BUILDING OPERATING MANAGEMENT'S NFMT2015

Addressing Moisture in Concrete for Roofing and Flooring Applications

Session W1.47 – Wednesday, 11 March 2015, 9:00 am to 9:50 am, Room 347

Presented by
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Abstract

Repair of roofing and floor finish failures are typically very costly, time consuming, and disruptive to facility operations. This presentation will help building owners, facility managers, architects, and contractors understand the causes of concrete substrate moisture-driven roofing and flooring failures, and how the failure mechanisms must be considered in the design or repair process. Both the roofing and flooring industries have come to understand the importance of addressing moisture in concrete substrates for roofing and moisture-sensitive flooring applications.

Abstract

This presentation will discuss the science behind moisture drive through concrete substrates, the implications of ignoring such moisture issues in both roofing and flooring systems, and methods for consideration to mitigate these moisture issues in roofing and flooring substrates. We will augment this presentation with case studies of concrete substrate moisture-driven roofing and flooring failures and repairs. The presenters will discuss: similarities between identifying and testing for moisture in concrete substrates in roofing and flooring systems; common considerations for causes of moisture-driven roofing and flooring failures; similar strategies for repairing failed roofing systems and floor finishes; and common considerations that must be addressed during concrete substrate moisture-driven roofing and flooring repair projects.

Learning Objectives

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At the end of this presentation, participants will be able to:

1. Understand the importance of addressing moisture in concrete substrates for roofing and flooring applications.
2. Recognize concrete substrate moisture-driven roofing and flooring failure mechanisms and understand how to address such mechanisms in roofing and flooring repair design.
3. Identify critical issues to be considered during design and repair of roofing and flooring systems over a moisture-laden concrete substrate.
4. Select a roofing or floor finish repair strategy that addresses existing conditions and meets performance, operational and budgetary requirements.

Presentation Outline

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- **Moisture in Concrete Substrates**
  - Why Do We Care?
  - Sources of Moisture
  - Some Reasons for Increase in Roofing and Flooring Failures
- **Similarities in Identifying and Testing for Moisture**
  - Perform Proper Moisture Testing
  - Ideas to Minimize the Chance of Failures
- **Case Studies**
- **Summary: Concrete Substrate Moisture Considerations**

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Moisture In Concrete Substrates

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Why Do We Care?

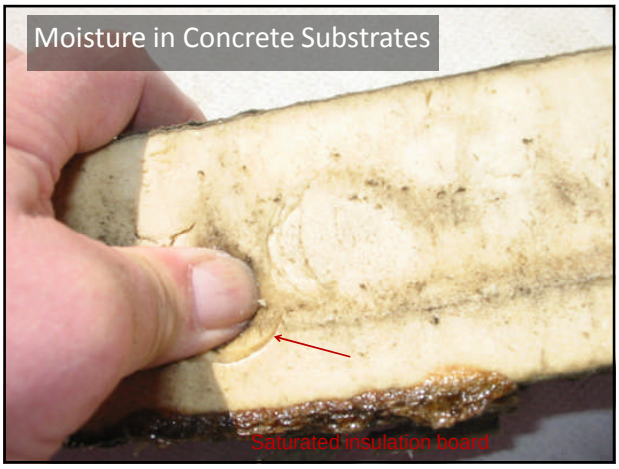
- Roofing failures
  - Excessive residual moisture in concrete substrate can be a primary cause of rigid insulation and roofing membrane detachment

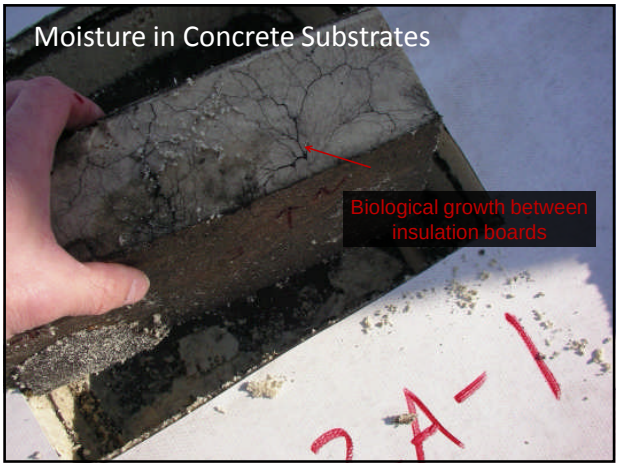
Moisture in Concrete Substrates

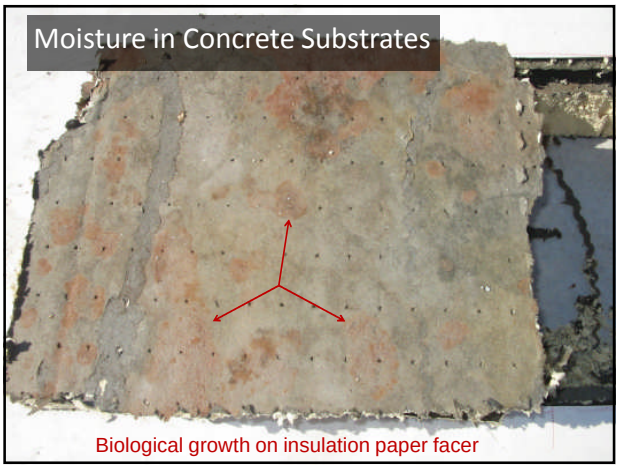
Warped and detached insulation under membrane

Moisture in Concrete Substrates

Wet insulation paper facer under membrane


Moisture in Concrete Substrates
Saturated insulation board


Moisture in Concrete Substrates
Biological growth between insulation boards


Moisture in Concrete Substrates
Biological growth on insulation paper facer

Moisture In Concrete Substrates

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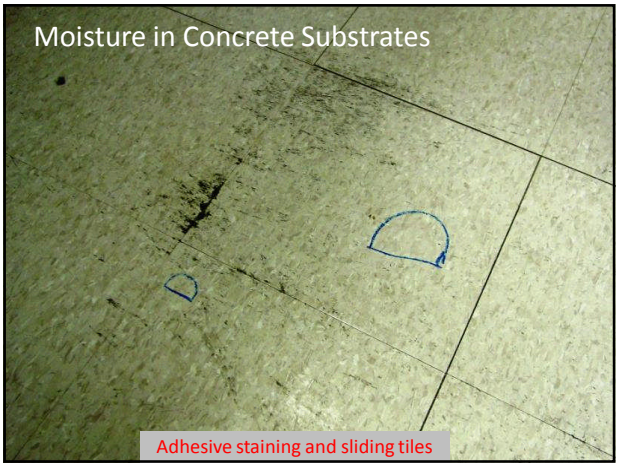
Why Do We Care?

- Roofing failures
  - Excessive residual moisture in concrete substrate can be a primary cause of rigid insulation and roofing membrane detachment
- Flooring Failures
  - Excessive residual moisture in concrete substrate can be a primary cause of flooring failure

Moisture in Concrete Substrates



Adhesive staining and sliding tiles

Moisture in Concrete Substrates

Concrete slab-on-grade with no vapor retarder beneath slab
Discolored artificial stone tiles

Moisture in Concrete Substrates

Elevated deck with wet lightweight concrete
Stains on engineered wood flooring at un-taped seams in underlayment

Moisture in Concrete Substrates

Concrete slab-on-grade, but vapor retarder is beneath blotter layer
Epoxy terrazzo blisters

Moisture in Concrete Substrates

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Sources of Moisture

- Roofing
  - Residual moisture in concrete from placement
  - Unprotected deck after initial placement or tear-off
  - Leakage due to failed roofing systems
- Flooring
  - Underlying soil
  - Residual moisture in concrete from placement
  - Cleaning and maintenance
  - Ambient conditions

Moisture In Concrete Substrates

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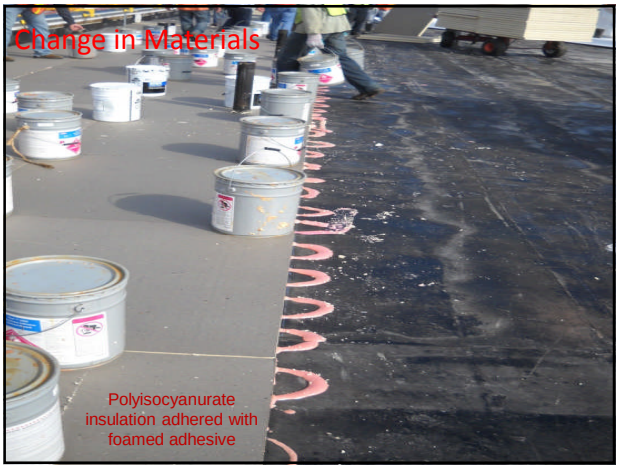
Some Reasons for Increase in Roofing and Flooring Failures

- Change in materials

Change in Materials

Polyisocyanurate insulation adhered with hot asphalt

Change in Materials



Polyisocyanurate insulation adhered with foamed adhesive

Change in Materials

- Hot asphalt as an adhesive
  - Traditional product with a proven track record
  - Typically, continuous application over entire surface
- Foamed adhesive
  - Contemporary product that can provide reliable performance
  - Is different from traditional hot asphalt used as adhesive
  - Requires different installation techniques
  - Installation in accordance with manufacturer's recommendations is key
  - Less tolerant of moisture in concrete substrate

Change in Materials

Use of asphalt cut back adhesive almost gone

Change in Materials

- Asphalt cut back adhesive
  - Traditional product with a proven track record
  - Tolerant of some moisture in concrete substrate
- Water-based adhesive
  - Contemporary product that can provide reliable performance
  - Is different from traditional asphalt cut back adhesive
  - Installation in accordance with manufacturer's recommendations is key
  - Less tolerant of moisture in concrete substrate

Moisture In Concrete Substrates

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Some Reasons for Increase in Roofing and Flooring Failures

- Change in materials
- Blended cement (fly ash) concretes

Concrete with and without Fly Ash

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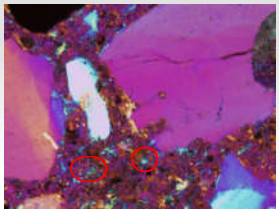
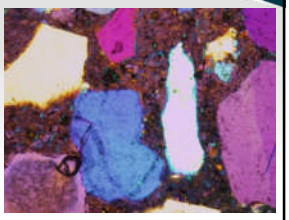
- Concrete microstructure *without fly ash* at 200X magnification.



- Concrete microstructure *with 20% fly ash* at 200X magnification.



Blue color in paste indicates voids. Less voids in fly ash concrete, so slower drying and more dense.

Moisture In Concrete Substrates

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Some Reasons for Increase in Roofing and Flooring Failures

- Change in materials
- Blended cement (fly ash) concretes
- Use of lightweight concrete

Normal Weight vs. Lightweight Concrete

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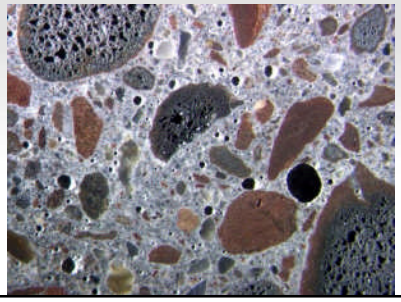
- 110 to 115 pcf vs. 145 to 150 pcf
- Expanded slate and shale aggregate



Normal-Weight vs. Lightweight Concrete

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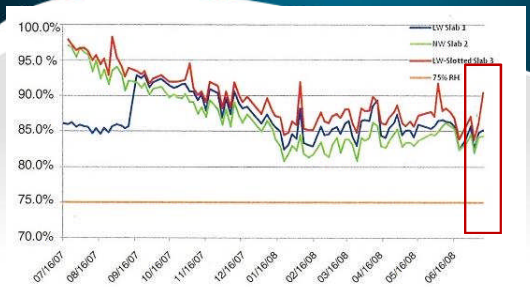

Fig. 6: RH history for Study 1, Nonconditioned Environment

From Concrete International, January 2012

Both NW and LW concrete may require long drying time, whether outdoors or in non-conditioned environment

Moisture In Concrete Substrates

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Some Reasons for Increase in Roofing and Flooring Failures

- Change in materials
- Blended cement (fly ash) concretes
- Use of lightweight concrete
- Fast track construction

Presentation Outline

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Similarities in Identifying and Testing for Moisture

- Roofing manufacturers and roofing adhesive manufacturers typically require installation over a "dry" concrete substrate
  - No definitive criteria for compliance, but we can typically rely on the flooring industry for some guidance
- Flooring manufacturers and flooring adhesive manufacturers typically require a concrete substrate compliant with the following criteria
  - Moisture Vapor Emission Rate (MVER) no greater than 3 lb/1,000 SF/24 hrs, and/or
  - Relative Humidity (RH) no greater than 75%
- So how do we comply?

ASTM Moisture Test Standards

- ASTM F1869 – *Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride*
- ASTM F2170 – *Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes*

ASTM F1869 – "Moisture Vapor Emission Rate"

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- ASTM F1869 - Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride
  - Quantitative; 60 to 72 hour duration

ASTM F1869: Limitations of Test

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- No documented scientific basis.
- No calibration procedures or standard reference.
- Only measures thin layer (1/2 in.) on surface of concrete.
  - Not a good indication of trapped moisture in lightweight concrete

ASTM F2170 – "Internal Concrete RH"

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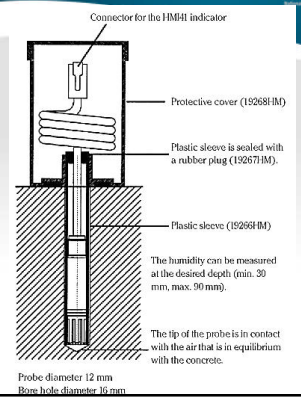
- ASTM F2170 – Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes
  - Quantitative; test standard requires 72 hours (to reach equilibrium)

ASTM F2170 – Internal Concrete RH



ASTM F2170: Limitations of Test

- Newer method
- Limited thickness of slab
- Different probes give different results

ASTM F2170: Standardization Among Manufacturers

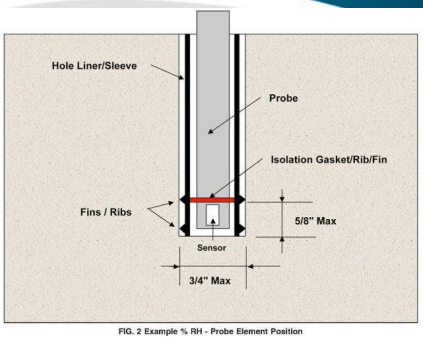


FIG. 2 Example % RH - Probe Element Position

Figure from ASTM F2170-11

ASTM F1869 vs. ASTM F2170

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	High RH	Low RH
High MVER	✗	✗
Low MVER	✗	✓

- **Average calculation not applicable, maximum value must be below limit**
  - Can consider breaking test area up into zones, but must be clearly defined by location, concrete pour, etc.

ASTM D4263 – "Plastic Sheet Method"

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- ASTM D4263 – Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method
  - Qualitative - Minimum 16 hour duration
  - Results can vary greatly, depending on when and where test is performed
  - Not used in the flooring industry

Electric Resistance Measurement

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- Electric resistance measurement
  - Example: Tramex CME 4
  - Can be used to estimate concrete substrate moisture content when calibrated with MVER and RH tests
  - Particularly useful in roofing industry (after calibration) due to test time constraints of MVER and RH tests
  - Not used in the flooring industry
  - Not an industry standard test

Ideas to Minimize the Chance of Failures

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- Plan ahead

Ideas to Minimize the Chance of Failures

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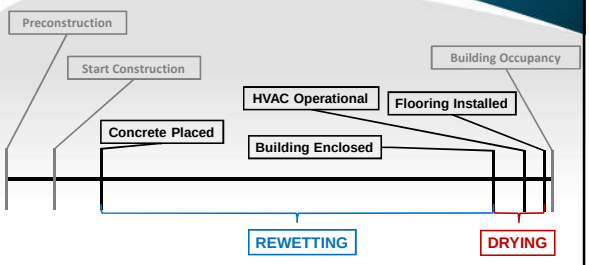

Typical Construction Timeline

Planning ahead for flooring installation

Ideas to Minimize the Chance of Failures

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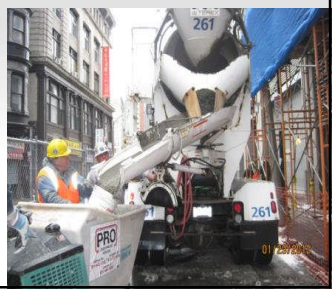
- Plan ahead
- Use low w/c ratio concretes without fly ash
  - Be aware of extra moisture in lightweight concrete

Concrete Mix Design

- Water/Cement Ratio
  - 0.40 W/CM for normal weight slabs
  - 0.45 W/CM for lightweight slabs
- Consider using water-reducing admixtures
  - Superplasticizers / high-range water reducing admixtures
- Prohibit addition of water in the field



Ideas to Minimize the Chance of Failures

- Plan ahead
- Use low w/c ratio concretes without fly ash
  - Be aware of extra moisture in lightweight concrete
- Consider the concrete curing method

Concrete-Curing Methods

- ~~Moisture Addition (water curing or wet covering)~~
  - Adds water to system.
  - May stain or discolor the slab.
- ~~Liquid Membrane-Forming Curing Compounds~~
  - Do not allow concrete to begin drying until removed.
  - Act as a bond-breaker and prevent adhesion of finishes.
- Moisture-Retaining Covers
  - Can be removed as soon as cure is complete.
  - Can be a nuisance and potential hazard during construction.

Ideas to Minimize the Chance of Failures

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- Plan ahead
- Use low w/c ratio concretes without fly ash
  - Be aware of extra moisture in lightweight concrete
- Consider the concrete curing method
- Use a vapor retarder for roofing applications

Vapor Retarder for Roofing Applications

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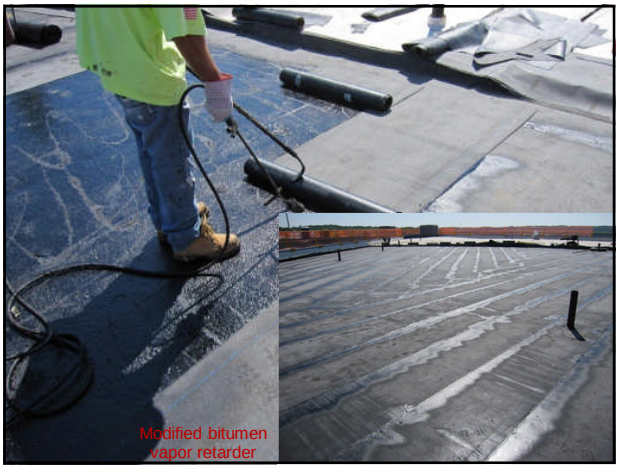
- Vapor Retarder
  - Limit residual moisture in the concrete substrate
  - Added benefit: will limit moisture from the space below from entering the roofing system
- Common Vapor Retarders
  - Hot rubberized asphalt
  - Modified bitumen
  - Self-adhered membrane
  - EPDM/Neoprene
  - Others



Vapor Retarder for Roofing Applications

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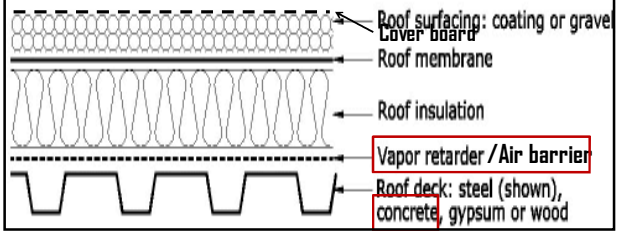
Figure 1:
TYPICAL ROOFING SYSTEM



Ideas to Minimize the Chance of Failures

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- Plan ahead
- Use low w/c ratio concretes without fly ash
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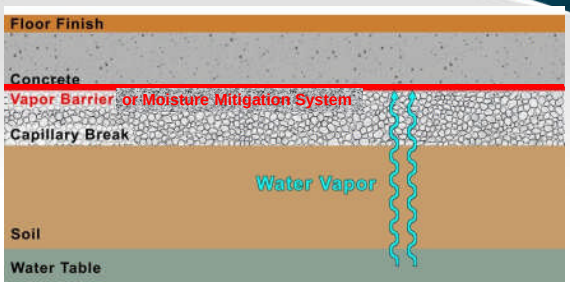
- Consider the concrete curing method
- Use a vapor retarder for roofing applications
- Use a moisture mitigation system for flooring applications
  - Use a product intended for the purpose
  - Make sure it gets installed properly

Moisture Mitigation System for Flooring Applications



Slab-on-ground with a moisture mitigation membrane

Types of Moisture Mitigation

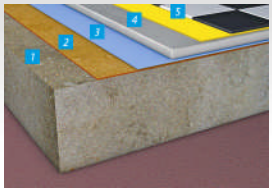
Type of Mitigation System	Typical Manufacturer Limitations	Typical Surface Preparation Requirements
Water-Based Acrylic Coating	Low	Cleaning.
Penetrating Treatment	Low	Cleaning and sanding.
Reactive Penetrant	Medium	General cleaning.
Loose-Laid Sheet	Medium	General cleaning.
Underlayment System	High	Shotblasting.
Modified Epoxy Coating	High	Shotblasting.
Concrete Admixture	NA	NA

Moisture Mitigation System Selection

- A long track record of success and a manufacturer that will work closely with you
- Epoxy-based, topical products seem to have best performance
  - Continuous coating
  - High pH tolerant
  - ASTM E96 < 0.1 perms
  - **ASTM F3010-13 (Two-Component Mitigation Coatings)!**
- Clear, specific, and simple installation instructions.

Mitigation System System Considerations

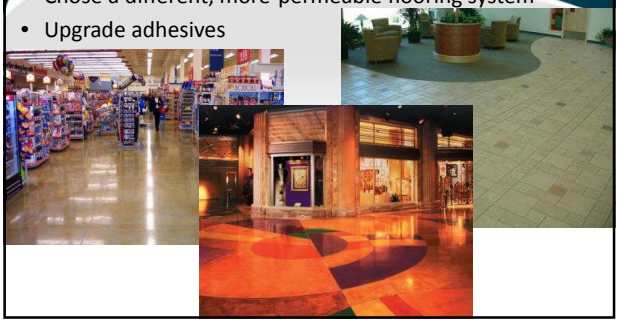
- Surface preparation (shot blasting)
- Leveling underlayment / "blotter" layer
- Assume $5 to $10 per square foot
- Include in bid upfront



1. Concrete
2. Mitigation Coating
3. Underlayment Primer
4. Cementitious Underlayment
5. Flooring with Adhesive

Other Flooring Options for Mitigating High Moisture Levels

- Chose a different, more-permeable flooring system
- Upgrade adhesives



Ideas to Minimize the Chance of Failures

- Plan ahead
- Use low w/c ratio concretes without fly ash
  - Be aware of extra moisture in lightweight concrete
- Consider the concrete curing method
- Use a vapor retarder for roofing applications
- Use a moisture mitigation system for flooring applications
  - Use a product intended for the purpose
  - Make sure it gets installed properly
- Wait longer
  - Not an option for roofing applications

Ideas to Minimize the Chance of Failures

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  - Use a product intended for the purpose
  - Make sure it gets installed properly
- Wait longer
  - Not an option for roofing applications
- "Accelerate" drying of the concrete substrate
  - Only applicable for flooring applications

Ideas to Minimize the Chance of Failures

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  - Use a product intended for the purpose
  - Make sure it gets installed properly
- Wait longer
  - Not an option for roofing applications
- "Accelerate" drying of the concrete substrate
  - Only applicable for flooring applications
- Perform proper moisture testing

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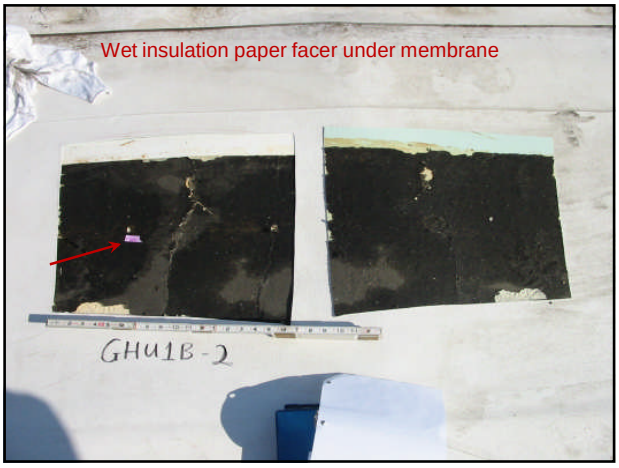
Roofing Case Study: Institutional Facility

Warped and detached insulation under membrane.
This is about 25% of one roof area.

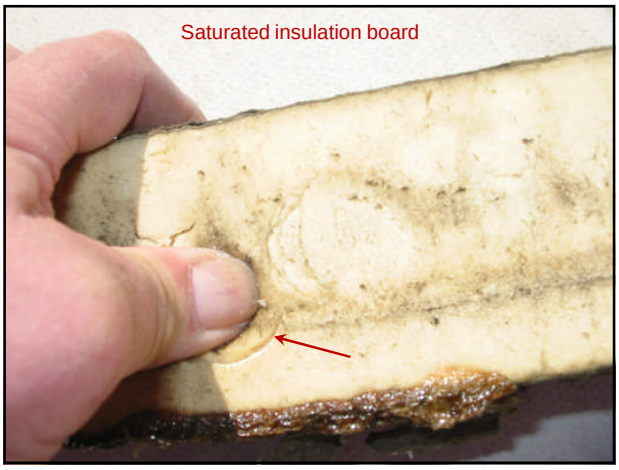
Detached and displaced insulation under inflated membrane

Detached and displaced insulation under membrane

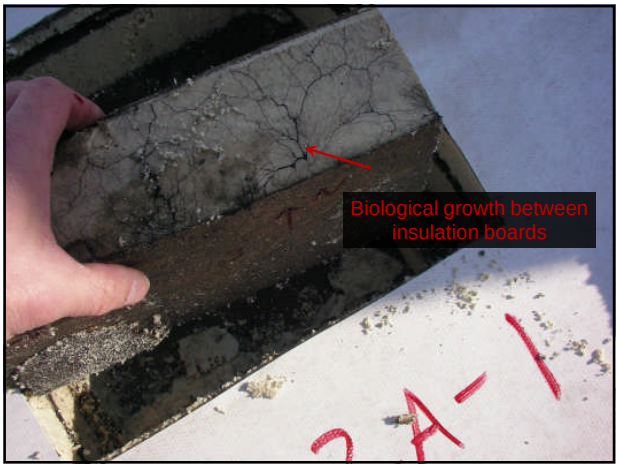
Detached and displaced insulation under membrane

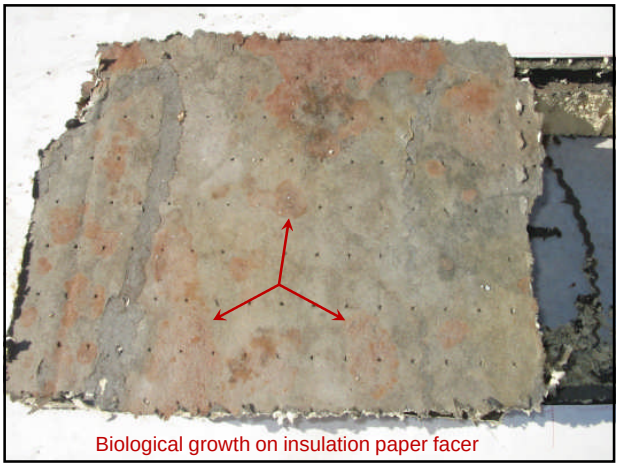


Wet insulation paper facer under membrane



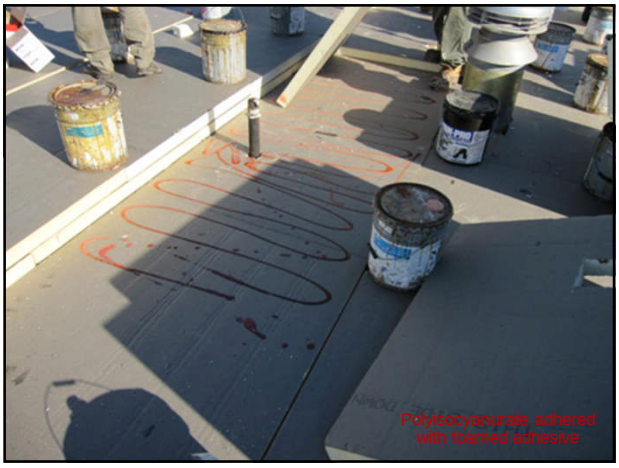
Saturated insulation board


Biological growth between insulation boards


Biological growth on insulation paper facer


Modified bitumen vapor retarder


Polyisocyanurate adhered
with foamed adhesive


Polyisocyanurate adhered
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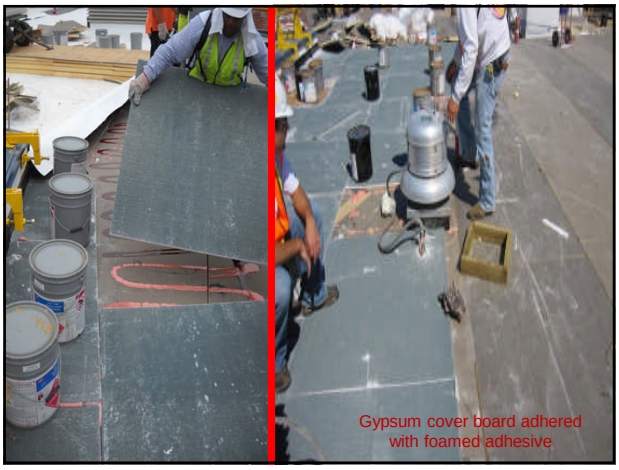
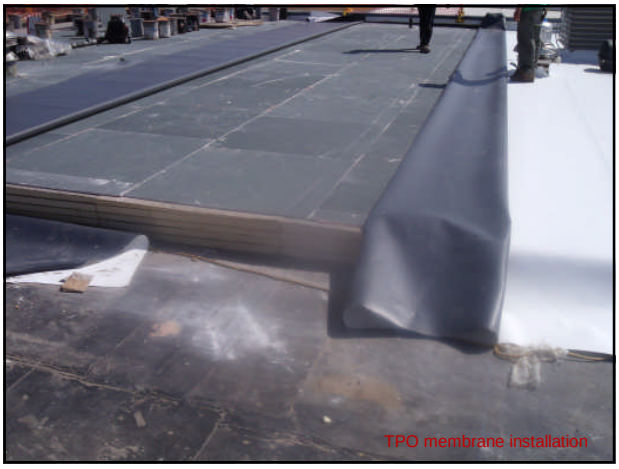
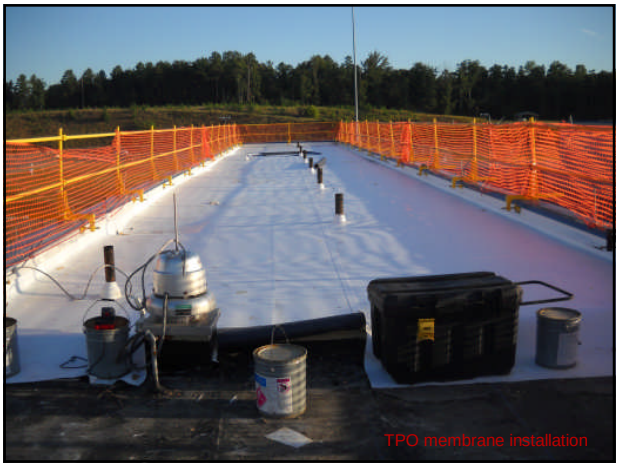

Gypsum cover board adhered
with foamed adhesive


TPO membrane installation


TPO membrane installation


Blisters in Epoxy Coating


Wet Site


Wet Site

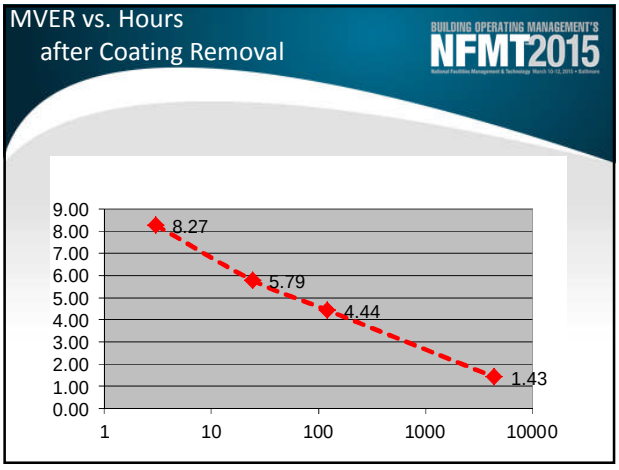

Temporary Swing Space
Required to perform repairs to avoid artifact damage.
Expensive because had to be temporarily conditioned to protect artifacts.


Conditioned Warehouse
Filled with Artifacts


Fluid on Flooring from…..


Osmotic Blisters


MVER Testing
DO NOT TOUCH


MVER vs. Hours
after Coating Removal
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9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1
10
100
1000
10000
8.27
5.79
4.44
1.43

Installation of New Vapor Retarder

Building designed and constructed as warehouse, did not include underslab vapor retarder, pointless to remove and replace epoxy coating.

Placement of Unbonded Concrete Overlay

Vapor retarder, sealed to perimeter walls and at joints, was placed between existing floor/coating and new unbonded concrete overlay.

Curing of Concrete Overlay

All openings, electrical devices, etc. had to be raised to accommodate new concrete overlay thickness.

Installation of New Epoxy Coating

Application of new epoxy top coat.

Completed New Epoxy Coating Installation

Facility More than 10 Years after Work Performed

Flooring still in excellent condition (with exception of minor scuffing damage from moving warehouse contents).

Presentation Outline

- Moisture in Concrete Substrates
  - Why Do We Care?
  - Sources of Moisture
  - Some Reasons for Increase in Roofing and Flooring Failures
- Similarities in Identifying and Testing for Moisture
  - Perform Proper Moisture Testing
  - Ideas to Minimize the Chance of Failures
- Case Studies
- **Summary: Concrete Substrate Moisture Considerations**

Summary: Concrete Substrate Moisture Considerations

Roofing

- Moisture in the roofing assembly
  - Can be a primary cause of rigid insulation and roofing membrane detachment
  - Can weaken and deteriorate the organic insulation facer, resulting in cohesive failure in the insulation facer well below the code required design wind pressures
  - May contribute to bowing insulation boards
  - Can result in the development of biological growth within the roofing assembly

Summary: Concrete Substrate Moisture Considerations

Roofing

- Need reliable quantitative testing to establish condition of concrete substrate prior to roofing installation
  - Ensure the roof deck is “dry” prior to roofing installation
  - Different from flooring applications (due to time constraints, exposure, etc.)

Summary: Concrete Substrate Moisture Considerations

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Roofing

- Provide a vapor retarder where required to limit the amount of moisture entering the roofing assembly
  - Design must prevent moisture from becoming trapped in roofing assembly
  - Prevents residual moisture in concrete substrate from diffusing into roofing assembly
  - Some vapor retarders can also function as an air barrier

Summary: Concrete Substrate Moisture Considerations

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Flooring

- Moisture in the flooring substrate
  - Can be a primary cause of flooring failure
  - Can be from sources other than concrete, such as underlying soil or ambient conditions
  - Can be dependent on
    - Exposure to weather or construction water
    - Amount of time concrete substrate is allowed to naturally dry
    - Amount of time installation area has been enclosed, with HVAC system operational

Summary: Concrete Substrate Moisture Considerations

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Flooring

- Need reliable quantitative testing to establish condition of concrete substrate prior to flooring installation
  - Ensure the concrete substrate moisture content meets flooring manufacturers' recommendations prior to flooring installation

Summary: Concrete Substrate Moisture Considerations

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Flooring

- Provide a moisture mitigation membrane where required to limit the amount of moisture entering the flooring assembly
  - Prevents residual moisture in concrete substrate from affecting flooring products
  - Required if there is moisture in the concrete substrate greater than the flooring manufacturer's recommendations

Learning Assessment Questions

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1. It is important to address moisture in concrete substrates for roofing and flooring applications.
- True False

2. Moisture in the concrete substrate can result in failure of roofing or flooring systems.
- True False

Learning Assessment Questions

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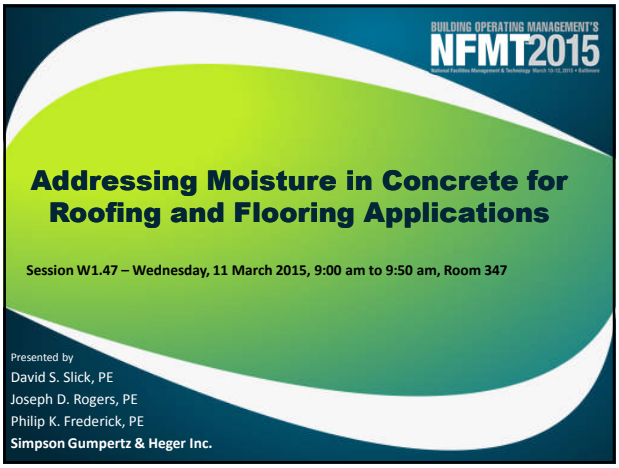
3. No similarity exists between potential damage to a roofing system from moisture in the concrete roofing substrate and potential damage to a flooring system from moisture in the concrete flooring substrate.
- True False

4. Repair of a failed roofing or flooring system damaged as a result of moisture in the concrete substrate can be expensive.
- True False


BUILDING OPERATING MANAGEMENT'S
NFMT2015
Addressing Moisture in Concrete for Roofing and Flooring Applications
Session W1.47 – Wednesday, 11 March 2015, 9:00 am to 9:50 am, Room 347
Presented by
David S. Slick, PE
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Philip K. Frederick, PE
Simpson Gumpertz & Heger Inc.