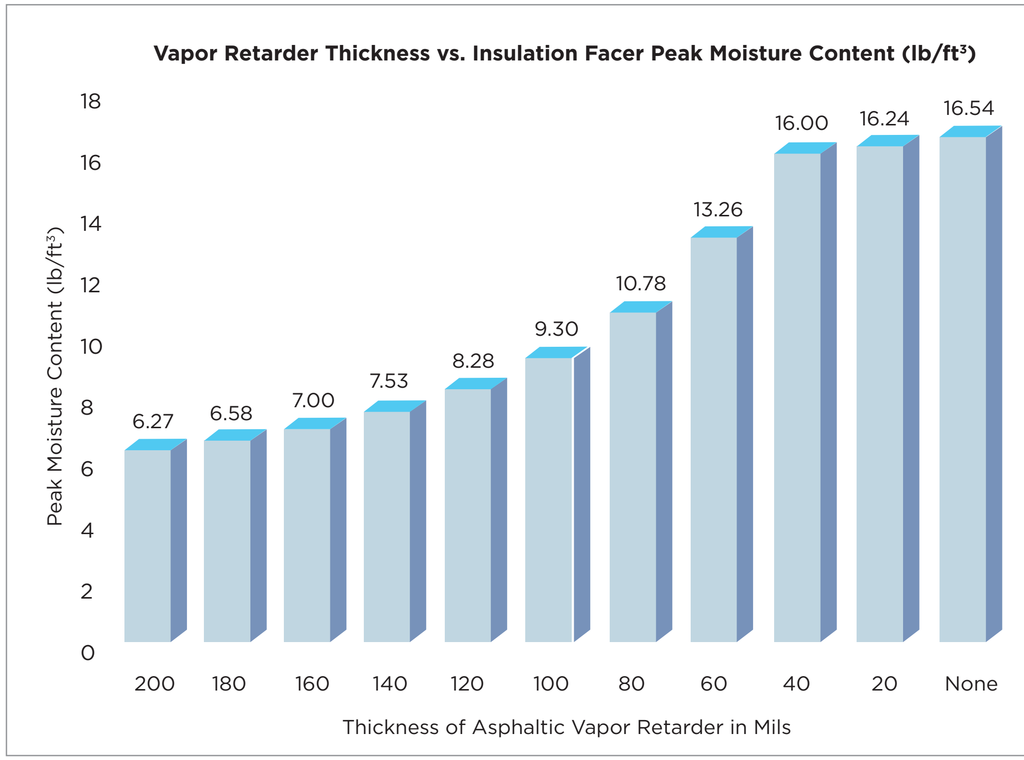

Figure 3: This graph shows simulation results for a roof modeled in Chicago. The results show the peak moisture content over time in a facer in the insulation system. Typically in northern climates, this will be the topmost facer under the roof membrane during the end of the winter season.

The results of Phase 2 were as follows:

1. The hygrothermal modeling using the WUFI program, German software that can calculate heat and moisture transfer, successfully validated against thermal and moisture measurements of full-scale roof systems installed over new concrete decks.
2. Extensive modeling of new roof systems installed over new concrete roof decks showed a vapor retarder was necessary in all ASHRAE climate zones except Zone 1 to keep moisture levels in the facers below critical levels. (The vapor retarder used in simulations was the polymer-modified bitumen base sheet used in the laboratory with a perm rating of less than 0.01 perm.)

Based on the laboratory and modeling research, the following general conclusions can be made by the researchers about new concrete roof decks:

1. Concrete mixes arrive at the construction site with large amounts of excess moisture (free evaporative moisture). Once cast and exposed to weather, a concrete roof deck will likely contain large amounts of free evaporative moisture even well after the 28-day compressive strength benchmark.
2. Lightweight structural concrete contains about twice as much free evaporative moisture as normal weight structural concrete.
3. Both concrete roof decks poured over steel form deck and those with strippable forms (exposed concrete on the underside) can lead to finished roof systems with excess moisture.
4. Surface dry condition of a concrete roof deck can be determined by electronic meter with confidence.

A full report will be available from research funding partners, such as the Roofing Alliance. There is sufficient information for an experienced hygrothermal modeler to create his or her own concrete materials in the program and model specific roof systems for performance. Any new technical guidance or installation instructions on roofing over new concrete decks should come from manufacturers and industry associations.

MATT DUPUIS, PH.D., P.E., is a principal with SRI Consultants, Middleton, Wis.

Are admixtures the answer?

Moisture in concrete roof decks continues to be problematic

by Mark S. Graham

NRCA's Technical Services Section has been receiving inquiries regarding the use and effectiveness of specific concrete mix additives and topical surface treatments to address moisture release-related concerns with concrete roof decks. Such admixtures broadly are referred to as moisture vapor reduction admixtures (MVRAs) or porosity-inhibiting admixtures. NRCA provides recommendations regarding their use.

MVRAs

Concrete admixtures intended as MVRAs are specific chemicals added during concrete's batching and mixing to provide an additional chemical reaction during the concrete's hydration and curing process. MVRAs use the concrete mix's excess water and chlorides to create a calcium silicate hydrate gel within the concrete. The gel is said to fill the small pores and capillary openings in curing concrete, minimizing the concrete's ability to pass and release moisture vapor. The gel is intended to be permanent and integral throughout the concrete's entire thickness.

MVRAs are available from several manufacturers and typically are added to a concrete mix at the concrete batch plant separately from the addition of any other admixtures. Some MVRA manufacturers permit their MVRAs to be added to concrete mixers at job sites provided a concrete mixer's drum is rotated for a manufacturer's recommended minimum amount of time after dosage and before concrete discharge and placement. Recommended MVRA dosages typically range from about 10 to 14 ounces per 100 pounds of cementitious materials.

Some MVRA manufacturers claim their admixtures also reduce placed concrete's bleed water, creating a richer surface paste, which can aid in concrete surface finishing.

MVRAs reportedly have been used successfully to address moisture release affecting flooring covering applications over concrete slabs on grade and intermediate floor levels. To attempt to address the roofing industry's concerns with moisture release from concrete roof decks, several MVRA manufacturers are promoting the use of MVRAs in concrete roof decks.

For an article related to this topic, see "The quest for dryness," June 2017 issue, page 50.

Several manufacturers also are promoting the use of spray-applied, porosity-inhibiting, topical surface treatments intended to function and perform similarly to MVRAs. Such surface treatments are applied after concrete placement and reportedly penetrate concrete to seal the concrete's surface to minimize the passage of moisture vapor. The depth of surface treatment penetration into concrete depends on several factors, including the specific type and amount of surface treatment being used and the concrete's surface porosity at the time of surface treatment application.

Roofing-related considerations

Designers' and general contractors' interest in specifying the use of MVRAs and porosity-inhibiting surface treatments are their acknowledgement and attempt to address moisture release-related concerns with concrete roof decks.

However, though MVRAs and porosity-inhibiting surface treatments may perform successfully in concrete slab on grade and intermediate floor level applications, concrete roof decks experience fundamentally different conditions.

Environmental conditions (temperature and humidity) above and below a building's intermediate floor slabs typically are about the same because these conditions are controlled by the building's HVAC system. As a result, there usually is little to no vapor pressure drive through floor slabs.

Conversely, with concrete roof decks the environmental conditions on the bottom side (interior) of a roof deck differ from those on the top side (exterior), resulting in measurable vapor pressure drive through roof decks. The magnitude and direction of this vapor pressure drive will change with weather conditions.

For MVRAs and porosity-inhibiting surface treatments to perform successfully in concrete roof deck applications, they need to be able to withstand the magnitude and direction of vapor pressure drive a roof assembly will experience during its service life. NRCA is not aware of any data documenting MVRAs' or porosity-inhibiting surface treatments' abilities to withstand these roof assembly conditions. There is anecdotal evidence and field experience to the contrary.

NRCA's recommendations

NRCA continues to have concerns regarding moisture release with newly placed concrete roof decks even when MVRAs or porosity-inhibiting surface treatments are used.

NRCA maintains its recommendation that designers specify a vapor retarder with high bond strength be adhered directly to newly placed concrete roof decks. This also applies to concrete roof decks on which MVRAs or porosity-inhibiting surface treatments are used. Roof system designs using mechanical fasteners penetrating vapor retarders should be avoided.

Additional information about concrete roof decks and moisture-related concerns is contained in Chapter 2-Roof Decks of The NRCA Roofing Manual: Membrane Roof Systems, which is available as a free download for NRCA members at shop.nrca.net.

Also, during the 2019 International Roofing Expo,® which will be held Feb. 11-13 in Nashville, Tenn., NRCA will present the latest findings from its concrete moisture research at the NRCA Technical Operations Committee: Technical Programs and Issues program.

MARK S. GRAHAM is NRCA's vice president of technical services.

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Putting it to the test

NRCA conducts testing of moisture vapor reduction admixtures

by Mark S. Graham

NRCA has conducted limited testing of a moisture vapor reduction admixture intended to minimize a concrete roof deck's ability to pass and release moisture vapor. Some background and an overview of NRCA's testing and results follow.

What's an MVRA?

Concrete admixtures intended as MVRAs are specific chemicals added during concrete's batching and mixing to provide an additional chemical reaction during the concrete's hydration and curing process. MVRAs use the concrete mix's excess water and chlorides to create a calcium silicate hydrate gel within the concrete. The gel is said to fill the small pores and capillary openings in curing concrete, minimizing the concrete's ability to pass and release moisture vapor. The gel is intended to be permanent and integral throughout the concrete thickness.

MVRAs are available from numerous suppliers and typically added to a concrete mix at the concrete batch plant separately from any other admixtures. Some MVRA suppliers permit their MVRAs to be added to concrete mixers at job sites provided the concrete mixer's drum is rotated for a supplier's recommended minimum amount of time after dosage and before concrete discharge and placement.

Recommended MVRA dosages vary somewhat between suppliers but generally range from about 10 to 14 ounces per 100 pounds of cementitious material.

MVRAs reportedly have been used successfully to address moisture release affecting floor coverings over concrete slabs on grade and at intermediate floor levels.

Several suppliers also are promoting use of their MVRA products for concrete roof decks to address the roofing industry's concerns with moisture release. However, their product literature, including product testing and data, show little to no applicability to roof decks.

For example, several manufacturers cite ASTM D5084, "Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter," as the basis for their water vapor transmission and permeability testing. This test applies to fully saturated (containing no air) soil and rock at a limited temperature range—conditions similar to below-grade applications—with little to no relevance to roof assembly components.

NRCA testing

NRCA obtained core specimens of newly poured, cast-in-place roof decks from a building project under construction. A unique aspect of this particular project is it had multiple concrete roof decks areas—several with an MVRA and one without an MVRA. The concrete mix design was reported to be similar for all the concrete roof decks with the MVRA being the known variable.

NRCA submitted the concrete core specimens to RDH Building Science Laboratories in Waterloo, Ontario, for laboratory testing and analysis. RDH Building Science Laboratories is widely recognized for its building science and laboratory testing expertise.

The concrete core specimens were cut into approximately 1-inch-thick slices and conditioned (dried). Testing was conducted using ASTM E96, "Standard Test Methods for Water Vapor Transmission of Materials." ASTM E96 is the standard method for determining water vapor transmission of building materials. ASTM E96 also is referenced in the International Building Code® as the basis for determining whether a building material is vapor-permeable or serves as a vapor retarder.

The results of the ASTM E96 testing are shown in the figure.

Review of the test data shows average tested values for the non-MVRA specimens to be generally consistent with previous NRCA testing of concrete specimens of a similar cured age.

The test data for the MVRA specimens shows permeability values greater than those of the non-MVRA specimens; this indicates the MVRA specimens are more "vapor open" than the non-MVRA specimens. These test results contradict claims an MVRA minimizes concrete's ability to pass and release moisture vapor.

	Deck 1 (no MVRA)		Deck 2 (with an MVRA)		Deck 3 (with an MVRA)	
Specimen No.	1-1	1-2	2-1	2-2	3-1	3-2
Permeability (U.S. perm)	1.9	1.8	3.7	3.4	3.7	3.8

Average tested permeability values

For additional information about NRCA's previous permeability testing, see "The quest for dryness," June 2017 issue.

The data presented applies specifically to the specimens tested at their cured age and may not necessarily apply to all concrete mix designs and concrete roof decks.

NRCA's recommendations

Based on its testing, NRCA finds the use of an MVRA provides no measurable benefit in a concrete roof deck's ability to minimize the passage and release of moisture vapor.

NRCA maintains its previous recommendation: Designers should specify a high-bond strength vapor retarder be adhered directly to concrete roof decks in new construction situations. This recommendation also applies to concrete roof decks where an MVRA is used. For reroofing situations where an existing roof deck shows evidence of moisture-related problems, a high-bond strength vapor retarder also should be adhered directly to the deck. When a vapor retarder is used, roof system designs using mechanical fasteners penetrating the vapor retarder should be avoided.

Additional information about concrete roof decks is contained in Chapter 2-Roof Decks of *The NRCA Roofing Manual: Membrane Roof Systems—2019*. NRCA members can download the manual for free at shop.nrca.net.

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