Strategies for Repairing Failed Floor Finishes

Presented by

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BUILDING OPERATING MANAGEMENT'S
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Abstract

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This presentation reviews the causes of flooring failures, discusses various strategies for repairing failed floor finishes, and presents important considerations for every repair project. Recent changes in the composition of floor finishes and concrete floor construction practices have significantly increased the number of moisture-related floor finish failures. Although there are many design- and construction-phase recommendations for reducing moisture levels and limiting performance issues, failures still occur regularly. Repair of floor finish failures are typically very costly, time consuming, and disruptive to operation. This presentation will help architects, contractors, and building owners understand the causes of flooring failures and how the failure mechanisms must be considered in the repair process. Attendees will learn the options for repairing their floor failures given typical operational, budgetary, and existing condition constraints. Through discussion of case studies, we will review repair strategy considerations to arm decision makers with practical options for each of their flooring repair projects.

Learning Objectives

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

1. Identify industry changes and current practices that result in elevated concrete moisture levels and contribute to floor finish failures.
2. Recognize critical floor failure mechanisms and understand how to address such mechanisms in the floor repair design and implementation.
3. Design and construct floor finish repairs that consider substrate quality and preparation, environmental conditions, code requirements and safety concerns.
4. Select a floor finish repair strategy that addresses existing conditions and meets performance, operational and budgetary requirements.

Presentation Outline

- Causes of Flooring Failures
- Reasons for Increase in Flooring Failures
- Ideas to Minimize the Chance of Failures
- Options for Mitigating High Moisture Levels
- Considerations for Repairing Failed Flooring
  - Concrete Surface Preparation
  - Concrete Composition and Quality
  - Sources of Moisture
  - Code Requirements
  - Safety Considerations

Presentation Outline

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Causes of Flooring Failures

- Primary Causes
  - Moisture

Adhesive Staining + Sliding Tiles

Wet Concrete

Discolored Artificial Stone Tiles

Concrete Slab-on-Grade
No Vapor Retarder beneath Slab

Stains on Engineered Wood Flooring

Elevated Deck with Lightweight Concrete

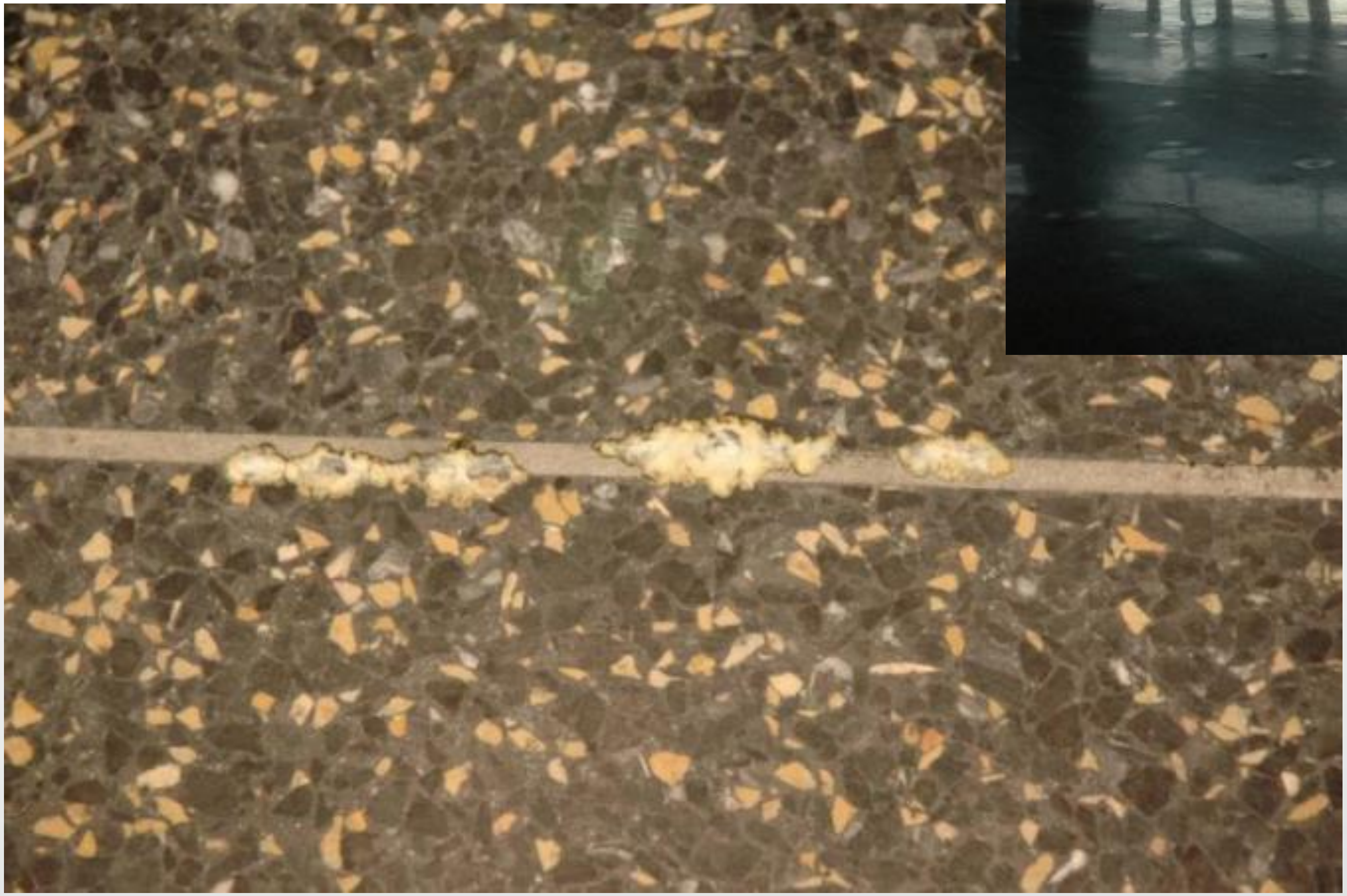
Damage at Building Perimeter

Water Infiltration at Windows

Ruts in Sheet Vinyl with Soft, Migrating Adhesive

Elevated Deck with Lightweight Concrete

Epoxy Terrazzo Blisters + Surface Deposits



Concrete Slab-on-Grade
Vapor Retarder beneath Blotter Layer

Causes of Flooring Failures

- Primary Causes
  - Moisture
  - Quality and Preparation of Concrete

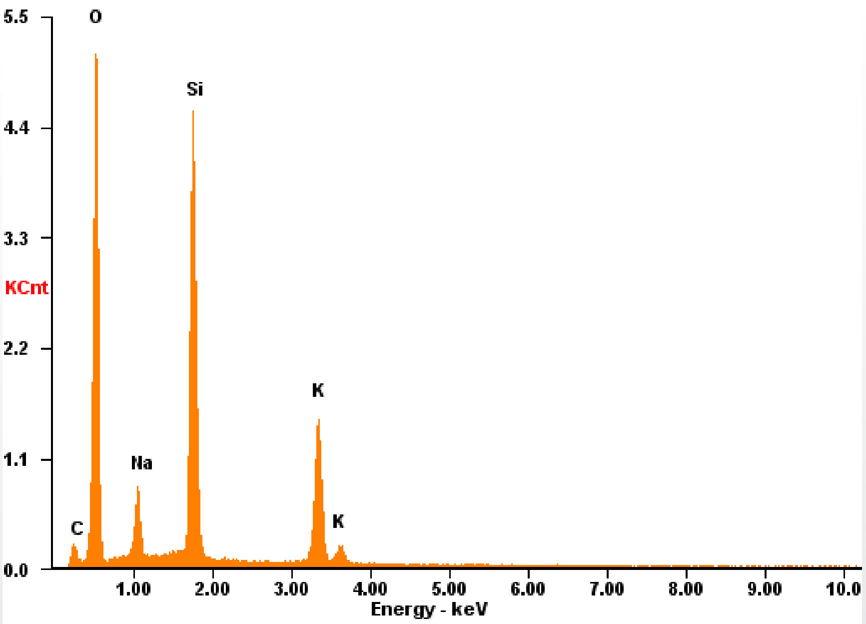
Delaminated Ceramic Floor Tiles

Ineffective Surface Preparation
Contaminated Surface

Slippery White Deposits on Warehouse Floor

Surface Contamination of Silicate Hardener Residue

Blisters in Epoxy Floor Coating



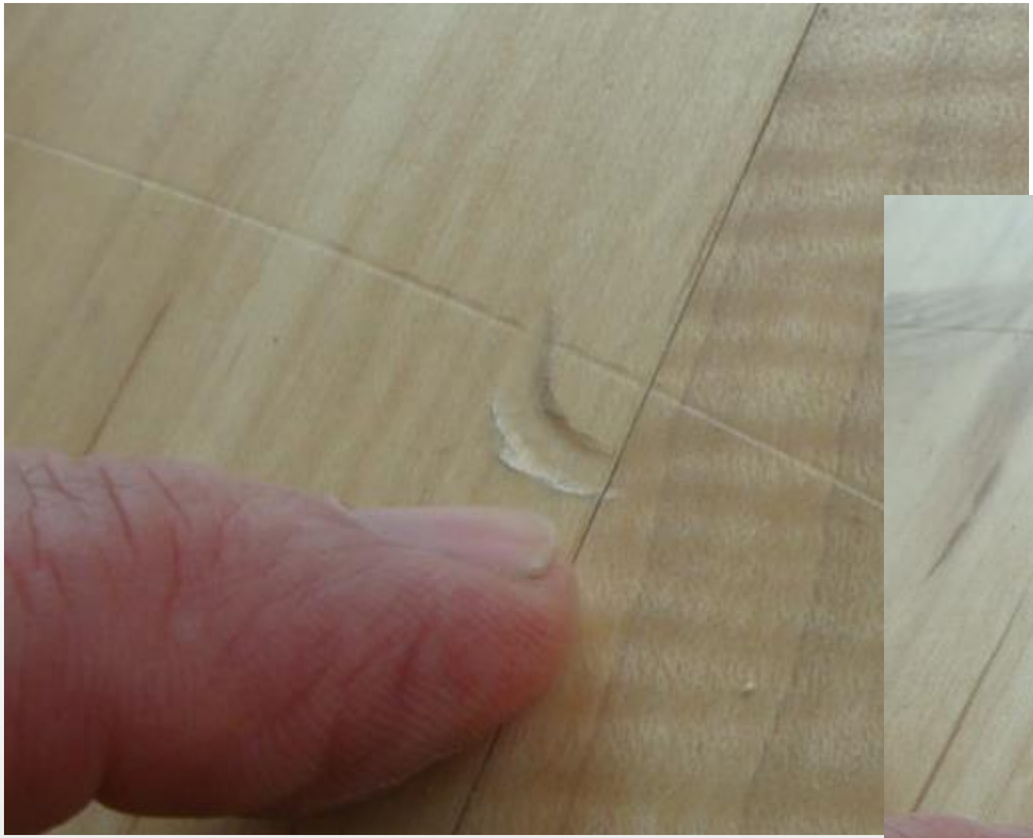
Surface Contamination of Silicate Hardener Residue

Causes of Flooring Failures

- Primary Causes
  - Moisture
  - Quality and Preparation of Concrete

- Secondary Causes
  - Product Selection
  - Cleaning and Maintenance
  - Environmental Exposure (humidity, sun, etc.)

Product Selection Issues



Damage due to soft flexible underlayment

System Selection Issues

Damage due to soft flexible underlayment

System Selection Issues

Reversion of adhesive because old adhesive was not completely removed

System Selection Issues

Reversion of adhesive because old adhesive was not completely removed

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Reasons for Increase in Flooring Failures

- Change in materials (government regulations)

Change in Materials

Use of asphalt cut back adhesive almost gone

SCAQMD Rule 1168 (2005)

VOC Limit*, Less Water and Less Exempt Compounds in Grams per Liter

Architectural Applications	Current VOC Limit
Indoor Carpet Adhesives	50
Carpet Pad Adhesives	50
Outdoor Carpet Adhesives	150
Wood Flooring Adhesive	100
Rubber Floor Adhesives	60
Subfloor Adhesives	50
Ceramic Tile Adhesives	65
VCT and Asphalt Tile Adhesives	50
Dry Wall and Panel Adhesives	50

South Coast Air Quality Management District for indoor carpet adhesive has changed from 150 g/l to 50 g/l

Carpet Policy Dialogue

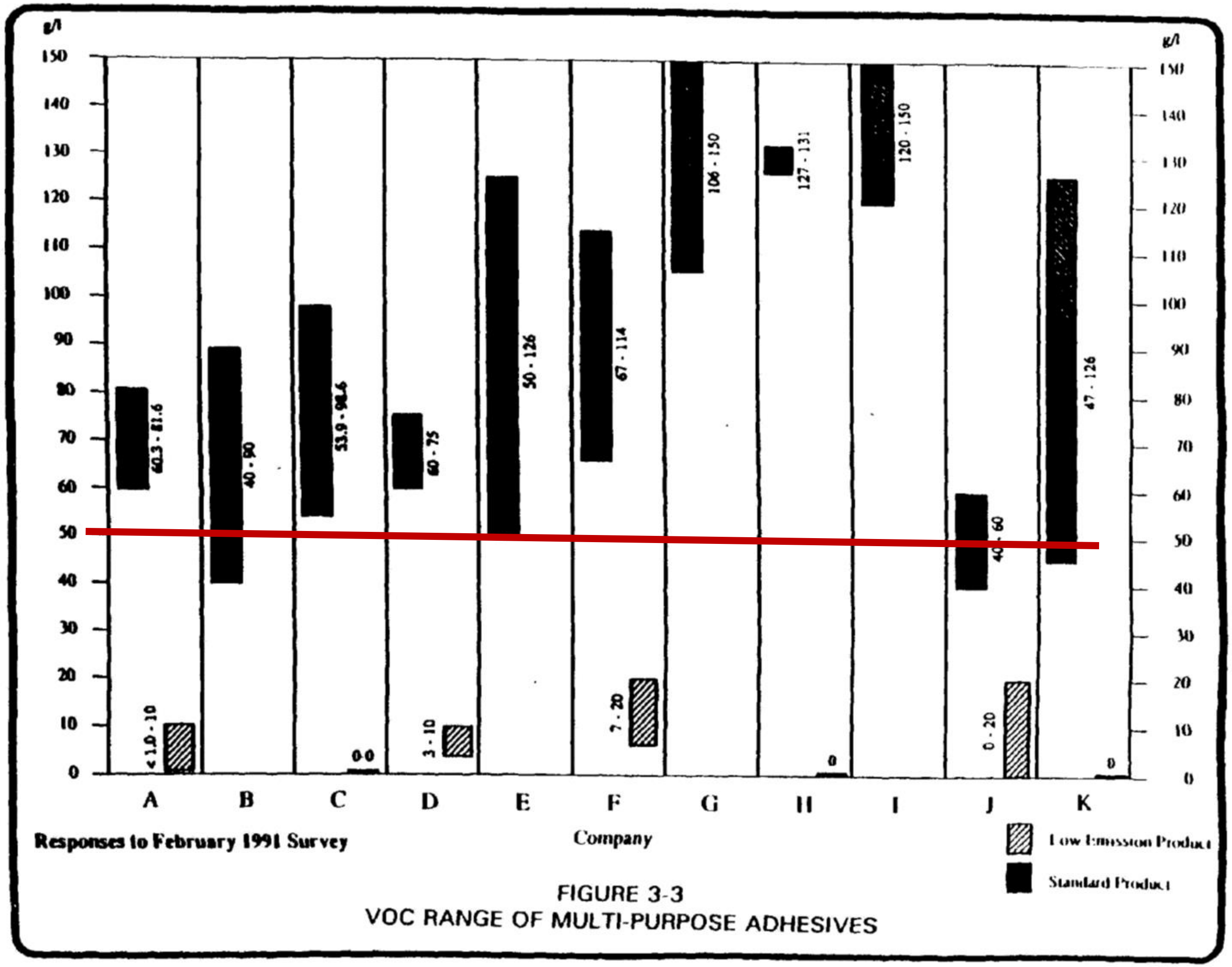


FIGURE 3-3
VOC RANGE OF MULTI-PURPOSE ADHESIVES

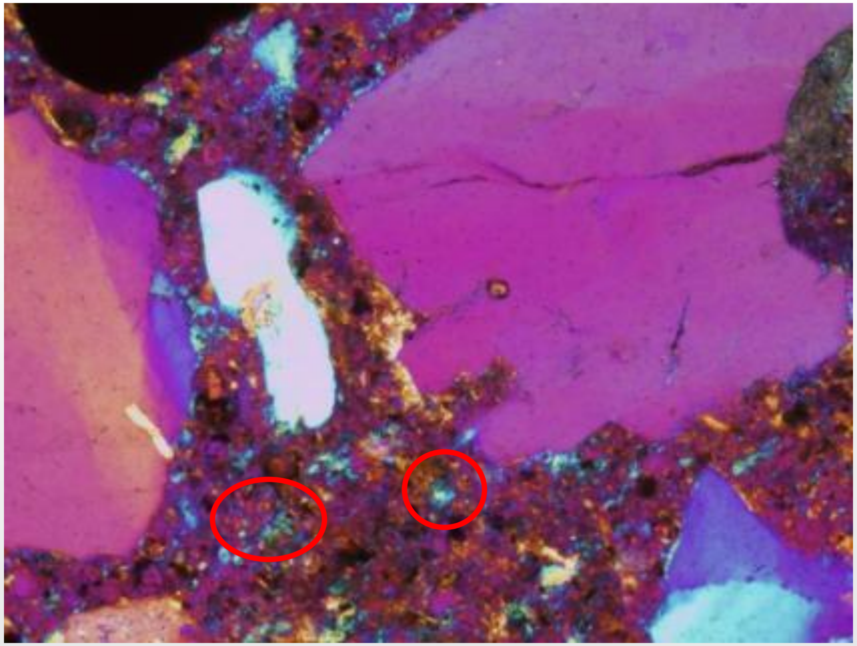
1991 South Coast Air Quality Management District limit was 150 g/l for carpet adhesives. Today limit is 50 g/l.

Reasons for Increase in Flooring Failures

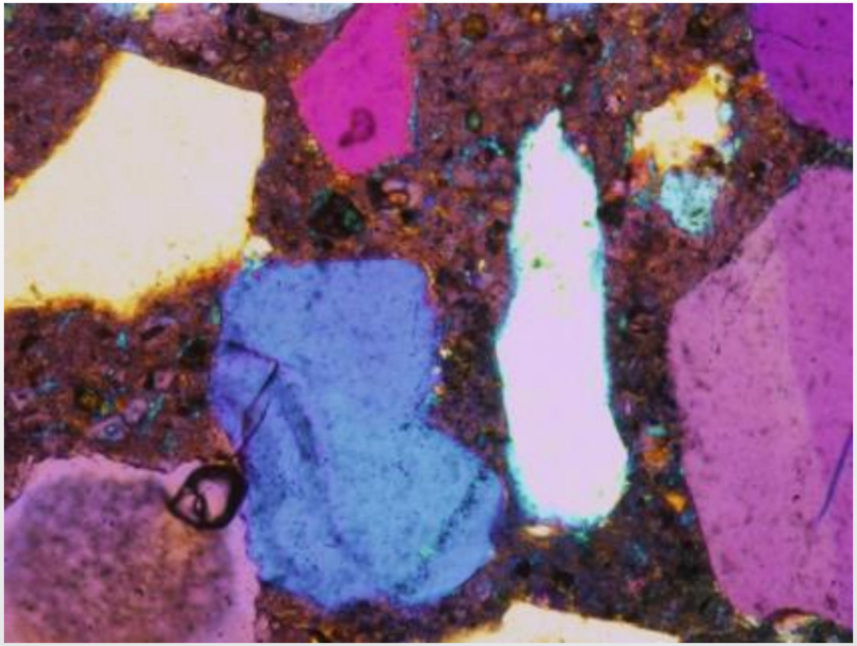
- Change in materials (government regulations)
- Blended cement (fly ash) concretes

Concrete with and without Fly Ash

- 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.

Reasons for Increase in Flooring Failures

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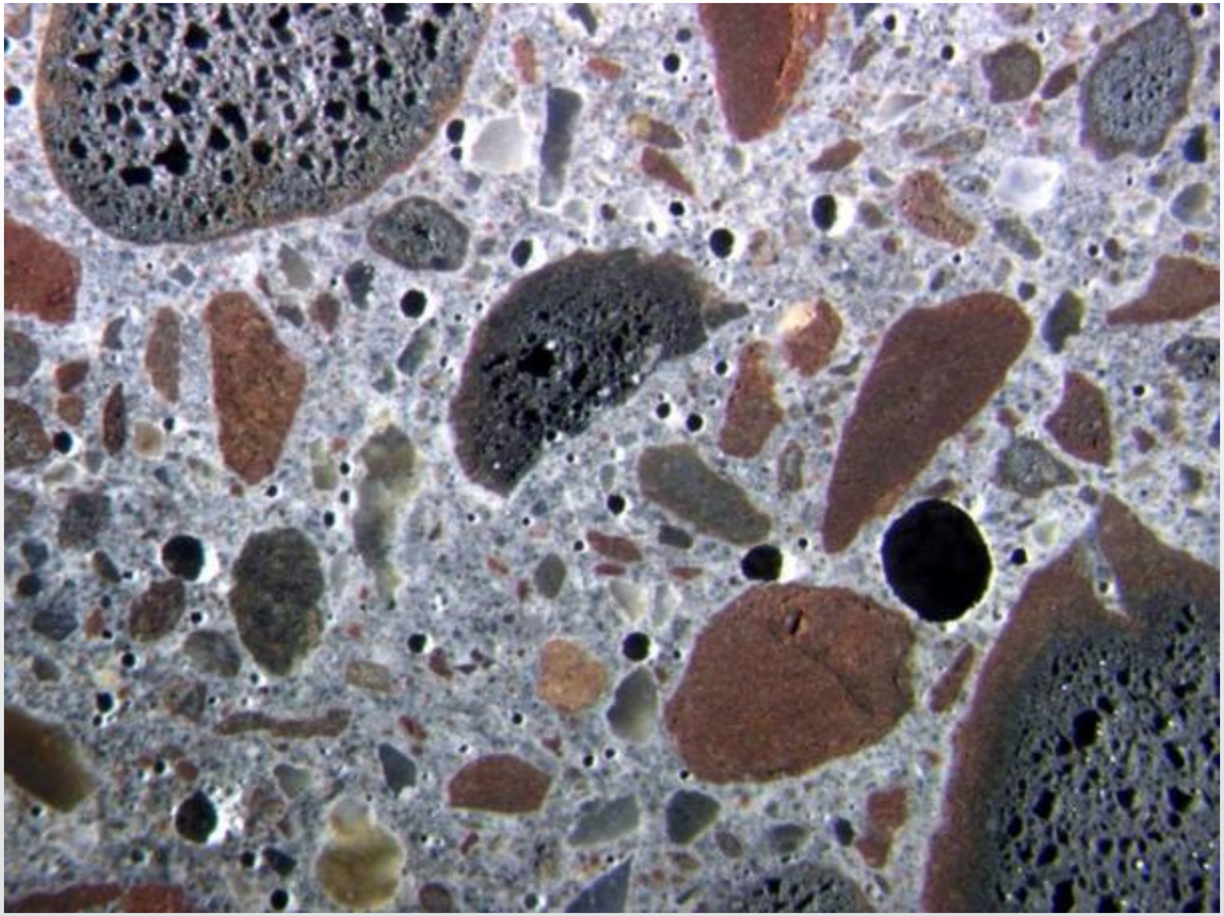
- Change in materials (government regulations)
- Blended cement (fly ash) concretes
- Use of lightweight concrete

Normal Weight vs. Lightweight Concrete

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



Normal-Weight vs. Lightweight Concrete

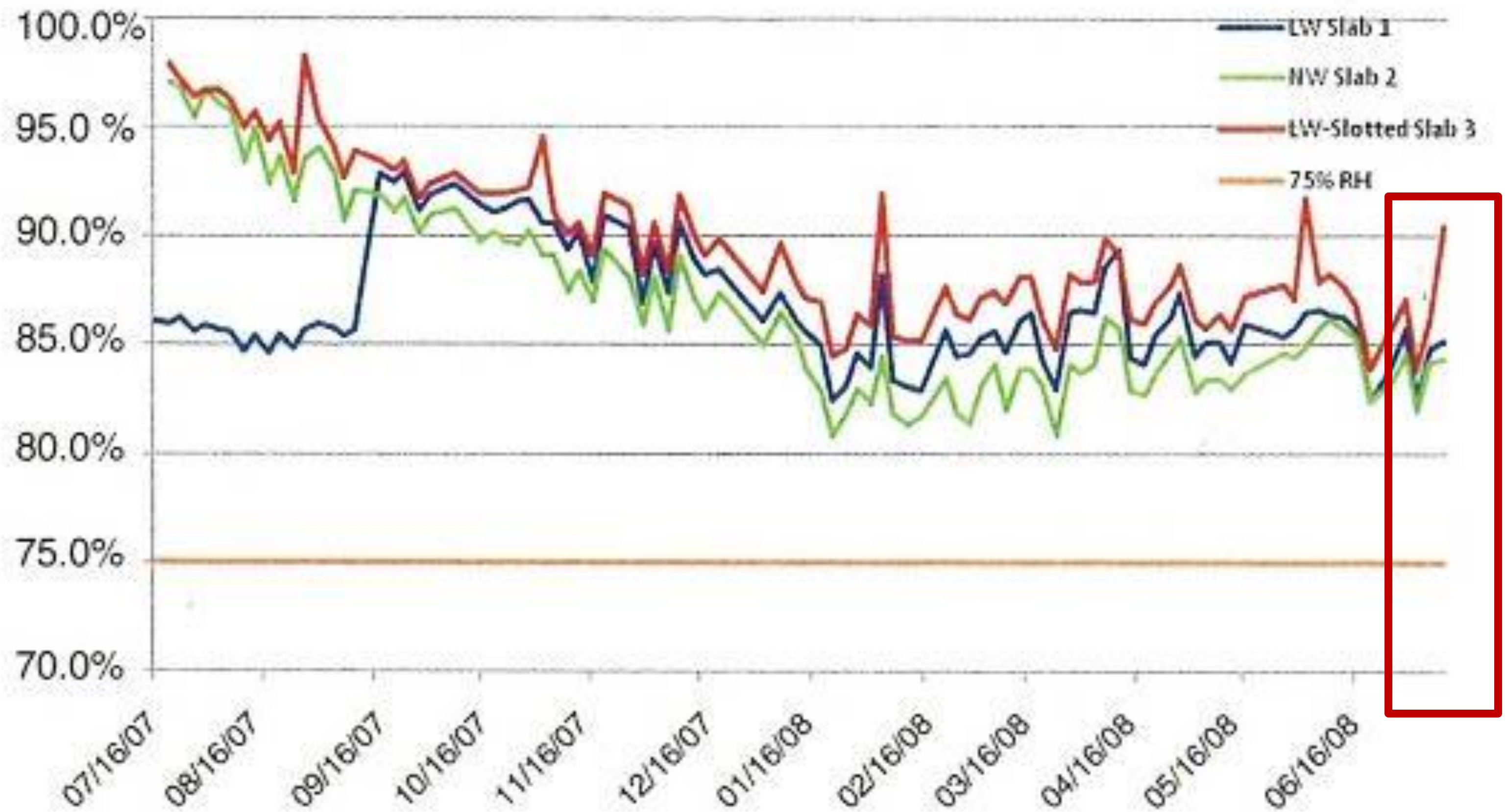


Fig. 6: RH history for Study 1, Nonconditioned Environment

From Concrete International, January 2012

Both NW <u>and</u> LW concrete may require long drying time in non-conditioned environment

Reasons for Increase in Flooring Failures

- Change in materials (government regulations)
- Blended cement (fly ash) concretes
- Use of light weight concrete
- Fast track construction

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Ideas to Minimize the Chance of Failures

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

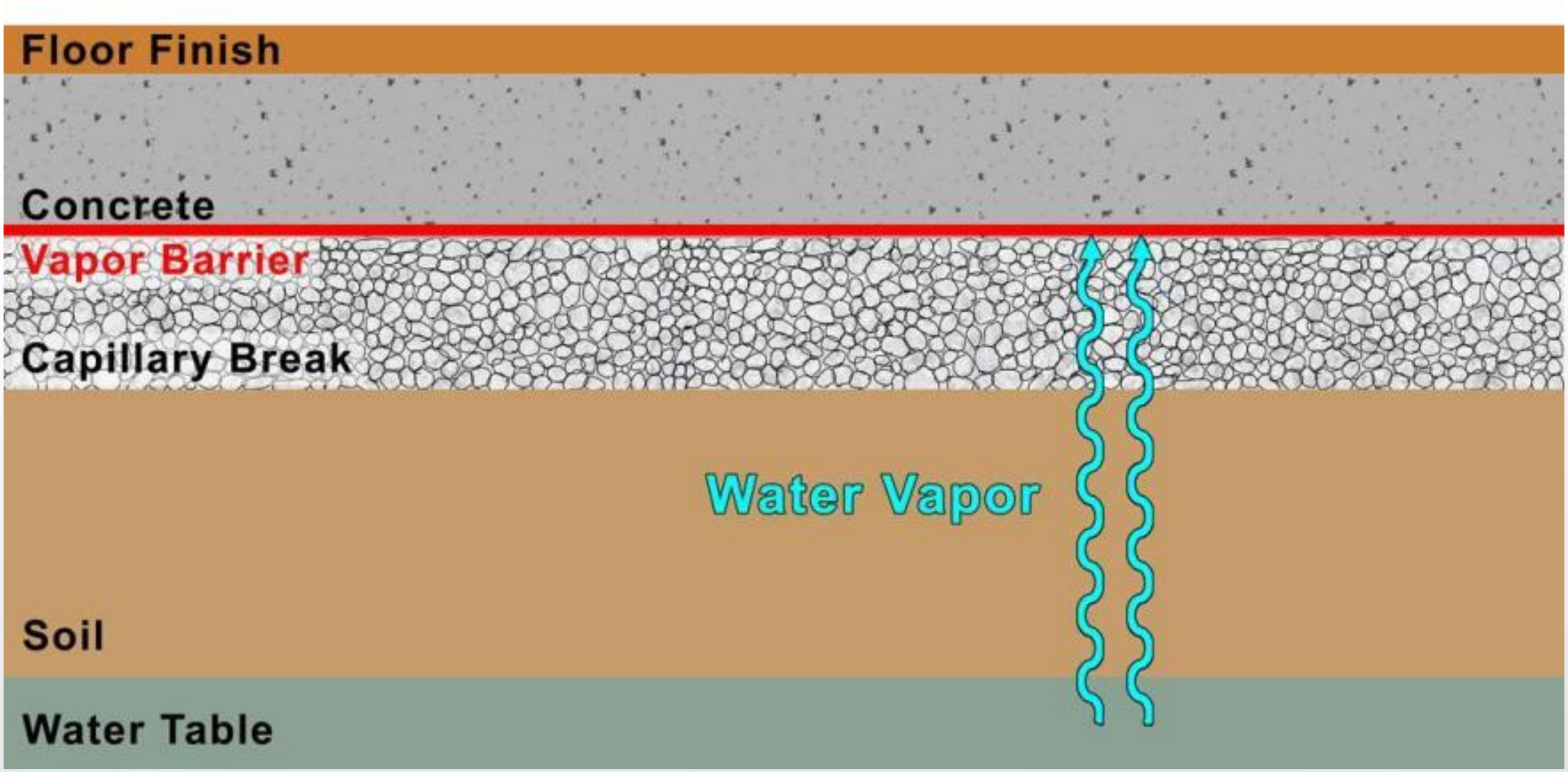
Concrete Mix Design

- 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

- Use low w/c ratio concretes without fly ash
  - Be aware of extra moisture in lightweight concrete
- Use a vapor retarder under slabs-on-ground
  - Use a product intended for the purpose
  - Make sure it gets installed properly

Slab-on-Ground *with* a Vapor Retarder



Ideas to Minimize the Chance of Failures

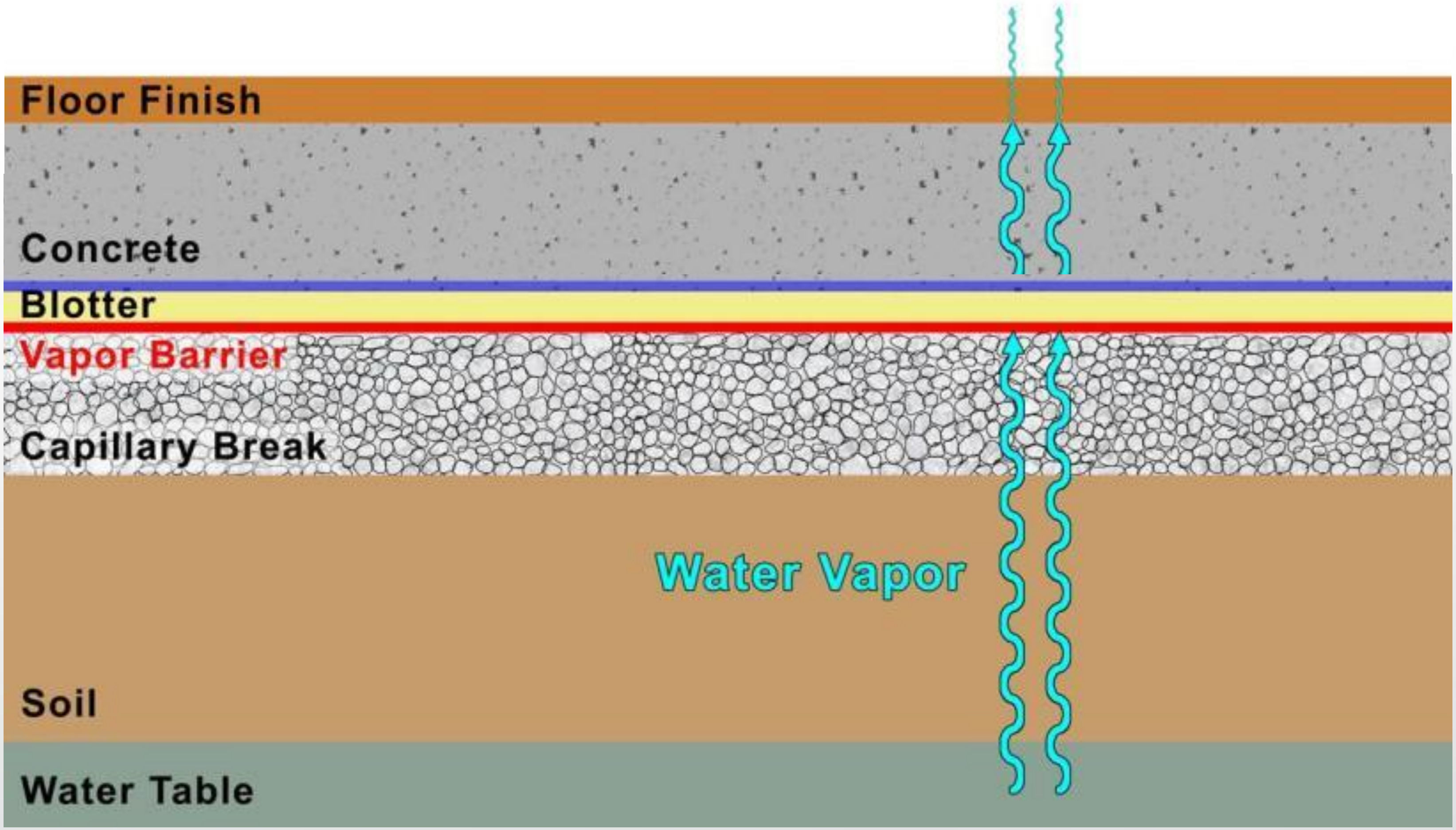
- Use low w/c ratio concretes without fly ash
  - Be aware of extra moisture in lightweight concrete
- Use a vapor retarder under slabs-on-ground
  - Use a product intended for the purpose
  - Make sure it gets installed properly
- Avoid blotter layers

Installation of Sand Blotter Layer

Preparation for Compaction of Blotter Layer

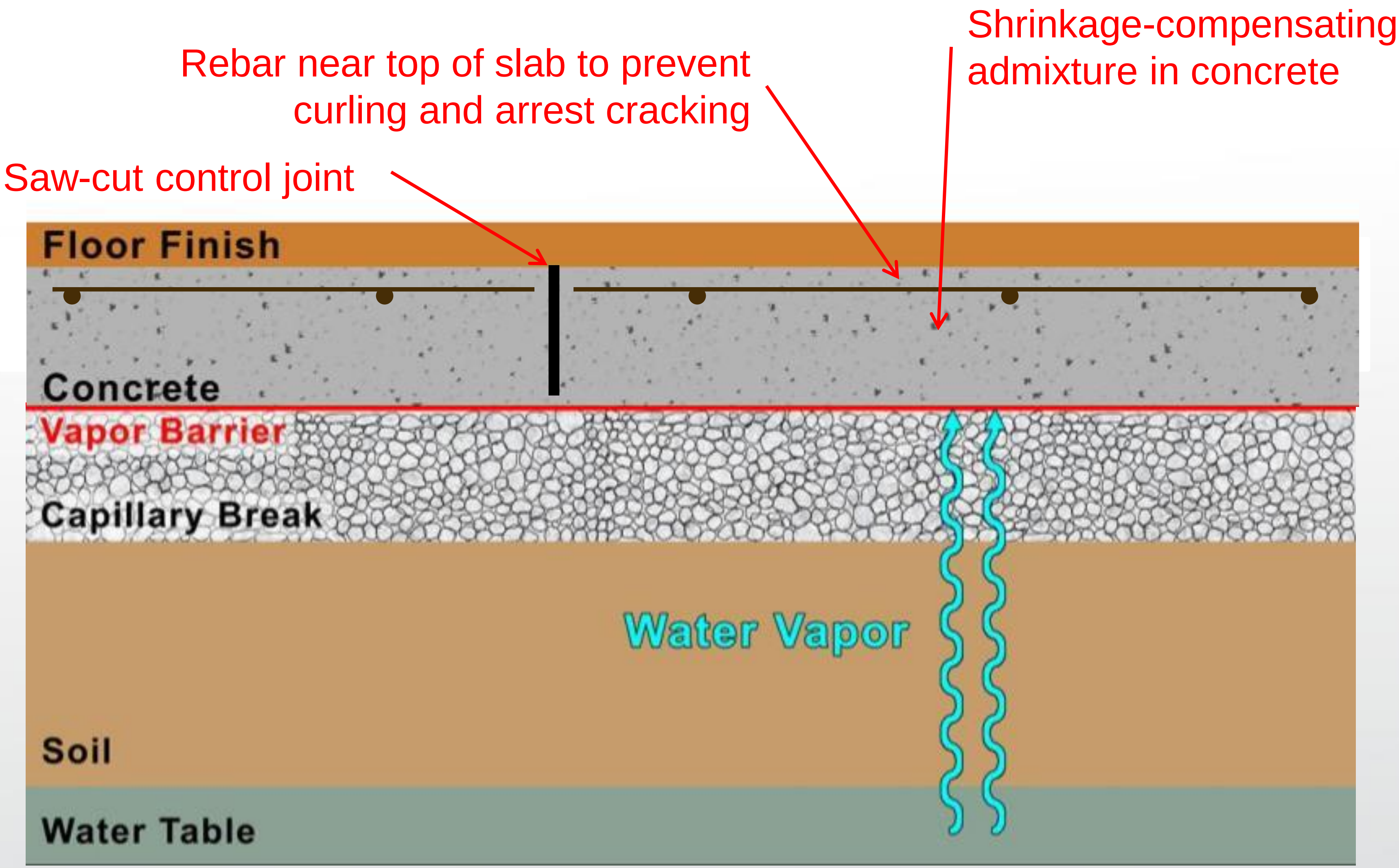
Oops! Is that water being applied to blotter layer above the vapor retarder?

Slab-on-Grade with Blotter Layer



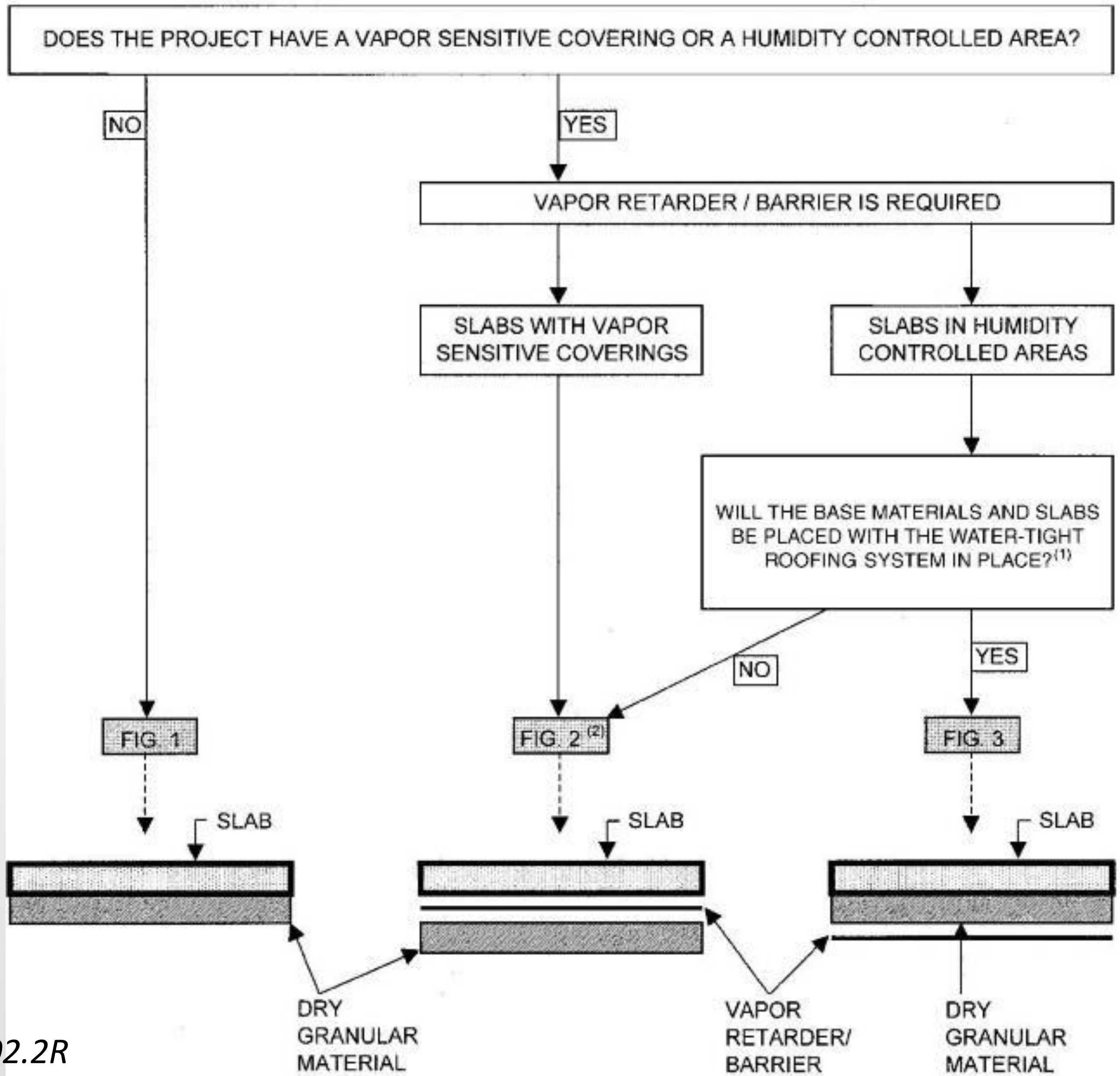
Make sure vapor retarder is not compromised by construction events

Slab-on-Grade and Curling



Consider the effect of admixtures on drying time

Location of the Vapor Retarder



From ACI 302.2R

Ideas to Minimize the Chance of Failures

- Use low w/c ratio concretes without fly ash
  - Be aware of extra moisture in lightweight concrete
- Use a vapor retarder under slabs on ground
  - Use a product intended for the purpose
  - Make sure it gets installed properly
- Avoid blotter layers
- 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.

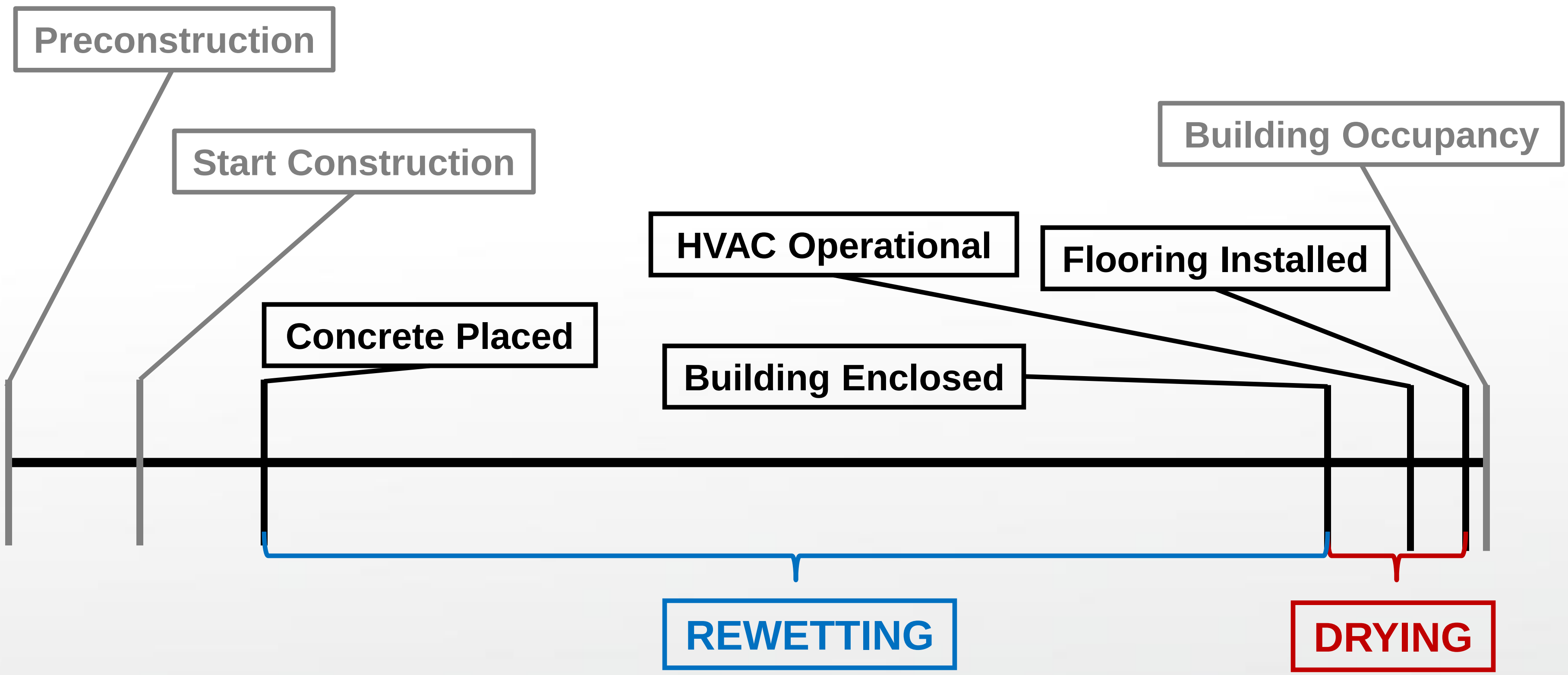
- ~~Liquid Membrane-Forming Curing Compounds~~
  - Do not allow concrete to begin drying until removed.
  - Act as a bond-breaker and prevent adhesion of finishes.

- 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

- Use low w/c ratio concretes without fly ash
  - Be aware of extra moisture in lightweight concrete
- Use a vapor retarder under slabs-on-ground
  - Use a product intended for the purpose
  - Make sure it gets installed properly
- Avoid blotter layers
- Consider the concrete curing method
- Plan ahead

Planning Ahead for Flooring Installation



<u>Typical Construction Timeline</u>

Ideas to Minimize the Chance of Failures

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  - Be aware of extra moisture in lightweight concrete
- Use a vapor retarder under slabs-on-ground
  - Use a product intended for the purpose
  - Make sure it gets installed properly
- Avoid blotter layers
- Consider the concrete curing method
- Plan ahead
- Perform proper moisture testing

ASTM Moisture Test Standards

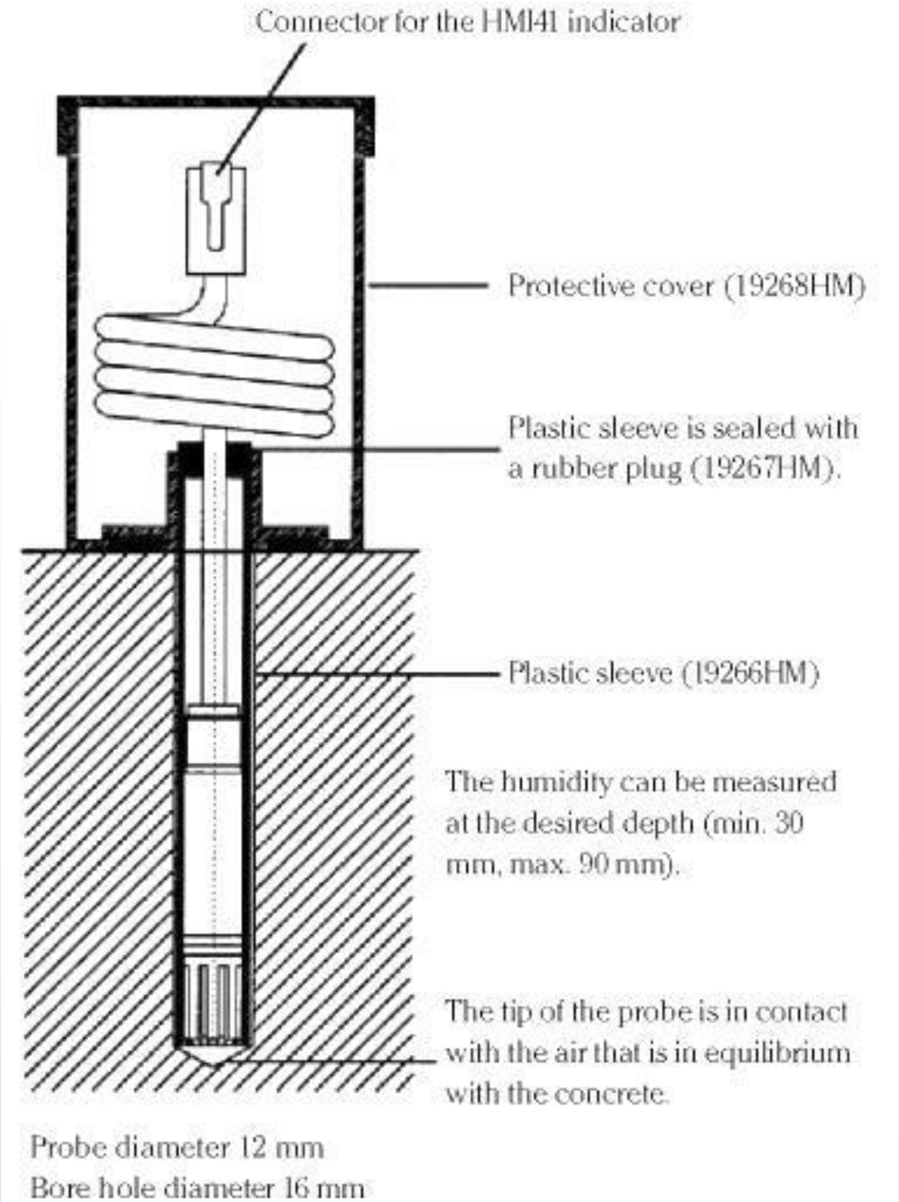
- ASTM F1869 – *Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride*
- ASTM F2170 – *Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes*
- ASTM F2420 – *Standard Test Method for Determining Relative Humidity on the Surface of Concrete Floor Slabs Using Relative Humidity Probe Measurement and Insulated Hood*
- ASTM F710 – *Standard Practice for Preparing Concrete Floors to Receive Resilient Flooring*

ASTM F1869 – Moisture Vapor Emission Rate

ASTM F1869: Limitations of Test

- 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



ASTM F2170: Limitations of Test

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

ASTM F2170 Changes

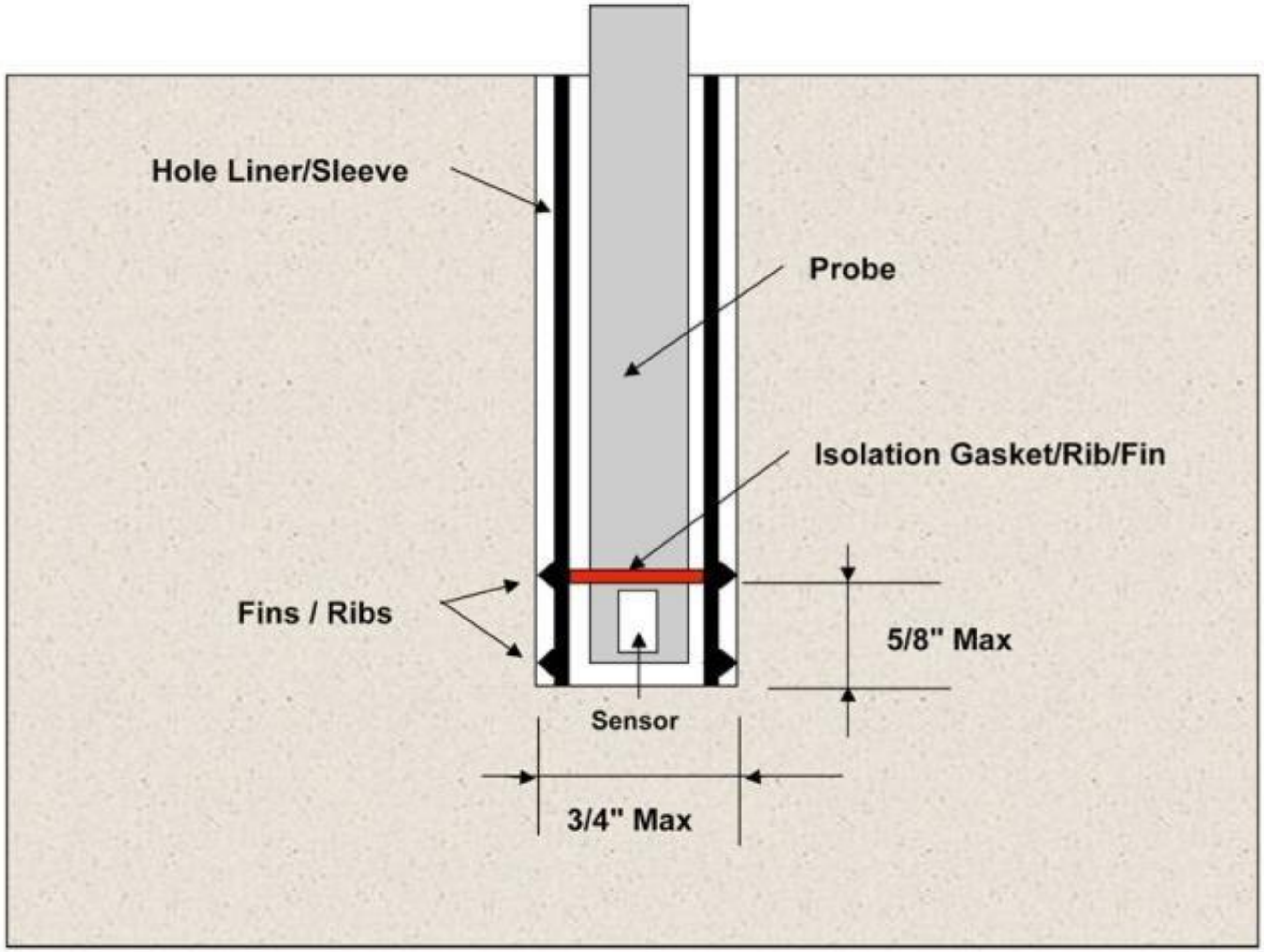


FIG. 2 Example % RH - Probe Element Position

Figure from ASTM F2170-11

ASTM F1869 vs. ASTM F2170

	High RH	Low RH
High MVER		
Low MVER		

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

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Options for Mitigating High Moisture Levels

- Wait Longer

Options for Mitigating High Moisture Levels

- Wait Longer

- “Accelerate” Drying of the Slab

"Accelerate" Drying of the Slab

Temporary conditioning of space

Options for Mitigating High Moisture Levels

- Wait Longer
- "Accelerate" Drying of the Slab
- Install a Moisture Mitigation System
  - Consider an allowance, alternate, or unit price in budget.

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

Mitigation System Selection

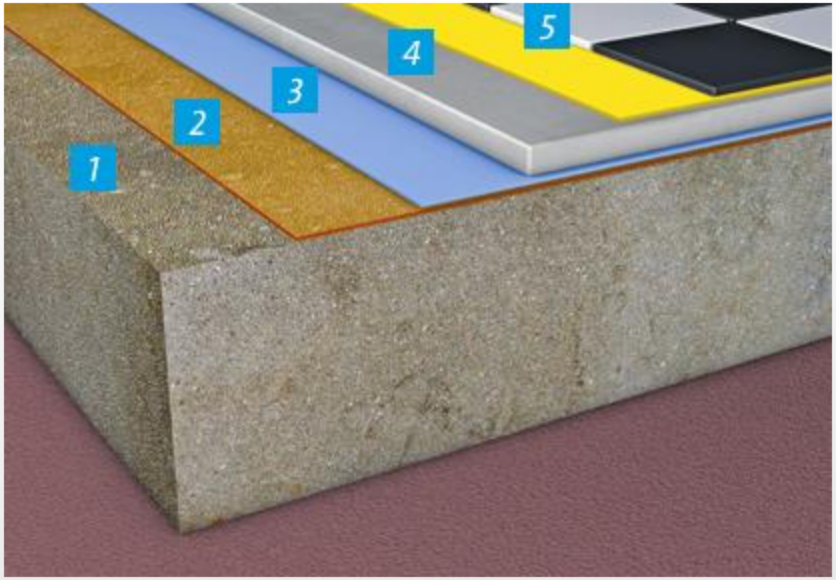
- A long track record of success and a manufacturer that will work closely with you.

- 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 Considerations

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



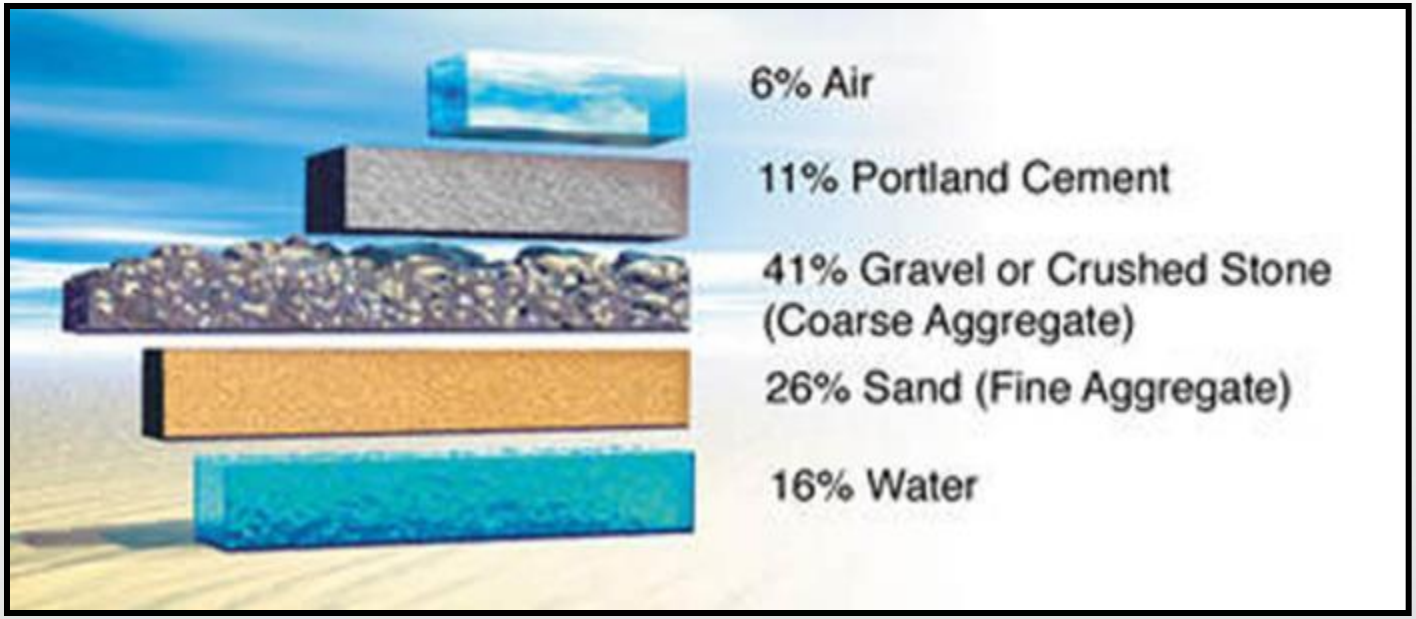
1. Concrete
2. Mitigation Coating
3. Underlayment Primer
4. Cementitious Underlayment
5. Flooring with Adhesive

Mitigation Systems to Avoid

- Penetrating coatings.
- Water-based materials.
- Concrete admixtures.

Concrete Admixtures

- Where does concrete mix water go?
  - Either into cement hydration products
  - Or resides within pore spaces, available for evaporation
- Designed to have a chemical reaction with the concrete to form a barrier to moisture migration.



Concrete Admixtures

- Cannot use standard ASTM tests for moisture.
- Studies show treated concrete is permeable.
- No track record for long-term performance or compatibility.
- Admixtures undetectable in hardened concrete.
- May increase soluble alkalis and potential for ASR.
- May increase surface pH of concrete.
- Does not address cracks and joints in the concrete.
- May create denser concrete with reduced ability for adhesive bond.

Options for Mitigating High Moisture Levels

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

Future Moisture Mitigation Options

- Proprietary ready-mix concrete mix that reduces the drying time associated with excess moisture vapor in concrete slabs.
  - Licensed ready-mix producers only
  - No lightweight concrete mix
  - $3 to $4 per square foot for 6 in. thick slab or less

- Waterproof and pH-proof adhesives.
  - No moisture limits
  - No testing requirements
  - No abrasive surface preparation
  - Fast cure

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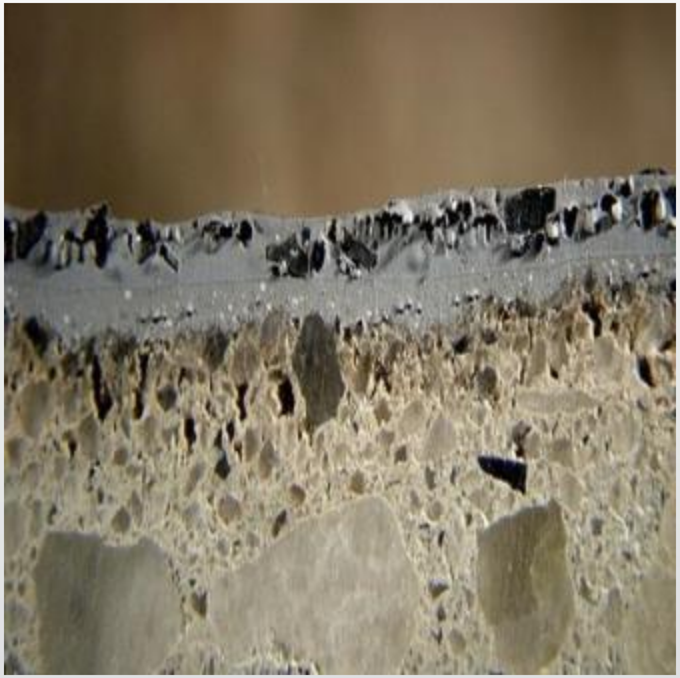
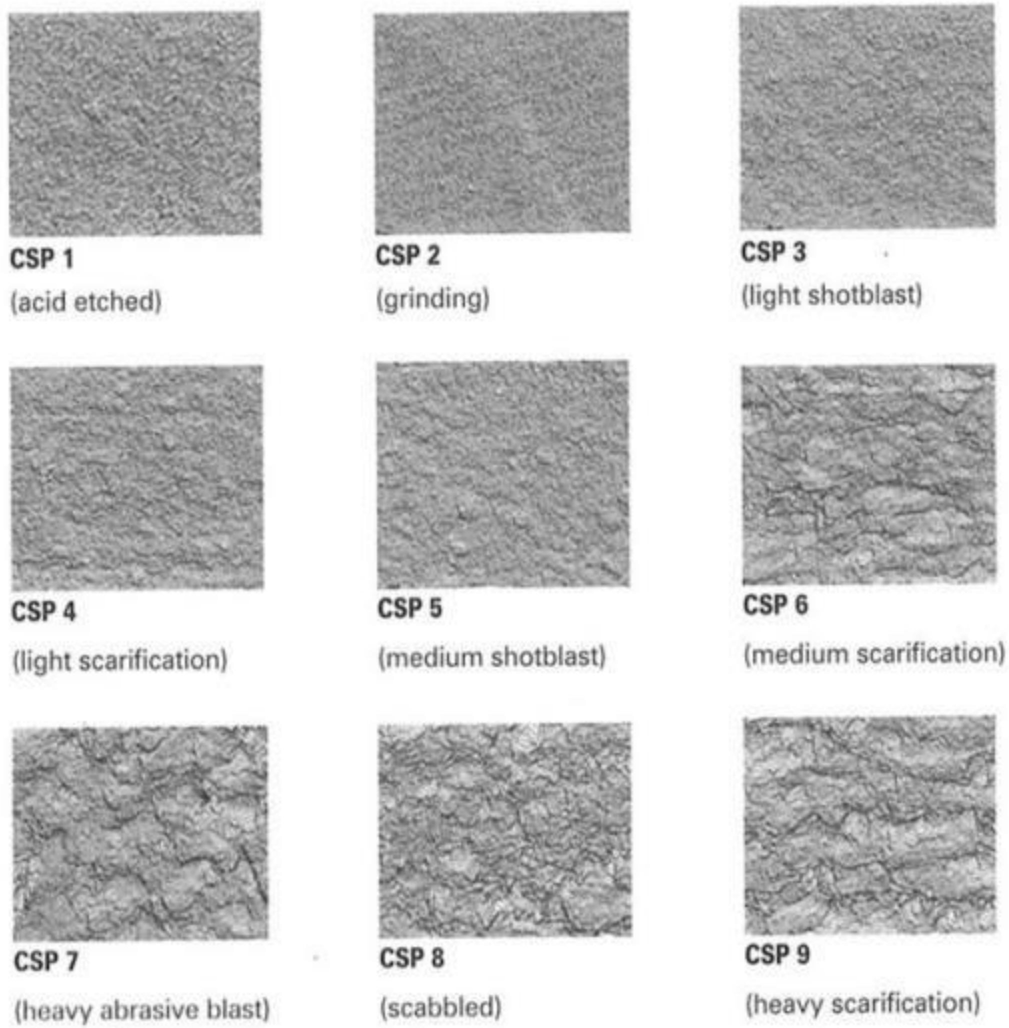
Surface Preparation

- Surface preparation directly affects adhesion.
- Remove bond-breaking substances to improve ***chemical*** adhesion.
- Roughen surface and remove unsound materials to improve ***mechanical*** adhesion.



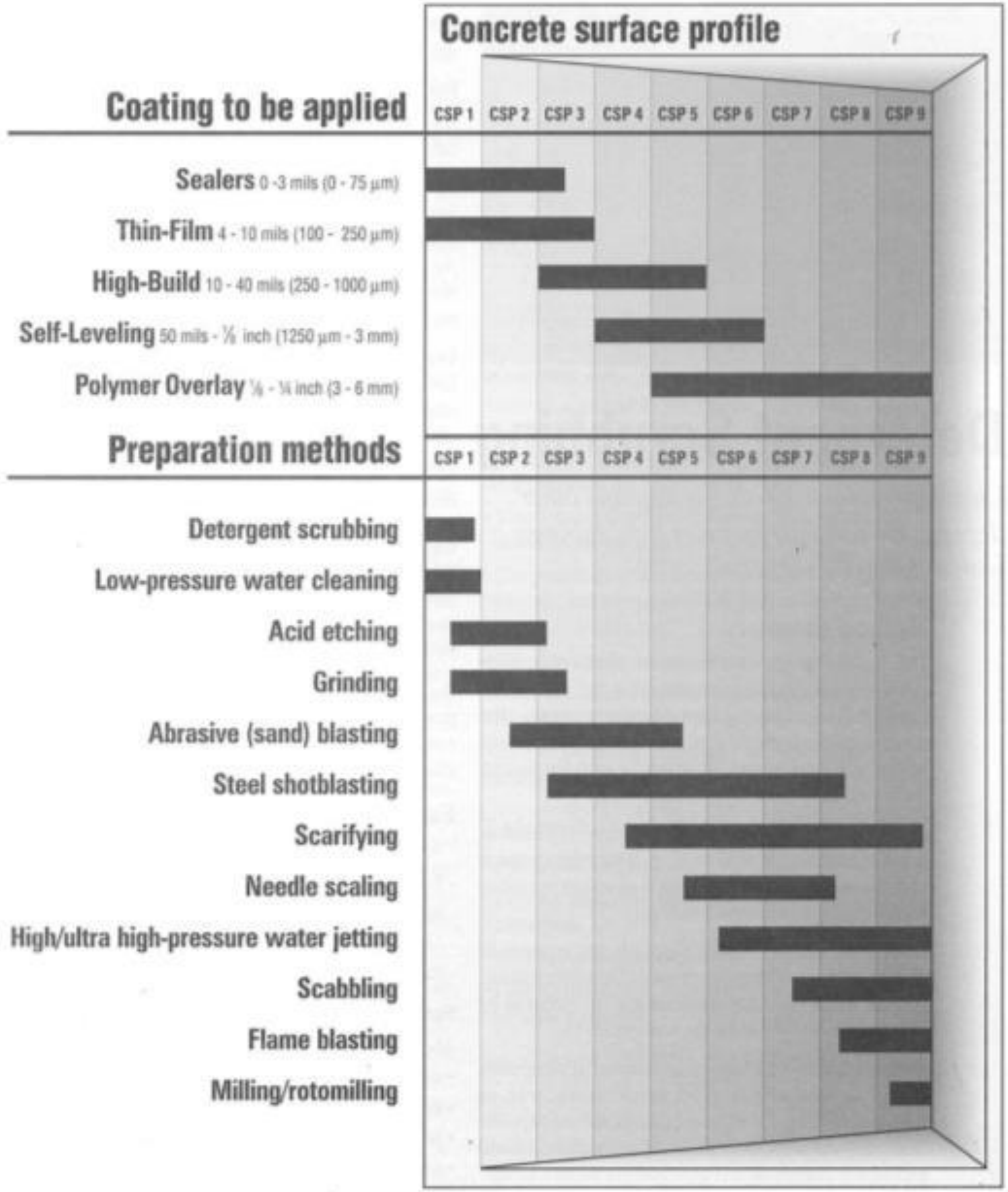
Concrete Surface Profiles (CSP)

Caution! *The texture and appearance of the profile obtained will vary depending on strength, the size and type of aggregate, and finish of the concrete surface. On sound substrates the range of variation can be sufficiently controlled to closely resemble the referenced CSP standard. As the depth of removal increases, the profile of the prepared substrate will be increasingly dominated by the coarse aggregate.*



Images generated using video density imaging techniques are courtesy of David Lange, Department of Civil Engineering, University of Illinois at Urbana-Champaign.

Concrete Surface Preparation Methods



Take Aways

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- Surface preparation is critical to achieving good bond.

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Case Study: Self Storage Concrete Composition

The First Repair

Shot blast

The First Repair

New finish

The First Repair

Looks good…….

Uh oh !

Blisters !

Uh oh !

Blisters from contaminant found in substrate

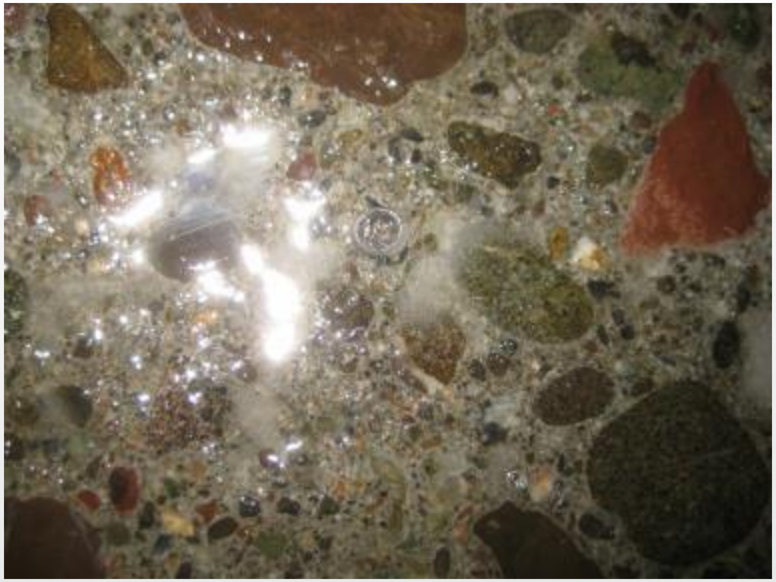
The Second Repair

Remove top ½ inch of concrete substrate

The Second Repair

Apply new finish……again

The Second Repair

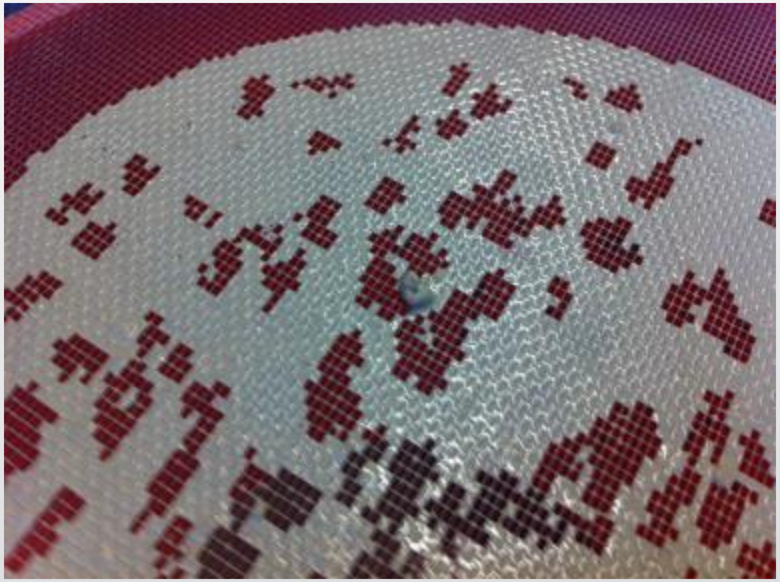


But applied primer had pinholes…….

The Second Repair

Guess what ?   Blisters !

The Second Repair



A material issue ?

Take Aways

- Surface preparation is critical to achieving good bond.
- Concrete composition will affect performance of finish.

Case Study: Coating in Maintenance Center

Delamination of Coating from Impact

Two days after the service center workshop opened……

Delaminated Coating Sample

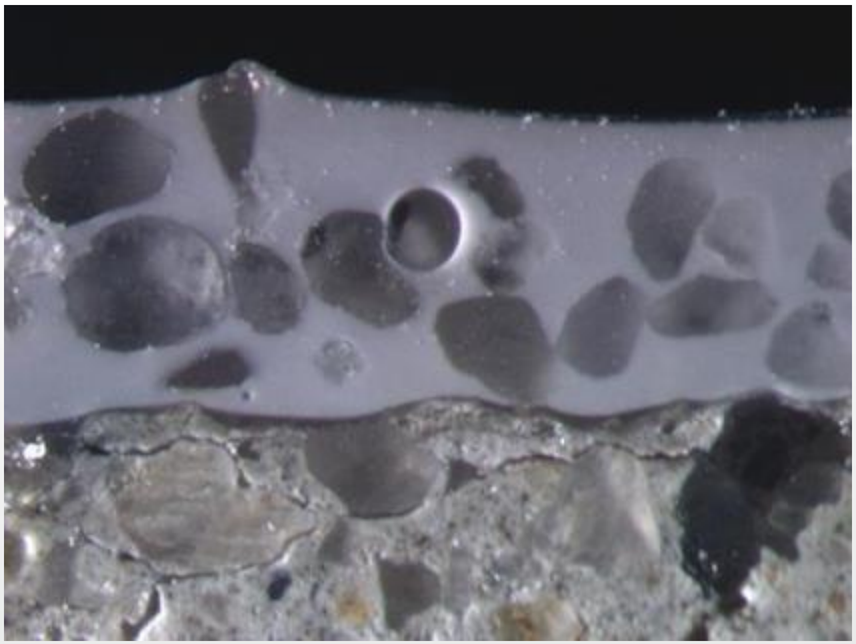
65% of delaminated coating underside is covered with a thin layer of concrete

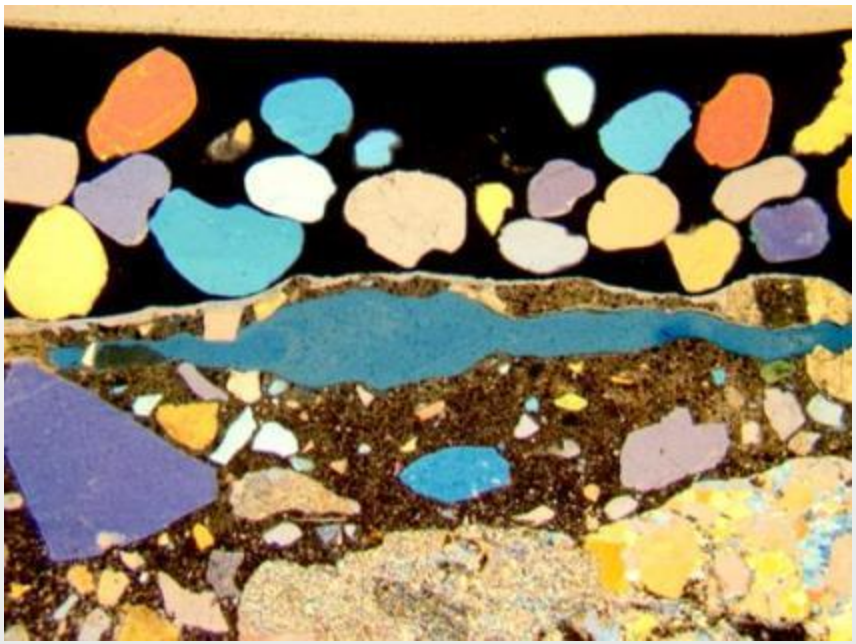
Pull-Off Adhesion Tests

Test No.	Tensile Force at Failure (psi)	Plane of Failure
P-1	200	Between disc and adhesive
P-2	200	Cohesive within top layer of concrete
P-3	380	Between disc and adhesive
P-5	300	Cohesive within top layer of concrete
P-7	250	Cohesive within top layer of concrete
P-9	200	Cohesive within top layer of concrete
P-10	220	Cohesive within top layer of concrete
P-11	300	Cohesive within top layer of concrete
P-12	275	Cohesive within top layer of concrete
P-13	500	Between adhesive and concrete
P-15	300	Between disc and adhesive
P-16	50	Between adhesive and concrete

Majority of tests reveal cohesive failure within top layer of concrete

Concrete Petrography





Concrete petrography confirmed cohesive failure within the concrete

Initial Recommendations

- Remove the coating system and a minimum of 5/16 in. of the surface of the slab.
  - Least aggressive form of surface preparation that will remove the existing coating and damaged surface layer of concrete
  - Surface preparation techniques should be evaluated through mock-ups
- Coating system used is appropriate - it can be reinstalled on a properly prepared substrate.

Mockups

Test No.	Mock-Up Area	Concrete Condition	Plane of Disc Adhesion	Force at Failure (psi)	Plane of Failure
1A	1- Phase II	Not Shot Blasted	Concrete	100	Cohesive within upper layer of concrete / adhesive to concrete
1B		Two Passes w/ Shot Blast	Concrete	100	Cohesive within upper layer of concrete
1C		Two Passes w/ Shot Blast	Concrete	< 100	Cohesive within upper layer of concrete
1D		Two Passes w/ Shot Blast	Concrete	50	Cohesive within upper layer of concrete
1E		Two Passes w/ Shot Blast	Concrete	100	Cohesive within upper layer of concrete
1AA		Two Passes w/ Shot Blast	Tile	72	Cohesive within Tile Adhesive
1BB		Two Passes w/ Shot Blast	Tile	89	Cohesive within Tile Adhesive
2A	2 - Phase II	Not Shot Blasted	Concrete	200	Cohesive within upper layer of concrete
2B		One Pass w/ Shot Blast	Concrete	100	Cohesive within upper layer of concrete
2C		One Pass w/ Shot Blast	Concrete	50	Cohesive within upper layer of concrete / adhesive to concrete
2D		One Pass w/ Shot Blast	Concrete	50	Cohesive within upper layer of concrete / adhesive to concrete
2E		One Pass w/ Shot Blast	Concrete	< 100	Cohesive within upper layer of concrete / adhesive to concrete
2AA		One Pass w/ Shot Blast	Tile	54	Cohesive within Tile Adhesive
2BB		Not Shot Blasted	Tile	54	Cohesive within Tile Adhesive
3A	3 - Phase I	Not Shot Blasted	Concrete	50	Cohesive within upper layer of concrete / adhesive to concrete
3B		One Pass w/ Shot Blast	Concrete	25	Cohesive within upper layer of concrete
3C		Two Passes w/ Shot Blast	Concrete	50	Cohesive within upper layer of concrete
3D		Two Passes w/ Shot Blast	Concrete	< 25	Cohesive within upper layer of concrete
3E		One Pass w/ Shot Blast	Concrete	50	Cohesive within upper layer of concrete / adhesive to concrete
3AA		One Pass w/ Shot Blast	Tile	54	Cohesive within Tile Adhesive
3BB		Two Passes w/ Shot Blast	Tile	125	Cohesive within Tile Adhesive
4A	4 - Phase I	Not Shot Blasted	Concrete	175	Cohesive within upper layer of concrete / adhesive to concrete
4B		One Pass w/ Shot Blast	Concrete	50	Cohesive within upper layer of concrete / adhesive to concrete
4C		One Pass w/ Shot Blast	Concrete	50	Cohesive within upper layer of concrete / adhesive to concrete
4D		One Pass w/ Shot Blast	Concrete	50	Cohesive within upper layer of concrete / adhesive to concrete
4E		One Pass w/ Shot Blast	Concrete	50	Cohesive within upper layer of concrete / adhesive to concrete
4AA		One Pass w/ Shot Blast	Tile	89	Cohesive within Tile Adhesive

A good plan !

Remedial Options – Concrete Surface Prep

- Shot Blasting ✔
  - + Removes coating and prepares concrete
  - – Causes damage to surface of concrete
- Scraping and Sand Blasting
  - + Will prepare concrete without causing significant damage
  - – Two-step process to remove coating and prepare concrete

Remedial Options – Repair Concrete Surface

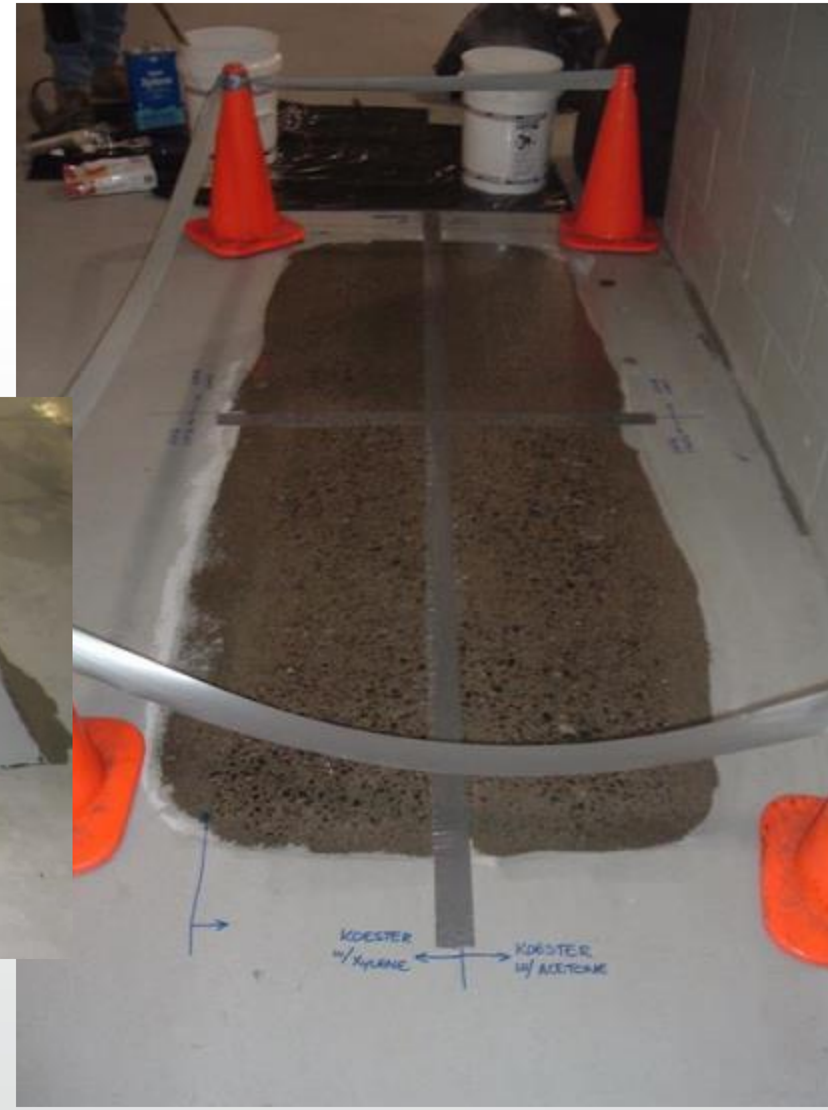
- Gravity Fed Epoxy ✔
  - + Easy to install
  - – May not fill all cracks
- Injected Epoxy
  - + Easier to install in smaller phased areas
  - – Labor intensive, time consuming, and ineffective on small cracks
- Concrete grinding
  - + Can reliably remove all damaged concrete
  - – Time consuming due to required surface repairs

Remedial Options – Floor Finishes

- Tile (with uncoupling membrane)
  - + Easily phased, minimal moisture problems
  - – Aesthetic change, prone to impact damage
- Polished and Stained Concrete
  - + No curing time, high durability, no moisture problems
  - – Poor resistance to staining, aesthetic change
- Epoxy Coating
  - + No aesthetic change, easily cleaned ✔
  - – Must overcome concrete damage and moisture levels

Mockups Confirmed

- Level of shot blasting
- Use of gravity fed epoxy material



Mockups

IAB Mock-ups (12/22)

Location	Pull-Off Tension (kN)	Pull-Off Stress (psi)	Failure Plane	Degree of Surface Preparation	Primer
PC-1	7.5	537	Cohesive within Coating System	Light (2 passes)	Koester/Acetone
PC-2	7.5	537	Cohesive within Coating System	Light (2 passes)	Koester/Acetone
PC-3	9.75	698	Cohesive within Coating System	Light (2 passes)	Koester/Acetone
PC-4	9	644	Cohesive within Coating System	Light (2 passes)	Koester/Acetone
PC-5	9	644	Cohesive within Coating System	Light (2 passes)	Koester/Acetone
PC-6	3.25	233	Adhesive between Coating and Koester	Light (2 passes)	Koester/Xylene
PC-7	3.25	233	Adhesive between Coating and Koester	Light (2 passes)	Koester/Xylene
PC-8	1	72	Adhesive between Coating and Koester	Light (2 passes)	Koester/Xylene
PC-9	2	143	Adhesive between Coating and Koester	Light (2 passes)	Koester/Xylene
PC-10	2.75	197	Adhesive between Coating and Koester	Light (2 passes)	Koester/Xylene
PC-11	7	501	95% Cohesive within Coating System; 5% Cohesive within Concrete	Heavy (6-7 Passes)	Koester/Acetone
PC-12	6.25	447	Cohesive within Coating System	Heavy (6-7 Passes)	Koester/Acetone
PC-13	7.75	555	Cohesive within Coating System	Heavy (6-7 Passes)	Koester/Acetone
PC-14	7	501	50% Cohesive within Coating System; 50% Cohesive within Concrete	Heavy (6-7 Passes)	Koester/Acetone
PC-15	7.5	537	Cohesive within Coating System	Heavy (6-7 Passes)	Koester/Acetone
PC-16	2.75	197	Adhesive between Coating and Koester	Heavy (6-7 Passes)	Koester/Xylene
PC-17	1.25	89	Adhesive between Coating and Koester	Heavy (6-7 Passes)	Koester/Xylene
PC-18	2.75	197	Adhesive between Coating and Koester	Heavy (6-7 Passes)	Koester/Xylene
PC-19	4.5	322	Adhesive between Coating and Koester	Heavy (6-7 Passes)	Koester/Xylene

Average Readings

Surface Prep	Primer	Average Pull-off Stress (psi)	Typical Failure Plane
Light (2 passes)	Koester/Acetone	612	Cohesive within Coating System
Light (2 passes)	Koester/Xylene	175	Adhesive between Coating and Koester
Heavy (6-7 passes)	Koester/Acetone	508	Cohesive within Coating System
Heavy (6-7 passes)	Koester/Xylene	201	Adhesive between Coating and Koester

Final Specification

- Shot blasting to ICRI CSP 3-5.
- Application of mitigation/consolidation system diluted 50% with acetone.
- Wait 48 hrs.
- Application of 100% mitigation/consolidation system.
- Wait 12 hrs.
- Application of epoxy coating system.

Repairs

Surface preparation

Repairs

Epoxy application

Repairs

Completed coating

Take Aways

- Surface preparation is critical to achieving good bond.
- Concrete composition will affect performance of finish.
- Physical quality of concrete must be addressed.

Presentation Outline

- Causes of Flooring Failures
- Reasons for Increase in Flooring Failures
- Ideas to Minimize the Chance of Failures
- Options for Mitigating High Moisture Levels
- **Considerations for Repairing Failed Flooring**
  - Concrete Surface Preparation
  - Concrete Composition and Quality
  - **Sources of Moisture**
  - Code Requirements
  - Safety Considerations

Sources of Moisture

- Underlying Soil
- Concrete
- Cleaning and Maintenance
- Ambient Conditions

Case Study: Museum Warehouse

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

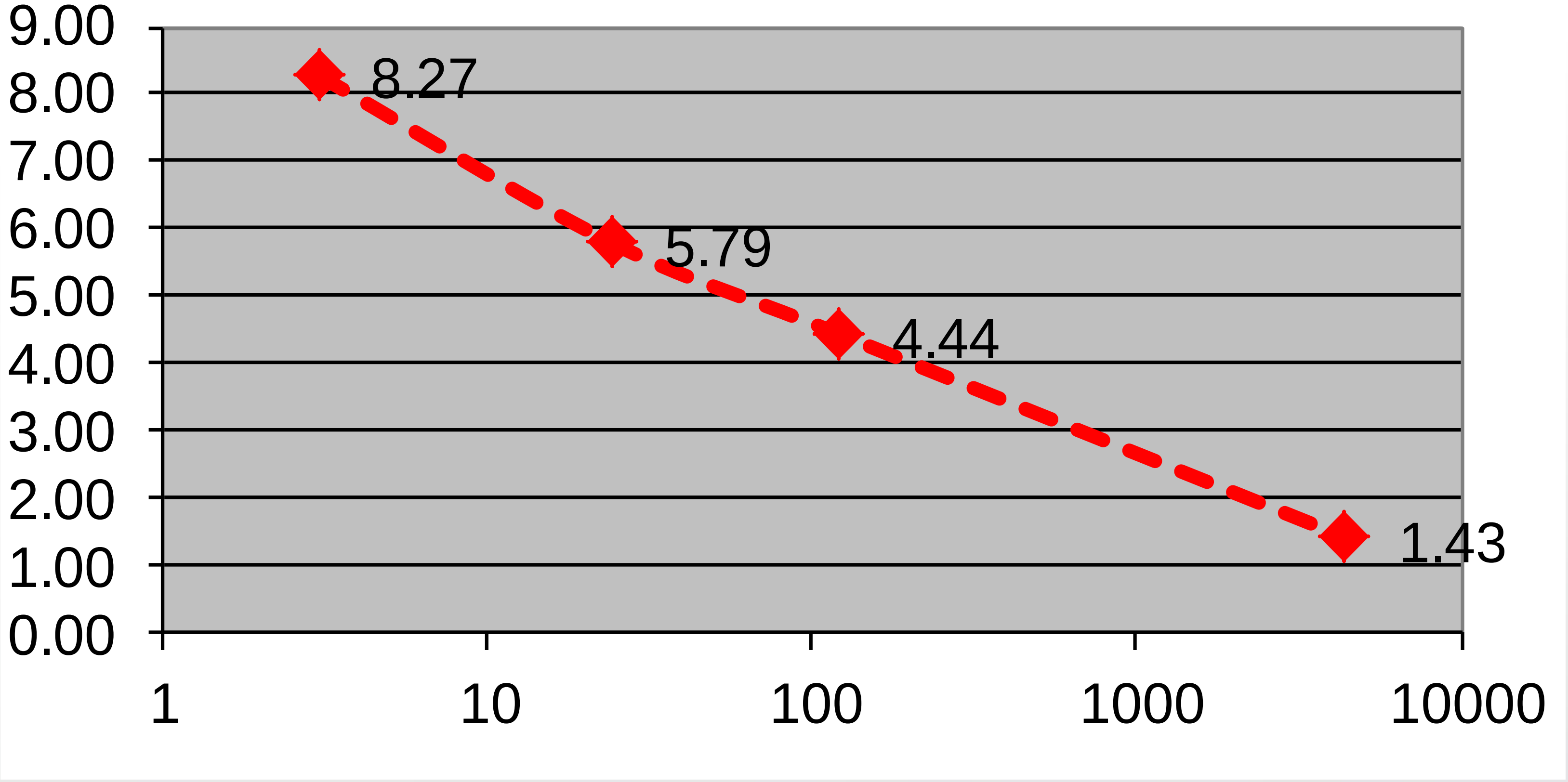
Filled with Artifacts

Fluid on Flooring from…..

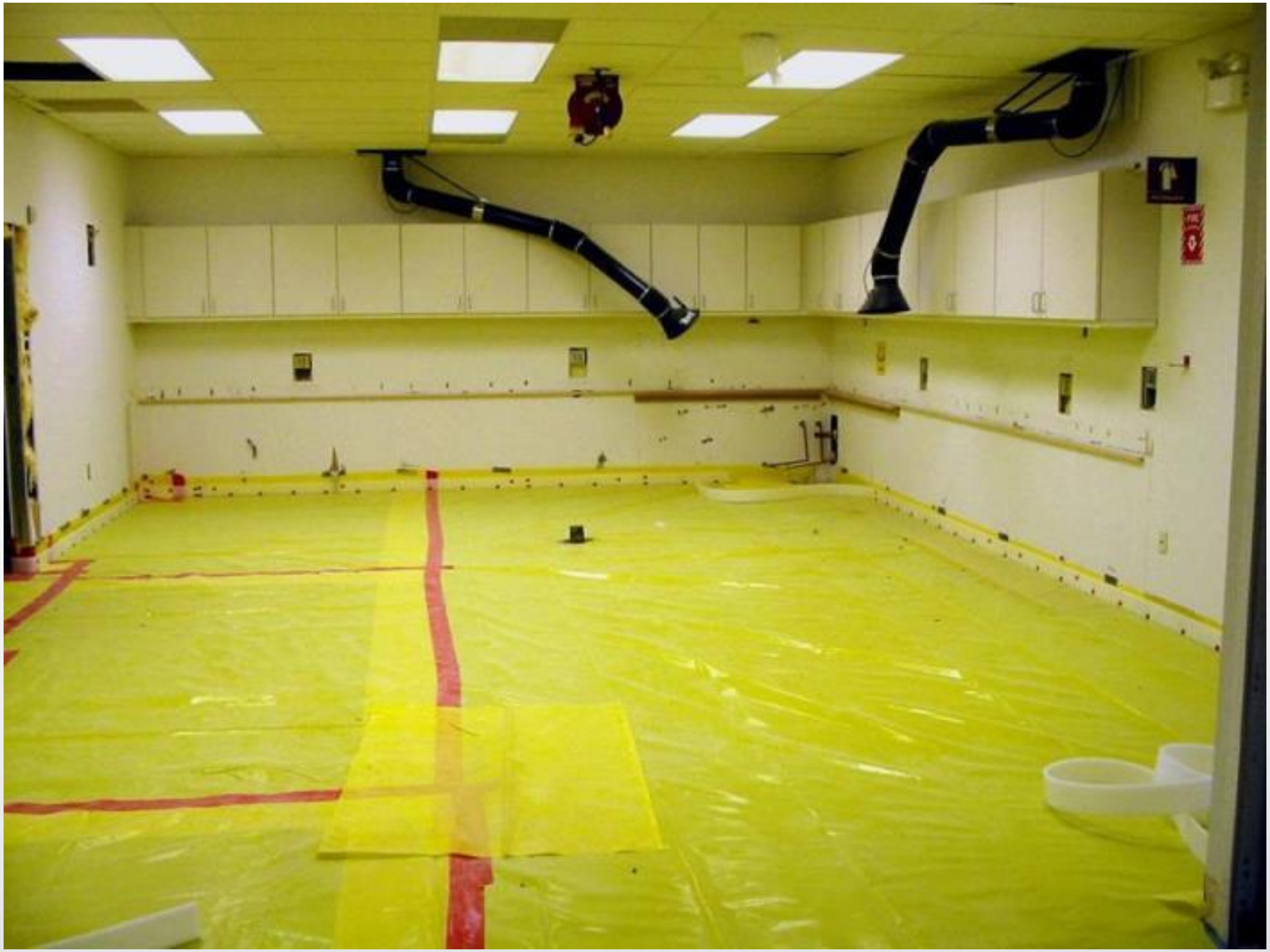
Osmotic Blisters

MVER Testing

MVER vs. Hours after Coating Removal



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

Surface Contaminant

Required new coating in loading dock area to be removed and reinstalled.

New Coating had to be Removed

Shot Blasting….
Again

Clean and Re-Prepared Concrete Substrate

Facility More than 10 Years after Work Performed

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

Take Aways

- Surface preparation is critical to achieving good bond.
- Concrete composition will affect performance of finish.
- Physical quality of concrete must be addressed.
- Consider and mitigate ALL possible moisture sources.
  – Underlying Soils

Case Study: Bamboo Flooring

Case Study: Bamboo Flooring

Case Study: Bamboo Flooring

Case Study: Bamboo Flooring

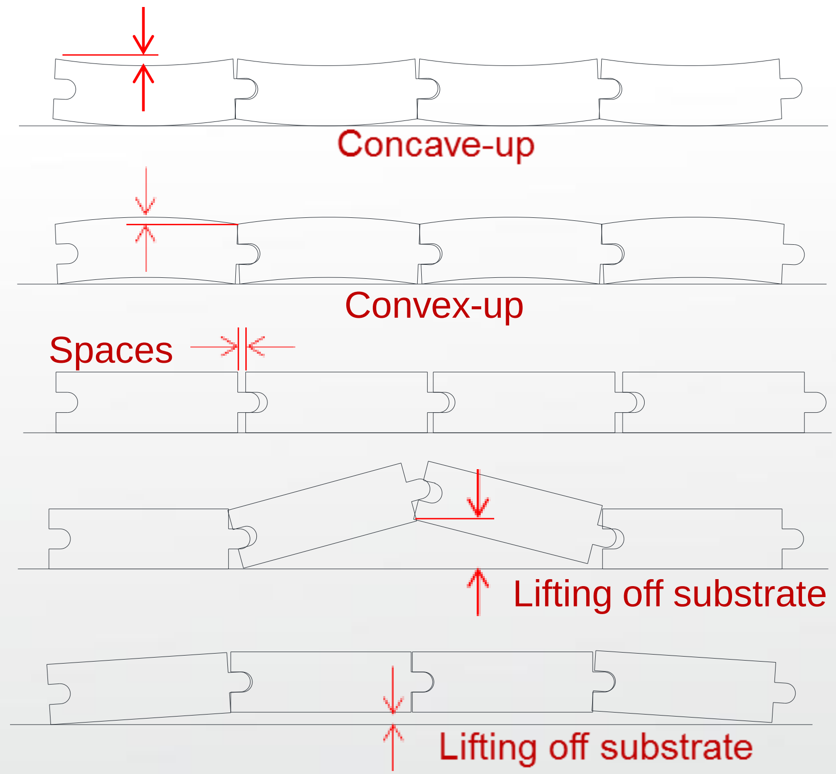
Delamination of bamboo flooring from substrate.

Case Study: Bamboo Flooring

Preparation of Relative Humidity testing.

Dimensional-Change of Wood Flooring

- Cupping
- Crowning (reverse cupping)
- Gaps
- Buckling/Tenting
- Debonding



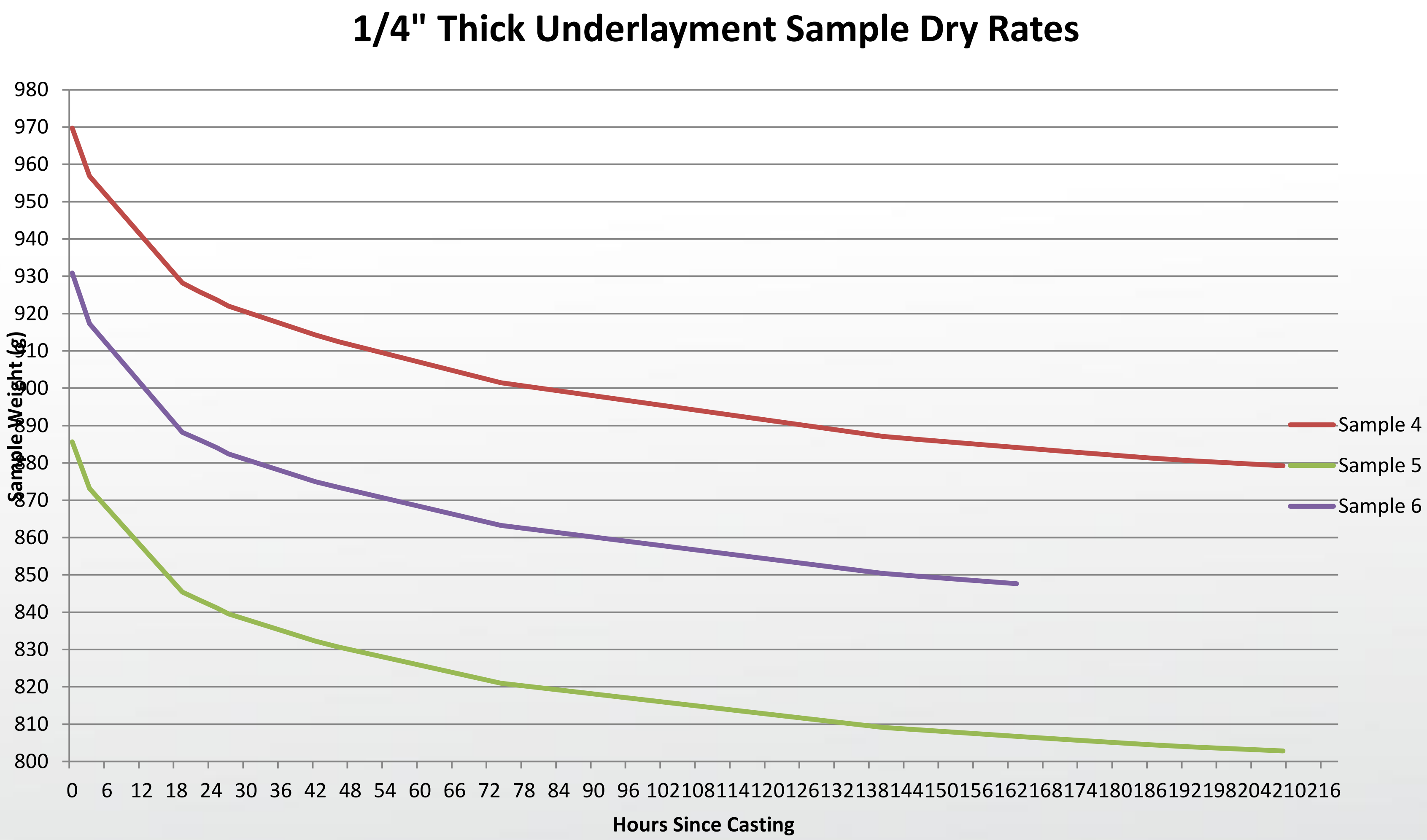
Cupping of flooring: Bottom portion of flooring is expanding ie, moisture coming from below. Amount of moisture in substrate under-estimated. Contractor didn't wait long enough after self-leveling underlayment placement to install moisture-sensitive bamboo flooring.

Underlayment Material

Self-Leveling Underlayment

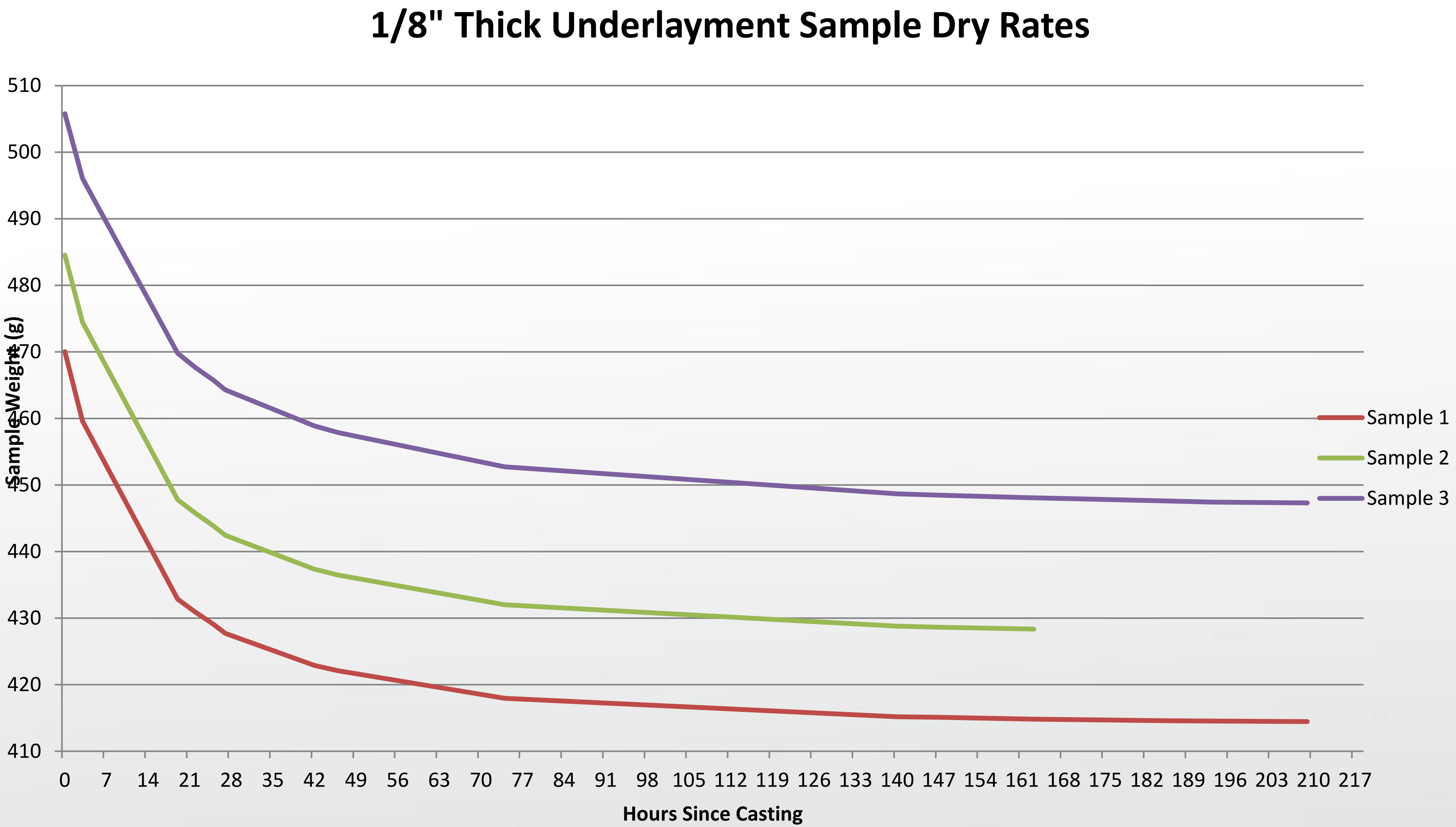
- Portland cement-based, microfiber reinforced
- Use to level and smooth interior concrete, terrazzo, ceramic and quarry tile, epoxy coating systems and non-water soluble adhesive residue on concrete
- Formulated with High Flow Technology for ultra thin applications
- Can smooth floors at 1/8" or less
- Installs from 1/16" to 1" thick, can be featheredged to meet existing elevations
- Walkable in 2 to 3 hours
- Install floor coverings after 16 hours

Mockups: Underlayment Drying



Drying curve doesn't begin to flatten out for first 24 hours after self-leveling underlayment placement. Manufacturer's application recommendations were correct, but not followed.

Mockups: Underlayment Drying



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Take Aways

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  - Underlayments

Presentation Outline

- Introduction
  - What are flooring failures?
  - What types of flooring are typically involved?
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  - Sources of Moisture
  - **Code Requirements**
  - Safety Considerations

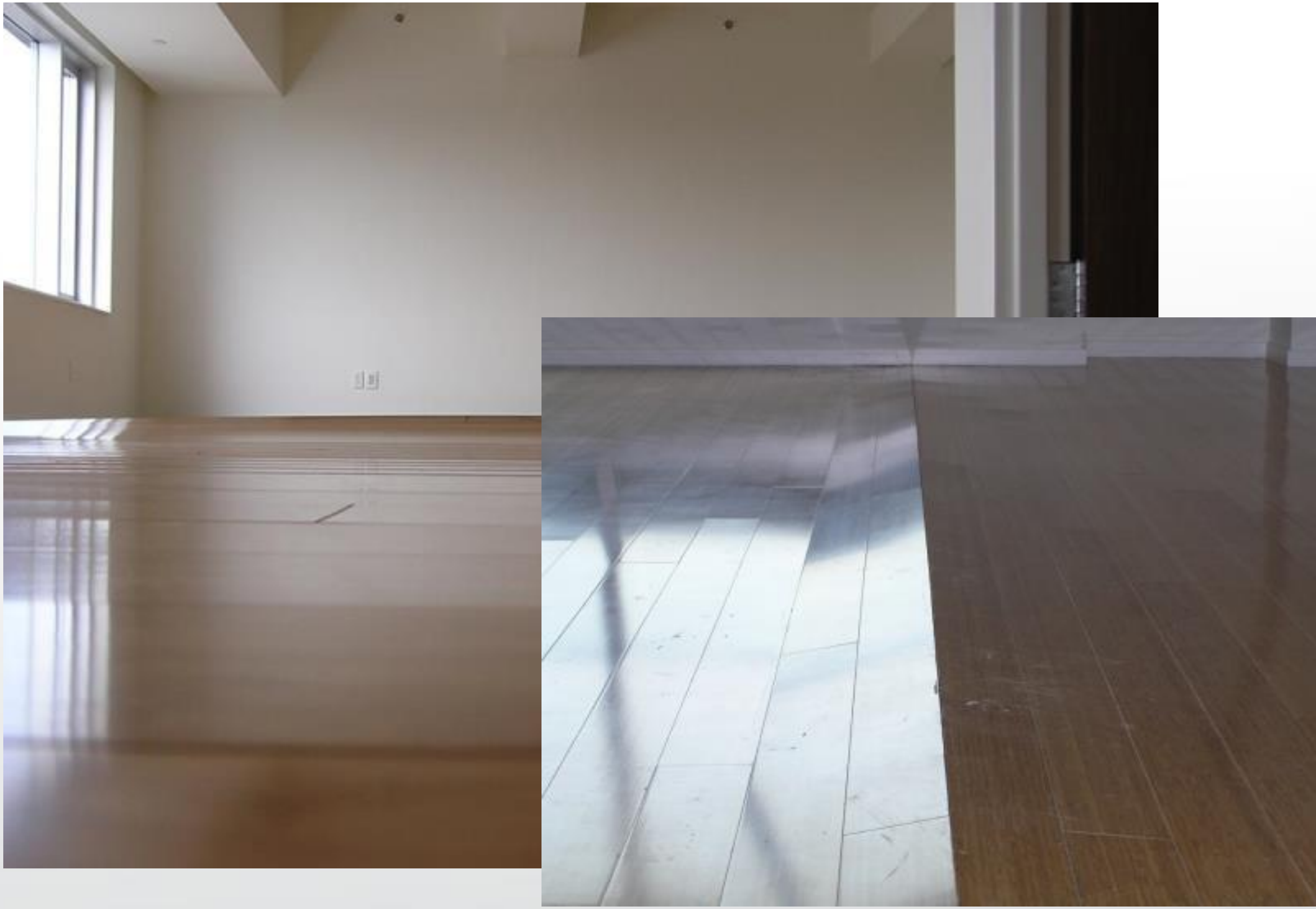
International Building Code 2009

- **804.1 General.** *Interior floor finish* and floor covering materials shall comply with Sections 804.2 through 804.4.1.
  - **Exception:** Floor finishes and coverings of a traditional type, such as wood, vinyl, linoleum or terrazzo, and resilient floor covering materials that are not comprised of fibers.
- **804.3 Testing and identification.** *Interior floor finish* and floor covering materials shall be tested by an agency in accordance with NFPA 253 and identified by a hang tag or other suitable method so as to identify the manufacturer or supplier and style, and shall indicate the *interior floor finish* or floor covering classification according to Section 804.2. Carpet-type floor coverings shall be tested as proposed for use, including underlayment. Test reports confirming the information provided in the manufacturer's product identification shall be furnished to the building official upon request.
- **804.4 Interior floor finish requirements.** In all occupancies, *interior floor finish* and floor covering materials in *exit* enclosures, *exit* passageways, corridors and rooms or spaces not separated from corridors by full-height partitions extending from the floor to the underside of the ceiling shall withstand a minimum critical radiant flux as specified in Section 804.4.1.

International Building Code 2009

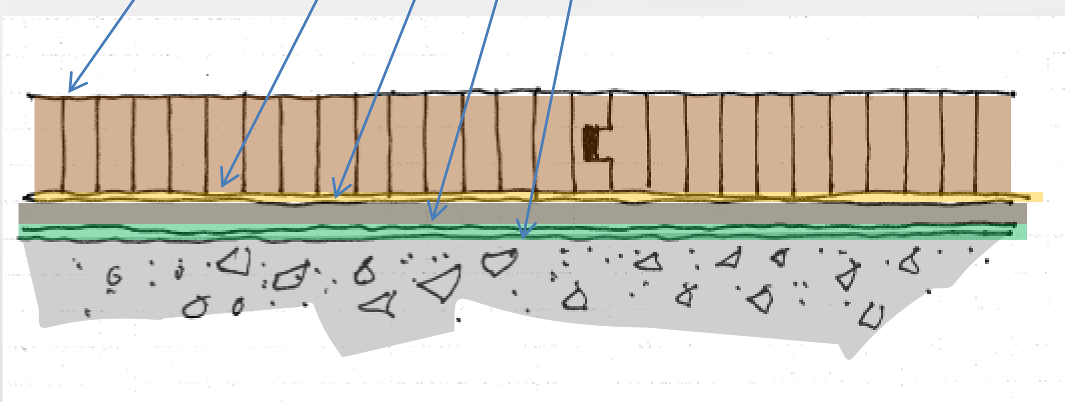
- **1207.3 Structure-borne sound.** Floor/ceiling assemblies between *dwelling units* or between a *dwelling unit* and a public or service area within the structure shall have an **impact insulation class (IIC) rating of not less than 50 (45 if field tested)** when tested in accordance with ASTM E 492.

Case Study: Wood Flooring in Condos



Floor System

1. Bamboo Strip Flooring
2. Strip Flooring to Underlayment Adhesive
3. Sound Attenuation Underlayment
4. Underlayment to Substrate Adhesive
5. Substrate

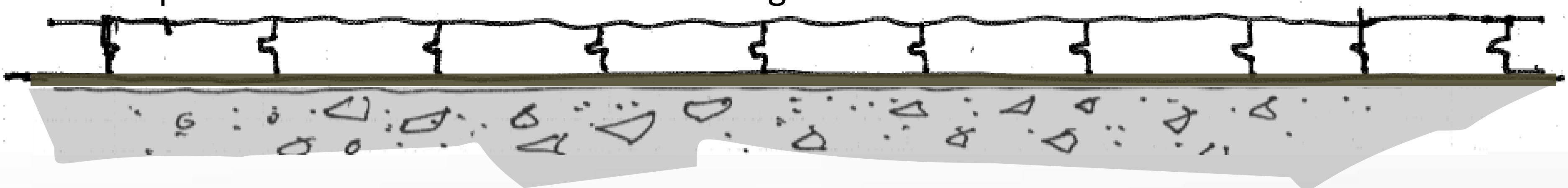


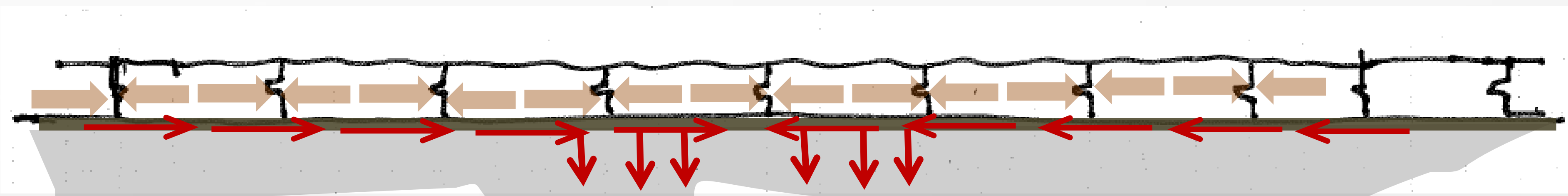
Failure Mechanism

- Bamboo swells (mostly perpendicular to “grain”) due to change in moisture content after installation.
- System of sound attenuation underlayment and adhesives cannot restrain expansion.
- Underlayment/adhesive system fail at slab interface.
- Bamboo floor buckles (“tents”) since bond to floor had failed.

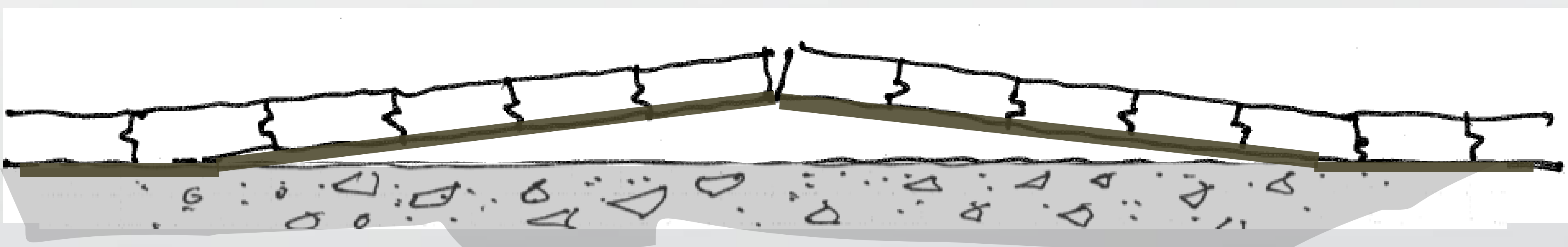
Stresses from Moisture Change

Conceptual cross section of installed flooring.





Increased moisture content causes flooring to swell. Swelling restrained by bond to substrate. Stresses in wood, underlayment and adhesive increase with increased swelling.



Bond fails. Flooring allowed to swell and change length. Stresses in flooring are relieved.

Causes of Failure

- Bamboo is composite of bamboo fiber and adhesive which can expand and contract with changes in moisture.
  - Acclimatization
  - Ambient conditions
  - Relatively low concrete slab moisture
- Sound isolation mat is not adequate to support bamboo.
  - Improper adhesive and adhesive application
  - Use of water-based adhesives
  - Allows expansion and contraction
  - Low tensile strength of mat

Field Impact Insulation Class

Impact Insulation Measurement Report

MacAllen Building - Residence 119 to Live-Work 202

Date of measurement: 5/15/2008
Consultant: JLF
Acentech Project: 619918

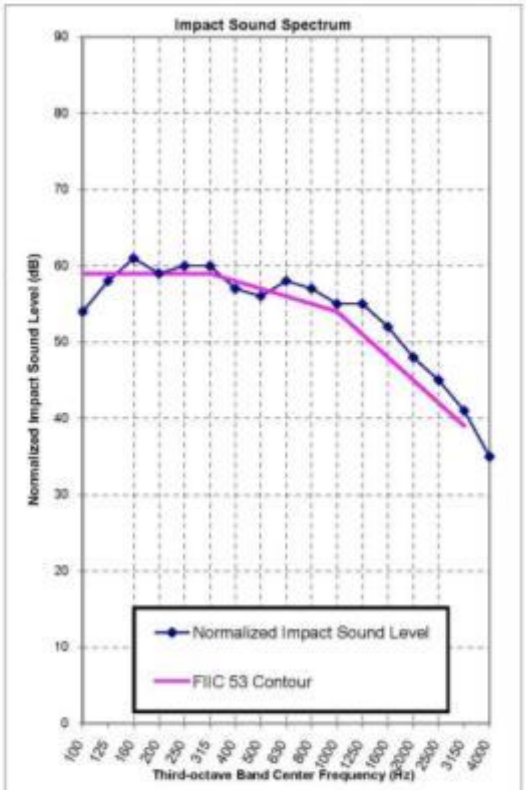
Description of construction:
Bamboo flooring, low VOC adhesive, Bostik MVP4 (about 1/8-inch thick), concrete slab (5-1/4-inch concrete filled metal deck), wire suspended GWB ceiling.

Third-Octave Band Center Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
Average Impact Sound Levels	49.3	52.5	55.2	52.9	53.7	53.3	51.9	51.0	52.3	51.2	49.4	50.0	45.4	41.8	39.0	33.8	27.6
Ambient Sound Levels	43.6	43.5	44.3	44.3	42.0	40.5	37.7	34.4	32.6	33.7	30.0	27.9	26.3	25.1	22.5	16.2	12.1
Absorption Effects	6.1	6.1	6.1	6.3	6.3	6.3	5.5	5.5	5.5	5.5	5.5	5.5	6.3	6.3	6.3	7.4	7.4
Normalized Impact Sound Levels	**54**	**58**	**61**	**59**	**60**	**60**	**57**	**56**	**58**	**57**	**55**	**55**	**52**	**48**	**45**	**41**	**35**

Field Impact Insulation Class (FIIC):	53

Description of Source Room:
Residential room 119 - unfurnished, humidity tent covering bamboo flooring sample

Description of Receiver Room:
LW202 - unfurnished with concrete floor, bare walls and bare ceiling



This test procedure was based on ASTM Standard E1007-04. This page alone is not a complete test report; please refer to the accompanying report for other details associated with these test results.

- Sound attenuation product under flooring required to meet Code requirements.
- A combination sound attenuation/moisture mitigation product was identified.
- Had to be tested to prove that it could comply with Code requirements.

Mockup

- Three-ply, cross-grain, horizontal-laminated bamboo flooring (6 in. wide strip flooring planks).
- Urethane wood flooring.
- Moisture vapor protection and sound isolation barrier coating.

Mockup

Mockup test chamber produced humid conditions within chamber to extent that water condensed on bamboo flooring.

Mockup

Bamboo flooring did not delaminate from new combination sound attenuation/moisture mitigation product.

Take Aways

- Surface preparation is critical to achieving good bond.
- Concrete composition will affect performance of finish.
- Physical quality of concrete must be addressed.
- Consider and mitigate ALL possible moisture sources.
  - Underlying soils
  - Ambient conditions and mechanical systems
  - Underlayments
- Know code requirements and industry practices.

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- Consider and mitigate ALL possible moisture sources.
  - Underlying soils
  - Ambient conditions and mechanical systems
  - Underlayments
- Know code requirements and industry practices.
- Understand floor use and safety concerns.

Summary of Repair Considerations

- History of the Slab
  - Has it been exposed to weather or construction water?
  - Has there been surface treatments, curing compounds, or contamination?
  - What type of concrete is it? Lightweight or normal weight?
  - How long has slab been enclosed, with HVAC running?
- Concrete Composition and Quality
  - Is the concrete contaminated in some way?
  - Has the concrete been damaged?
  - Is the quality of the concrete sufficient for selected finish?
- Moisture Content of the Concrete
  - How much moisture is in the slab (MVER and RH tests)?
  - Is there enough time to allow the floor to dry?
  - Are there sources of moisture other than concrete? Soil? Ambient?

Summary of Repair Considerations

- Product Selection and Installation
  - Is flooring compatible with concrete at existing ambient conditions – temperature, surface contaminations, and humidity?
  - Is the floor properly cleaned, shot blasted and prepped for the new systems?
  - Install a mock up and test it for adhesion and coating thicknesses.
  - Did the product arrive at the job-site in good condition?
  - Is the selected product right for the intended use? Safety concerns?
  - Does the designed system meet code?
  - Can the repair be properly maintained? Are maintenance procedures considered in the design?

Learning Assessment Questions

1. Moisture is a main cause of floor covering and floor coating problems for flooring systems installed on a concrete substrate.

- True False

2. A vapor barrier can be placed under a slab-on-grade during construction to limit moisture problems with floor coverings and floor coatings installed on the concrete substrate.

- True False

3. Moisture testing has proven to be ineffective when attempting to understand if there is moisture in a concrete floor that could affect an installed floor covering or floor coating.

- True False

Learning Assessment Questions

4. Moisture mitigation is an effective preventative measure that is available to limit floor covering or floor coating damage from high moisture levels in existing concrete floors.

- True False

5. Project cost and schedule is never impacted when moisture mitigation is ignored, and moisture related flooring failures occur.

- True False

Strategies for Repairing Failed Floor Finishes

Presented by

David S. Slick, PE
Philip K. Frederick, PE
Simpson Gumpertz & Heger Inc.

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