Concrete Roof Decks – Risks Posed to Roofing and Waterproofing Systems

Chicago Roofing Contractors Association

January 23, 2015

Presented by

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SRI Engineering

Topics to Cover

- Basics of Concrete
- Curing of Concrete
- Factors that Effect Drying
- Moisture in Concrete
- Bad and Worse
- What can be done to prevent problems
- Summary
- Field examples

Basics of Concrete

- Portland Cement is not concrete
  - Portland Cement is the binding agent
  - Concrete is the composite material
    - Aggregates
      - Coarse (40%-50%)
      - Fine (20% - 30%)
    - Portland Cement (10% - 15%)
    - Water (20% - 30%)
    - Additional “add mixtures”

Basics of Concrete

- Production of Concrete
  - Each batch plant will have hundreds or even thousands of recipes
    - Based on local aggregates and conditions
    - Requirements of Contractor’s order dictate which one they use
    - Developed over time
    - Science combined with some trial & error
- Forms for roof decks
  - Strippable forms
  - Steel form deck

Curing of Concrete

- **Note** we are discussing curing not drying
- Chemical process of hydration
- All about compressive strength gain
- Loss of moisture during this process can have adverse effects
  - Moist cure
  - Protect from freezing

Curing of Concrete

- Engineer specified strength
  - Typically specified at 28-day compressive strength
  - i.e. 5000psi at 28 days
- **28-days has nothing to do with moisture content only compressive strength**

Factors That Affect Drying

- Climactic conditions
- Concrete surface condition
- Rewetting of concrete
  - Rain, snow, ice, condensate
- Capillary closure

Factors That Affect Drying

- Capillary Continuity or Discontinuity in Cement Pastes, Powers, 1959

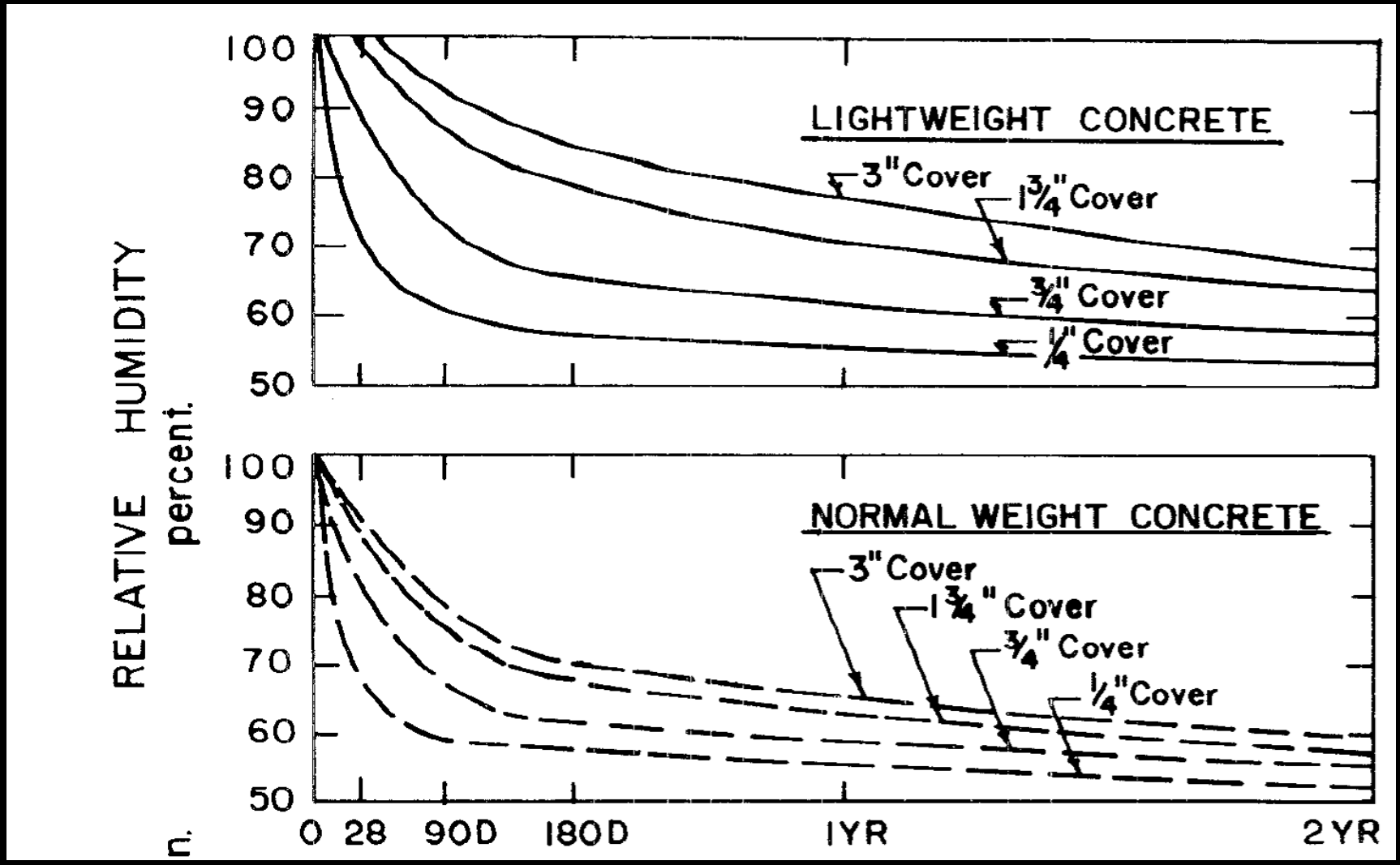
Time for Capillary voids to close versus W/C Ratio

w/c	Time Required
0.40	3 days
0.45	7 days
0.50	14 days
0.60	6 months
0.70	1 year
>0.70	impossible

Moisture in Concrete

- Effects of Curing and Drying Environments on Splitting and Tensile Strength of Concrete
  - J.A Hanson
  - 1968

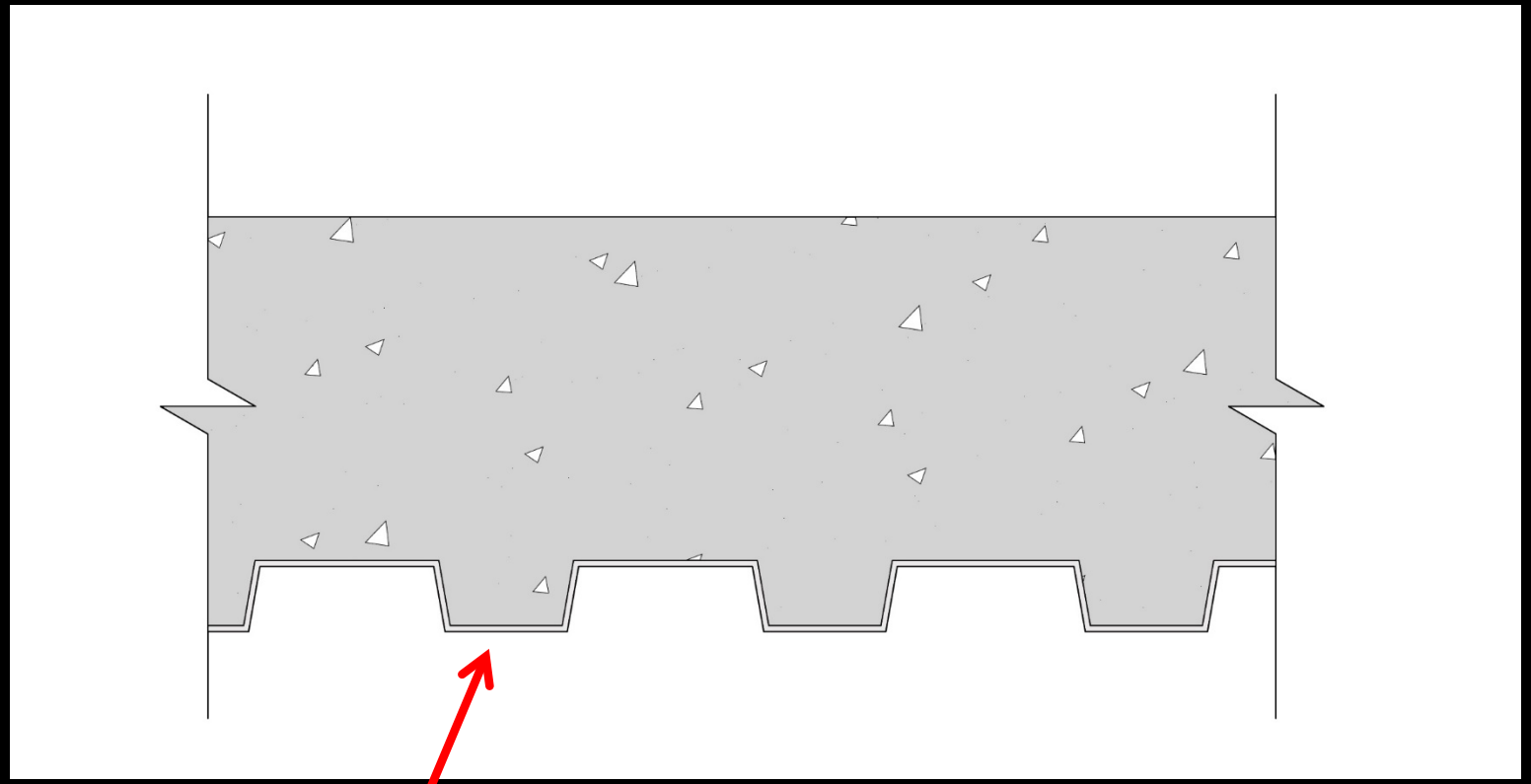
Moisture in Concrete



Effects of Curing and Drying Environments on Splitting and Tensile Strength of Concrete - Hanson

Moisture in Concrete

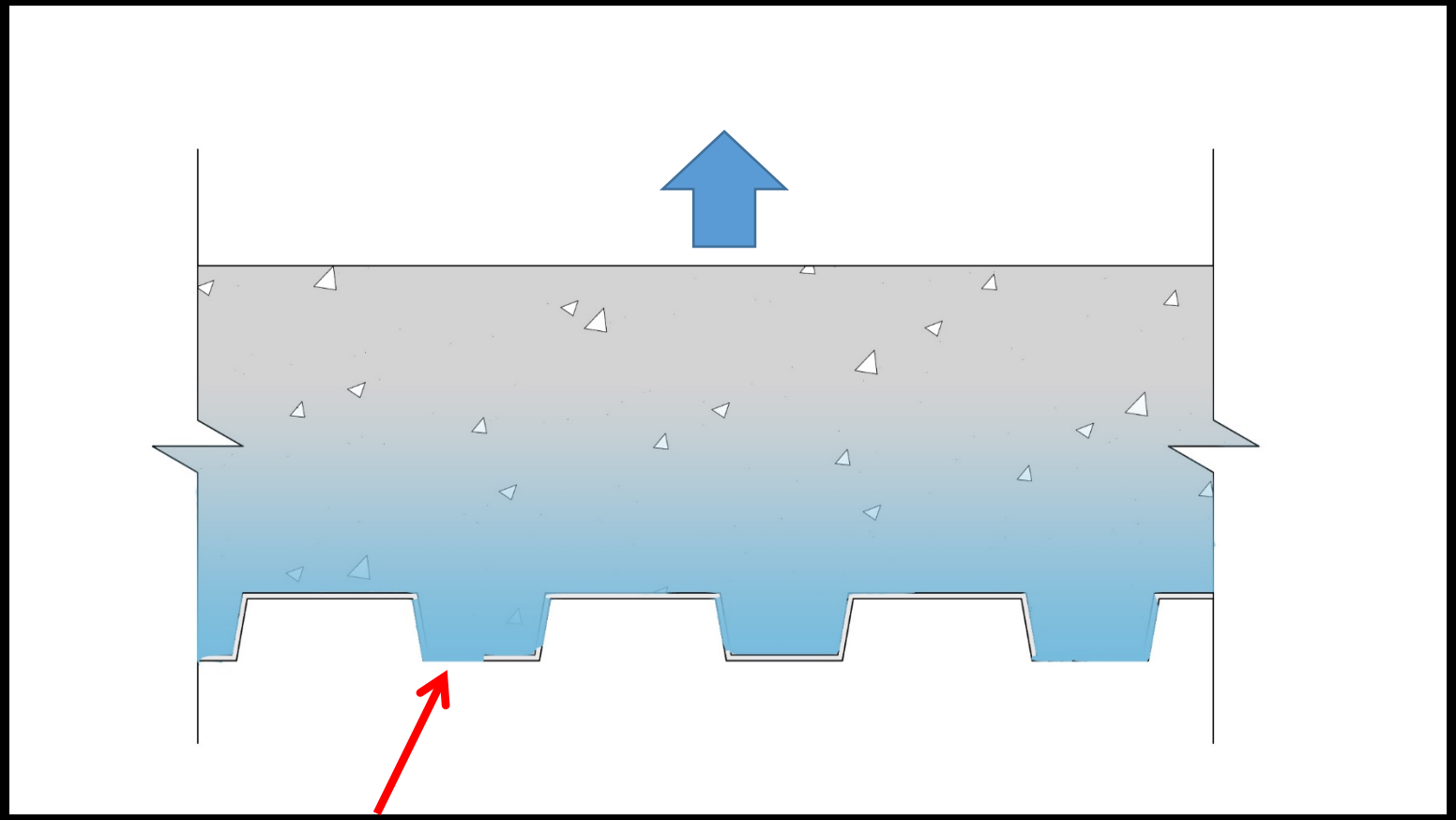
Steel Form Deck



Steel Deck

Moisture in Concrete

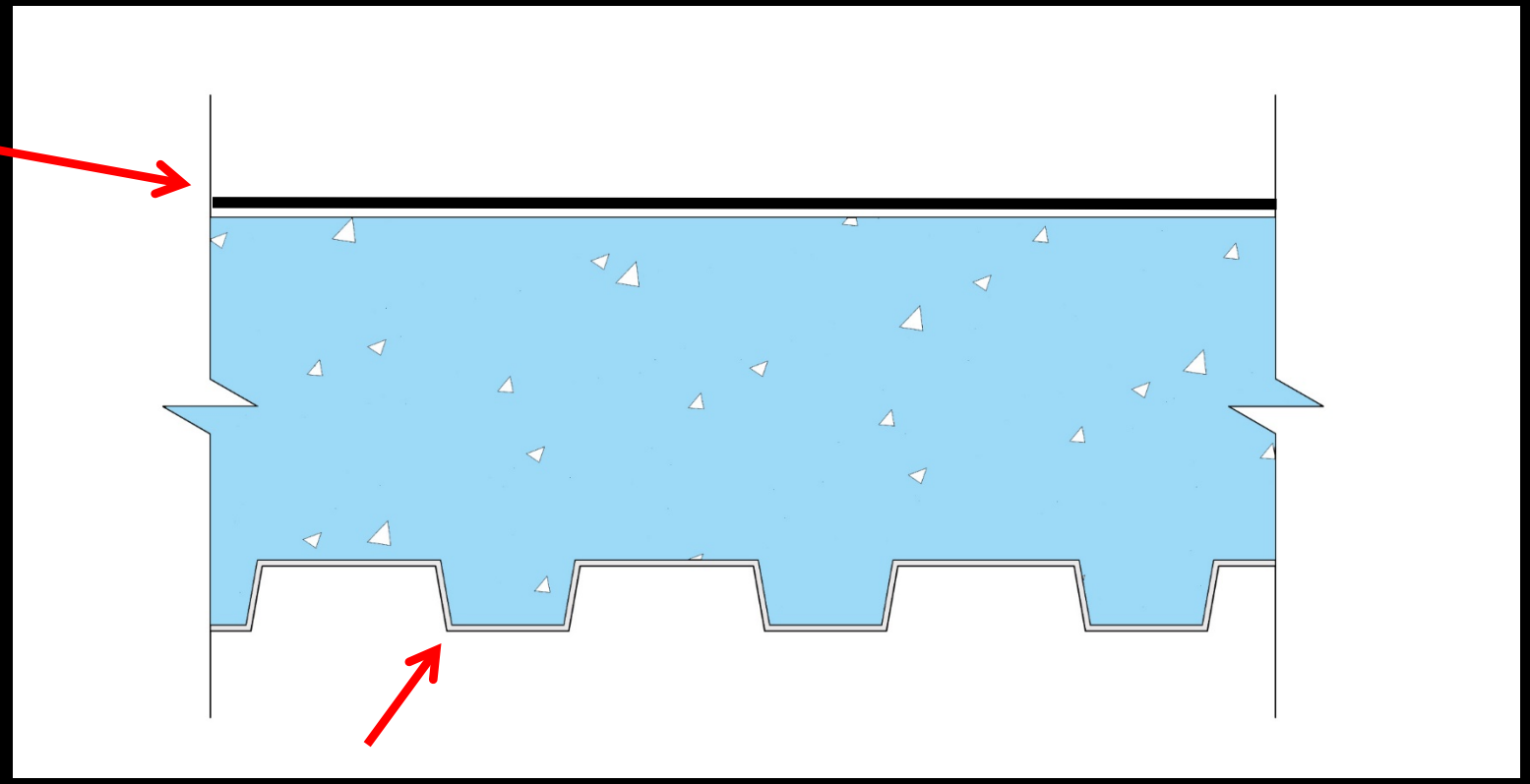
Steel Form Deck = one way drying



Steel Deck

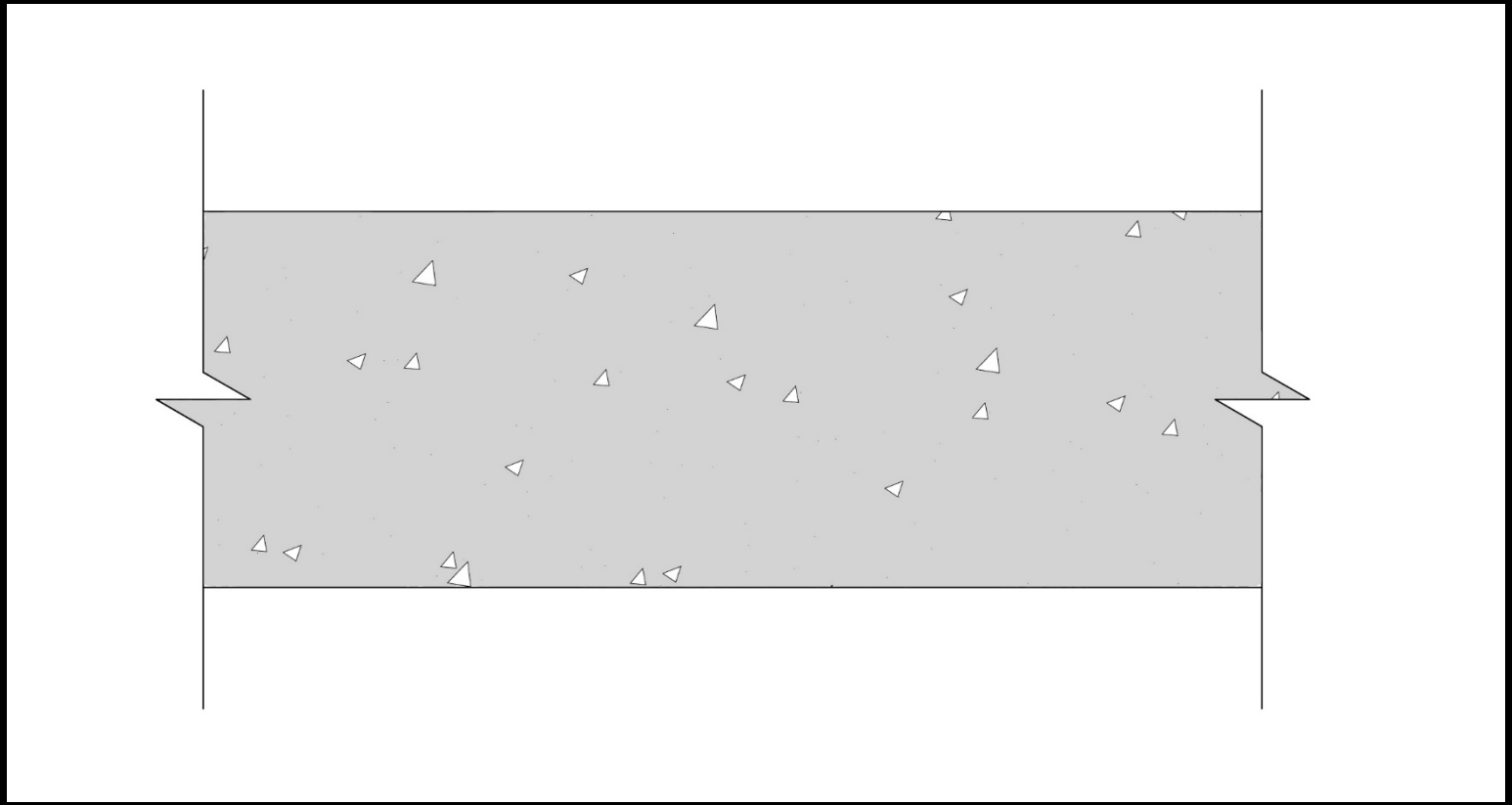
Moisture in Concrete

Steel Form Deck = one way drying
Vapor Retarder = moisture equalization



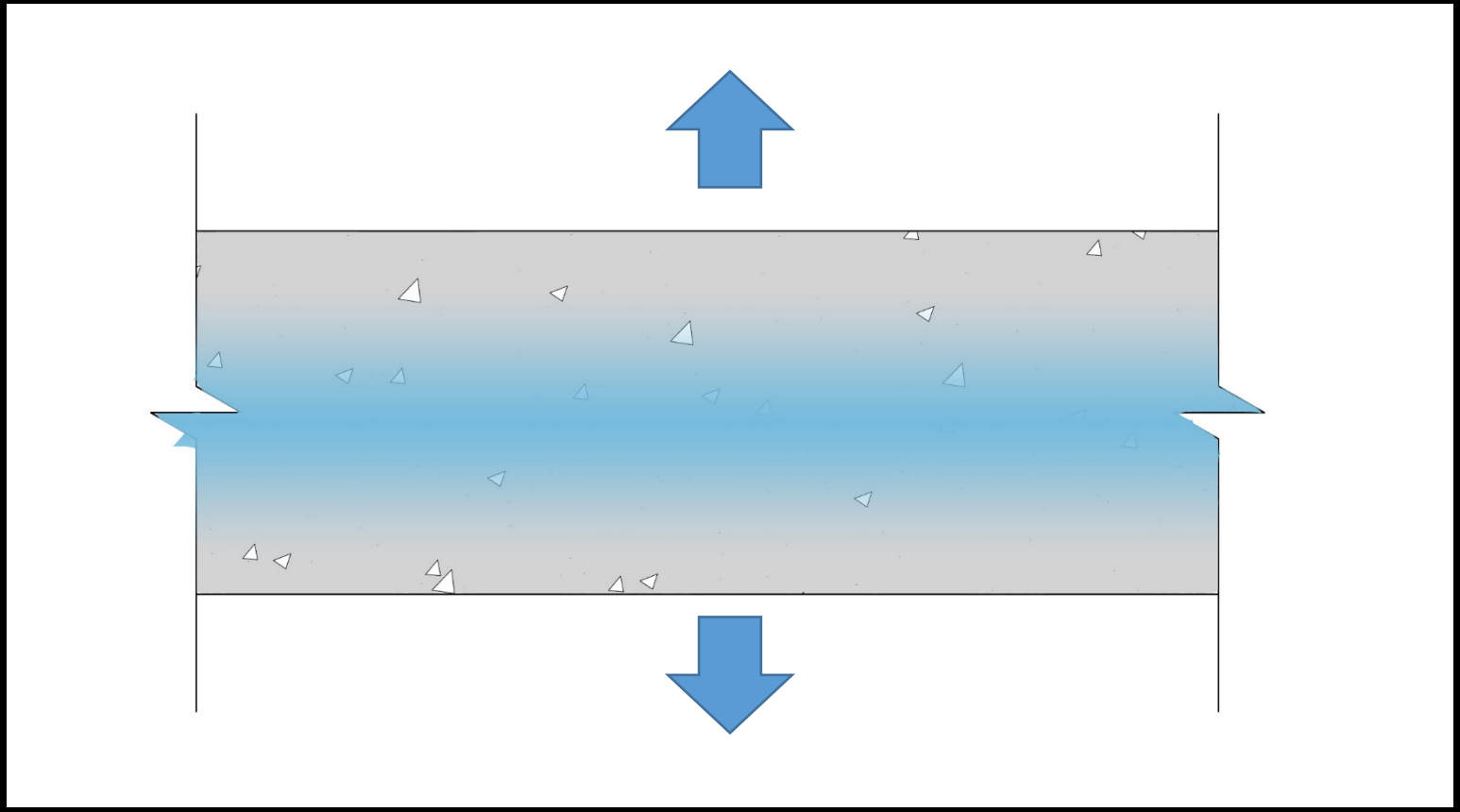
Moisture in Concrete

Stripped forms



Moisture in Concrete

Stripped forms = 2 way drying



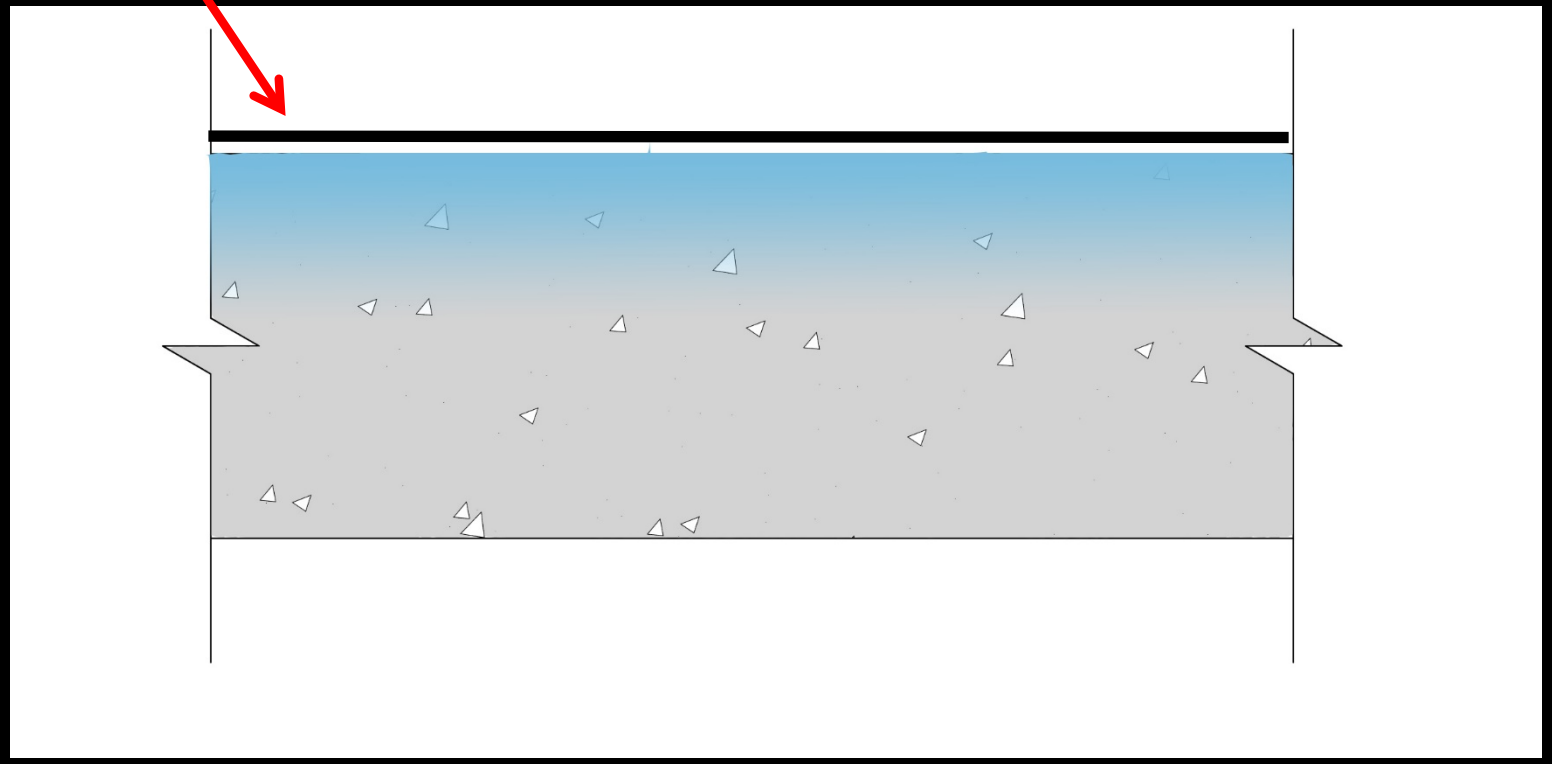
Moisture in Concrete

Stripped Forms = Two way drying

↓

Vapor Retarder = one way drying

Vapor Retarder



Moisture in Concrete

- How do we measure moisture content of placed concrete?
  - Surface emission
  - Electrical resistance
  - Electrical impedance
  - Relative Humidity at depth

Moisture in Concrete

- ASTM D4263 Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method
- Very qualitative
  - Environmental conditions can greatly influence results / signal
- Easy and inexpensive
- Can give false negative

Mo

Moisture in Concrete

- ASTM F-1869 Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride
- Dish of Calcium Chloride is weighed before and after 24hr exposure under a clear lid
- Pounds of water emitted per 1000ft² per 24 hours
- Very old test

Moisture in Concrete

- Calcium Chloride test

http://www.duraamen.com/images/mv_pic_01_test_kit_01.jpg

Moisture in Concrete

- ASTM F-2420 Determining Relative Humidity on the Surface of Concrete Floor Slabs Using Relative Humidity Probe Measurement and Insulated Hood
- Uncommon test
- Uses a relative humidity probe placed on top of slab inside a small insulated box
- Gives indication of moisture emitted at the surface not what is down in the slab

Moisture in Concrete

- Humidity Probe Measurement and Insulated Hood

http://www.esellersolutions.com/eSellerManager/images/upload/item/Southsurvey/itemImage_111_7_12_11_48_35.gif

Moisture in Concrete

- Electrical resistance measurement
- Drill two holes in concrete
- “brush” probes inserted and resistance between probes correlated to moisture content
- Not seen in the US currently

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FOR PROFESSIONAL APPLICATIONS

DE Professionelles Materialfeuchtemessgerät für 118 Holz- und 19 Baustoffsorten mit zusätzlichen Tiefen-Elektroden.

EN Professional material moisture device for 118 types of wood and 19 types of building material, also features depth electrodes.

NL Professioneel materiaalvocht-meettoestel voor 118 houtsoorten en 19 soorten bouwmateriaal, met extra diepte-elektroden.

DK Professionelt fugtighedsmålеapparat til 118 træ- og 19 byggematerialetyper med ekstra dybdeelektroder.

FR Instrument de mesure de l'humidité professionnel pour 118 types de bois et 19 types de matériaux de construction avec des électrodes de profondeur supplémentaires.

ES Medidor de humedad profesional, para 118 tipos de madera y 19 tipos de materiales de construcción, con electrodo de profundidad adicional.

IT Misuratore di umidità professionale per 118 tipi di legno e 19 tipi di materiale da costruzione con elettrodi di profondità addizionali.

PL Profesjonalny miernik wilgotności materiałów do 118 gatunków drewna i 19 rodzajów materiałów budowlanych z dodatkowymi elektrodami wgłębnymi.

FI Ammattilaisen kosteusmittari, 118 puulajille ja 19 muulle rakennusmateriaalille, lisänä syvältä mittaavat elektrodit.

PT Medidor profissional de humidade em materiais para 118 tipos de madeira e 19 tipos de materiais de construção com eléctrodos profundos adicionais.

SV Professionell materialfuktighetsmätare för 118 träslag och 19 byggnadsmaterial, med djupelektroder som tillbehör.

NO Profesjonelt måleapparat for materialfuktighet for 118 tre- og 19 byggestoffsorter med ekstra dybdeelektroder.

TR 118 ahşap ve 19 yapı malzemesi türü için profesyonel materyel nemi ölçme cihazı, derinlik elektrodları ilavelı.

RU Профессиональный прибор для измерения влажности материалов для 118 сортов древесины и 19 строительных материалов с дополнительными электродами для глубинного зондирования.

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Moisture in Concrete

- Impedance measurement of concrete surface
- Electric field is passed through concrete
- Instrument reads out moisture content percentage.
- Only reads top 1 inch or less of slab

Moisture in Concrete

- Tramex CMEX II

http://i.ytimg.com/vi/JJjEJyK4ia8/0.jpg

http://www.i-sells.co.uk/images/Resize%20of%20Electrodes.JPG

Moisture in Concrete

- ASTM F-2170 Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes
- Drill hole in concrete deck
  - 40% of depth for steel deck
  - 20% of depth for stripped forms
- Relative humidity probe inserted into hole
  - Sealed
  - Recovered / read after 72 hours

Moisture in Concrete

- ASTM F-2170 (Continued)
- Flooring manufacturers require minimum RH reading per F-2170 before floor is allowed to be installed
- Wide acceptance
- Good deal of research on the matter

http://www.southsurvey.co.uk/img/gi_20_38_466_700.jpg

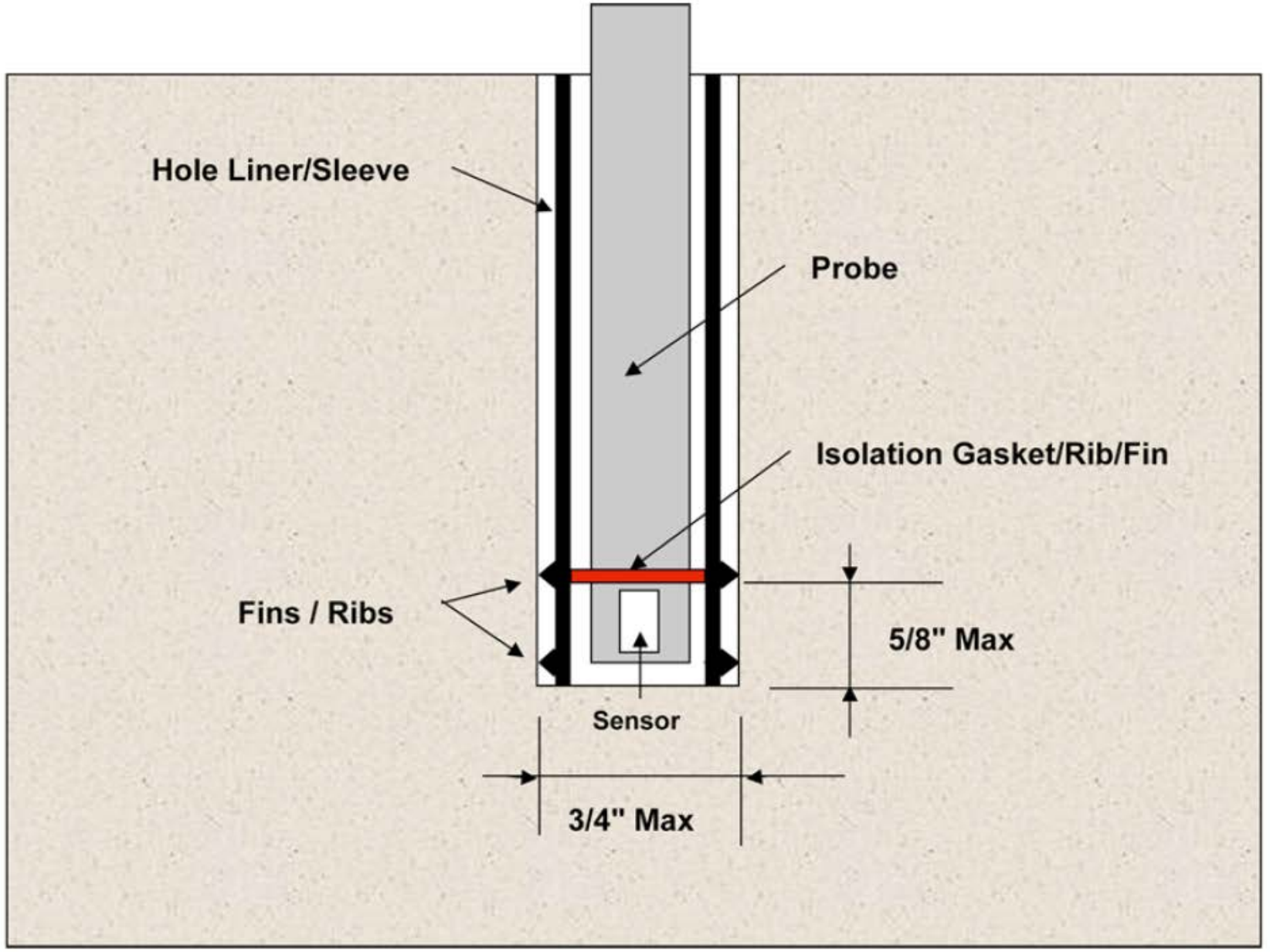


FIG. 2 Example % RH - Probe Element Position

Moisture in Concrete

- Flooring industry struggled with this issue at the turn of the century
- Flooring manufacturers specify at what test values (moisture content) their products can be installed over concrete
  - Typical values range from 75% to 85% RH via F-2170

Moisture in Concrete

- Table in next slide from Swedish Concrete Association 1997
- Time in days for concrete to reach F-2170 Relative Humidity when kept around lab conditions
- This time starts after the rewetting stops
- “w/c” is water to cement ratio

Moisture in Concrete

RH %	w/c = 0.4	w/c = 0.5	w/c = 0.6	w/c = 0.7
85%	50 days	90 days	135 days	180 days
90%	20 days	45 days	65 days	95 days

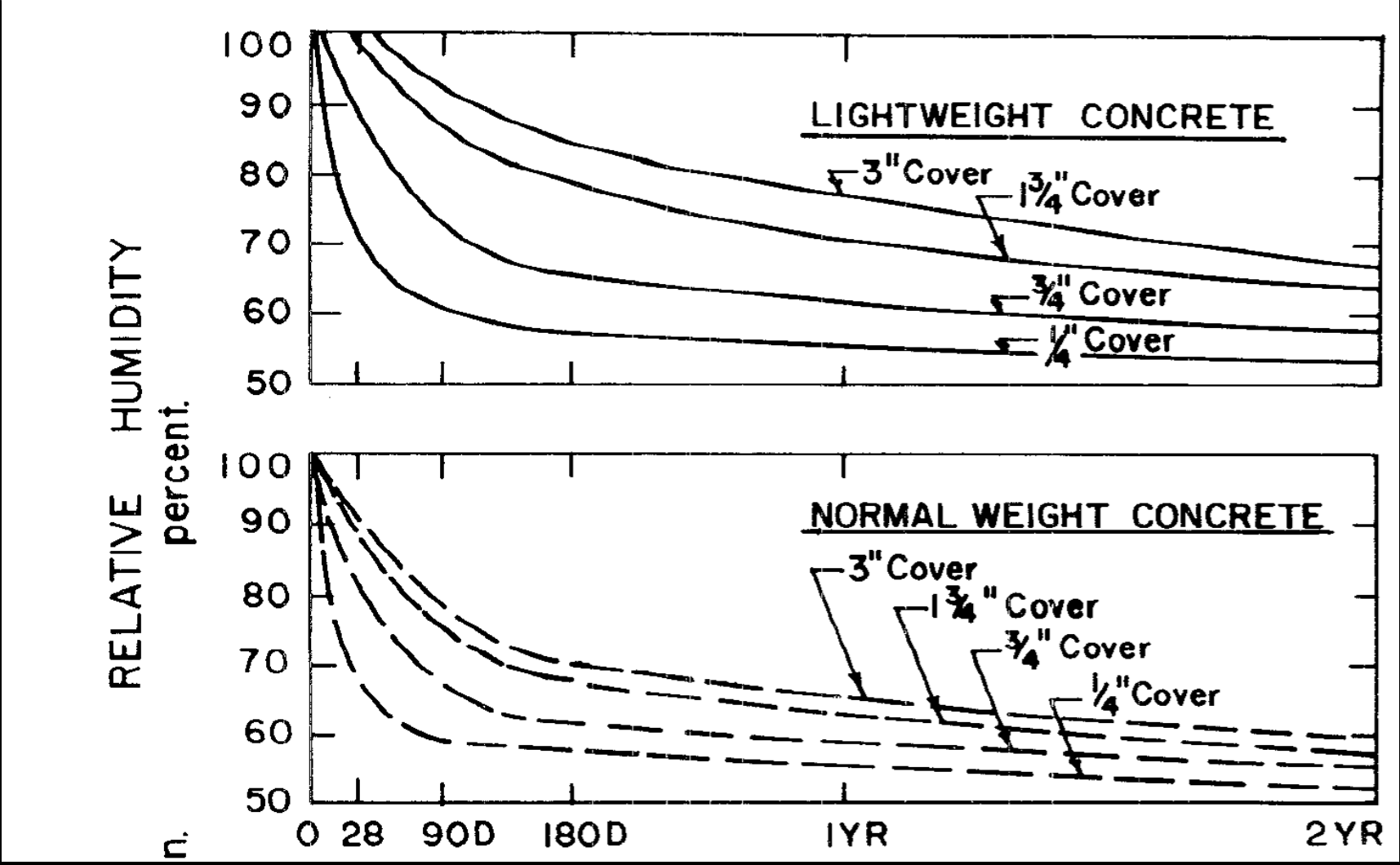
Moisture in Concrete

- Keep in mind this table is for after REWETTING STOPS.
- Rewetting can be rain, snow, ice or technically even night time condensation.
- So how does the roofing industry keep rewetting from occurring on concrete roof decks?
  - Flooring contractors have benefit of our roof above to stop rewetting and they are one of the last trades to perform
  - Roofing contractor is one of the first to perform
    - Leaves the roofing contractor at the mercy of the elements

Moisture in Concrete

- How do we plan construction schedule for roof deck dry time?
- Flooring industry dictated by F-2170 measurements
  - So the flooring contractor has it easy right?
- Remember the Hanson graphs?

Bad and Worse



Effects of Curing and Drying Environments on Splitting and Tensile Strength of Concrete - Hanson

Bad and Worse

- Light weight aggregates
  - Expanded shales and clays
  - Alternately can be referred to as “prewetted aggregates”
  - Need to be ponded or soaked for days to months before being batched into a concrete mix
    - Water fills pores and prevents light weight aggregates from interfering with mix hydration and placement / forming performance

Bad and Worse

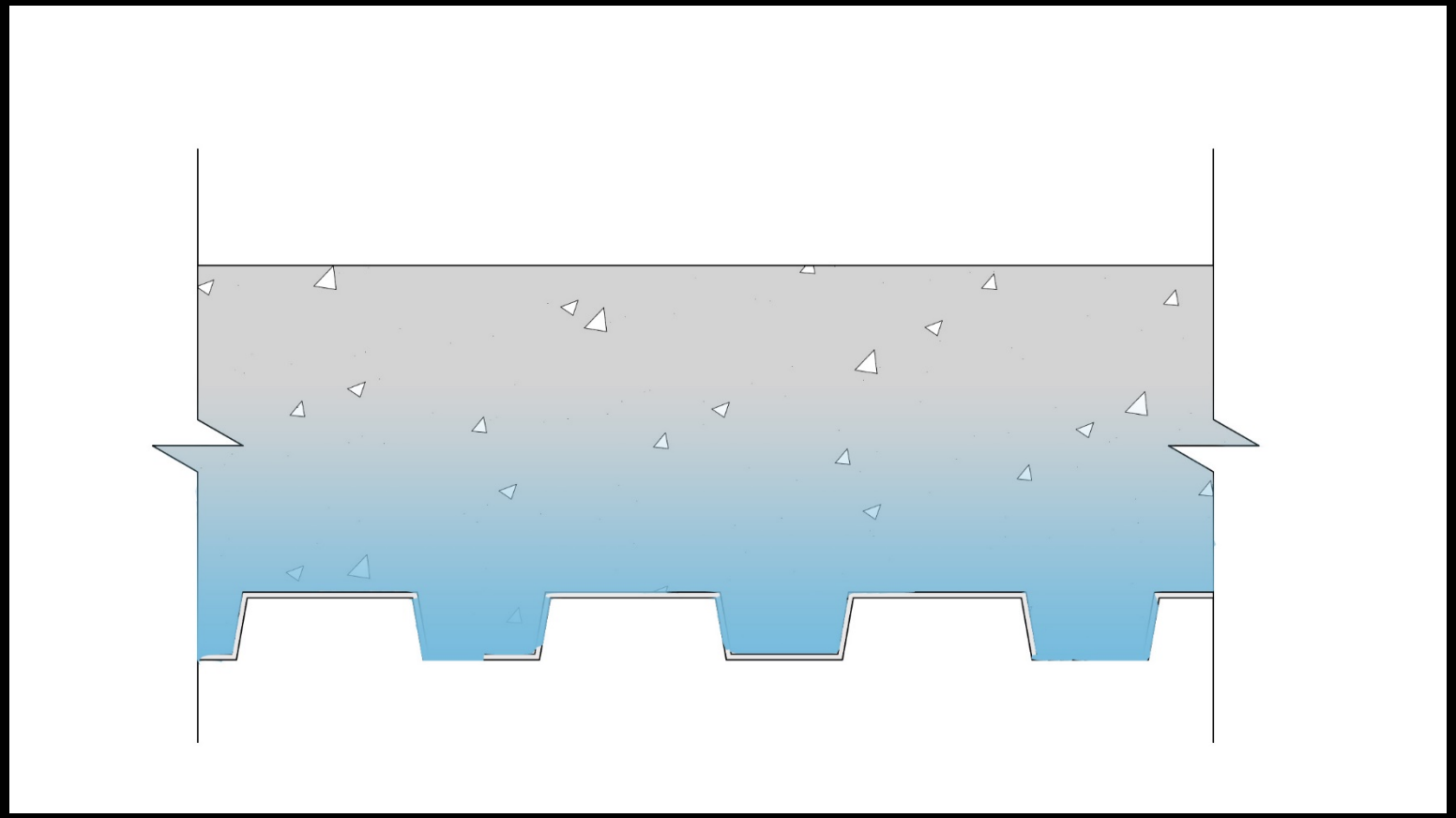
- Differences between Regular Weight Concrete (RWSC) and Light Weight Structural Concrete (LWSC)
- Mass (approximate)
  - RWSC 150 lb/ft^3
  - LWSC 110 lb/ft^3
- Starting water content
  - Regular weight aggregates have 8 - 15 lb/yd^3 of concrete
  - Light weight aggregates have 150 – 200 lb/yd^3 of concrete
- Both can achieve the same compressive strengths
  - LWSC just does it with less weight

Bad and Worse

- Extra water brought to the table by LWSC
  - Consider an 8 inch slab for a roofing square requires about 2.5 cubic yards of concrete…
  - Considering the mix design is similar, but light weight aggregates bring approximately an extra 163.5 pounds of water per cubic yard of concrete
  - This is 408.75 pounds of water per roofing square = approximately ½ gallon of water per square foot!
  - This extra water has to go somewhere!
  - This extra water takes more time to migrate out

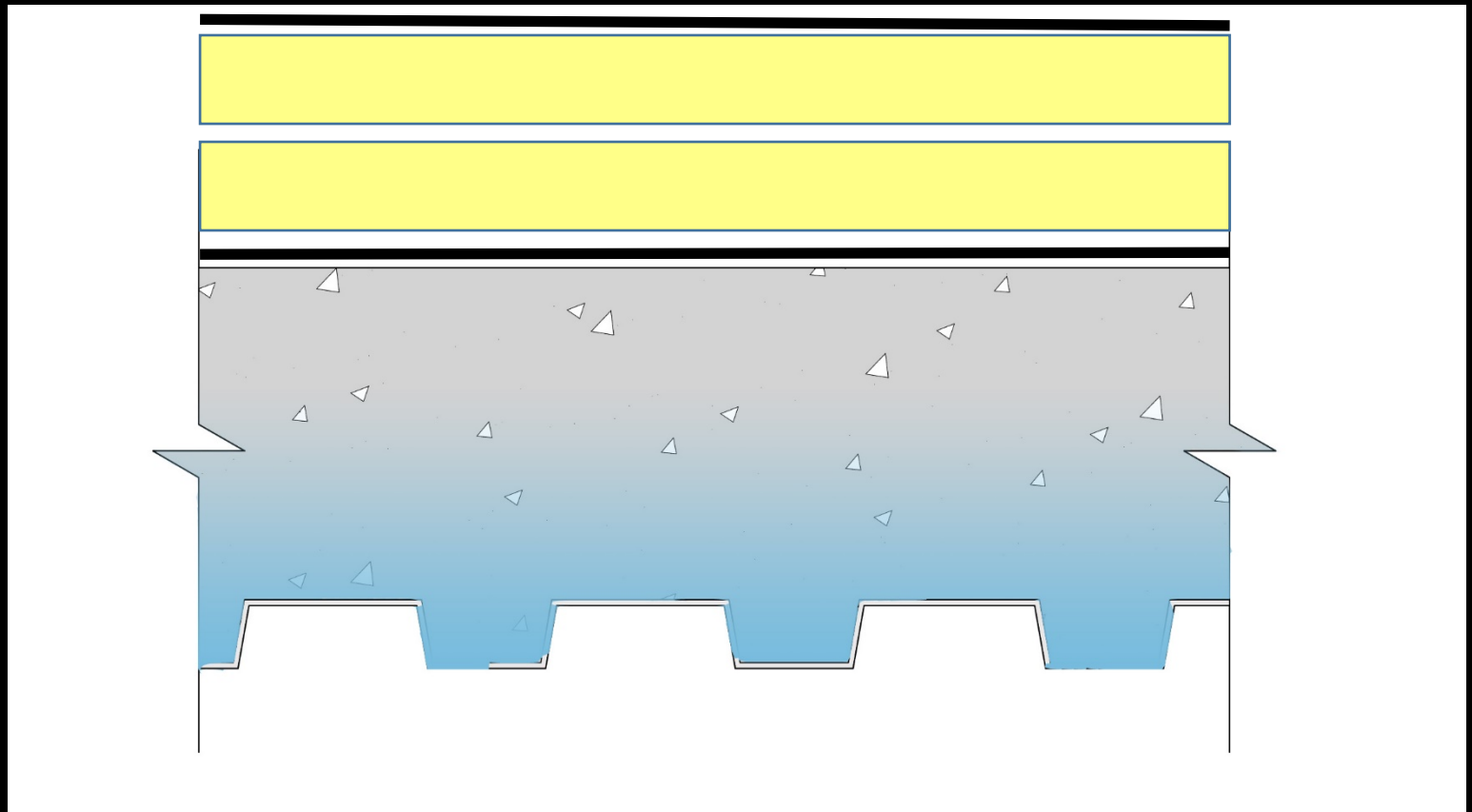
Bad and Worse

Steel Form Deck = one way drying



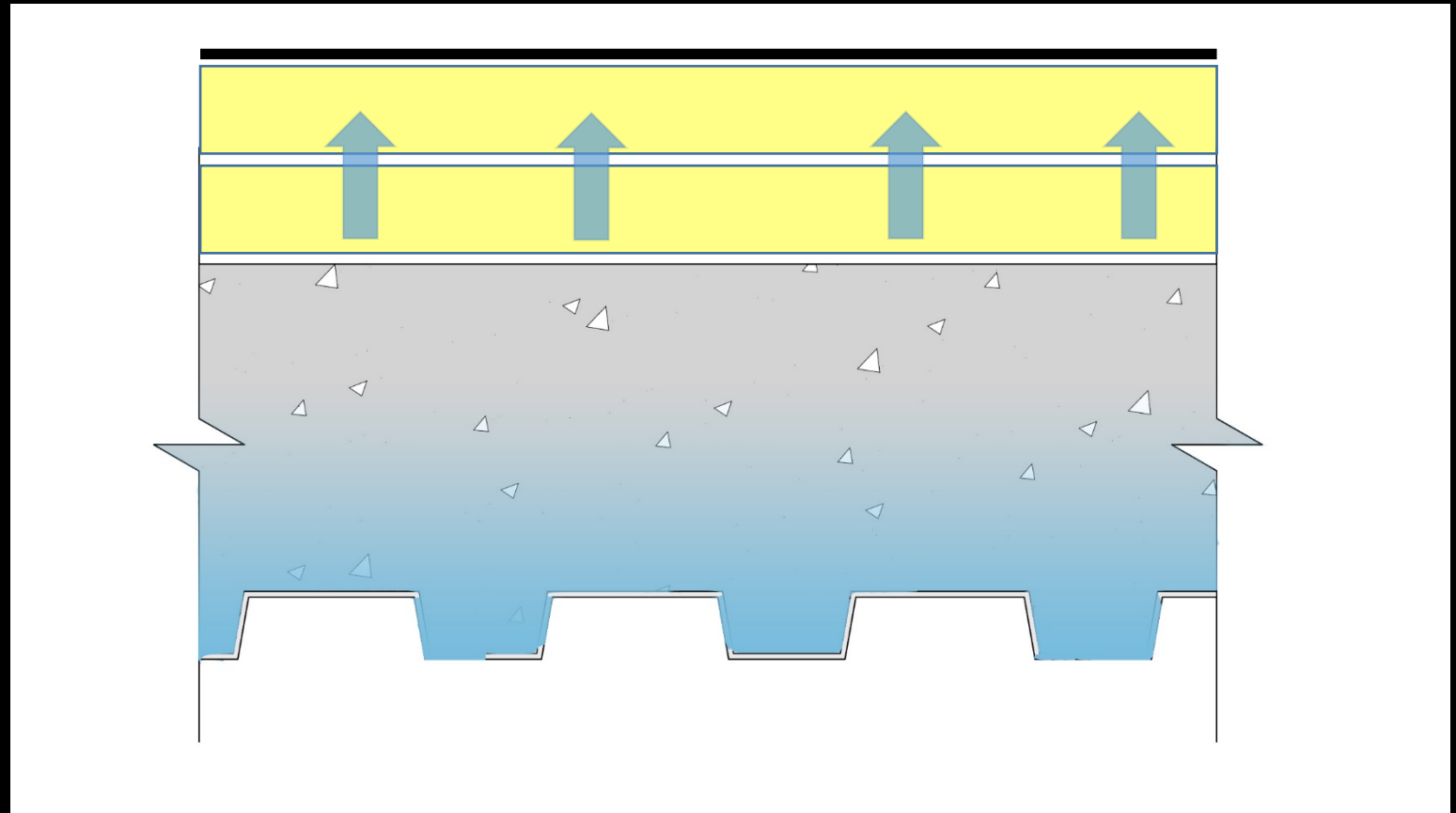
Bad and Worse

Vapor retarder keeps moisture in the deck and out of the roof system
We don’t care in this case if its RWC or LWSC….right?



Bad and Worse

No vapor retarder and now moisture in concrete slab is free to migrate up into the roof system.
Now, would we want the amount of moisture in RWC or LWSC free to move into our roof?!?!



Bad and Worse

- Lightweight structural concrete has repeatedly been shown to take much longer than regular weight concrete to dry.
- Only one study that suggests light weight structural concrete is not as bad as all other studies suggest
  - “…however the difference in the drying time recorded in these studies is considerably less than that which has been historically reported and understood. “
  - Published by Expanded Shale, Clay and Slate Institute, a trade association for light weight aggregate manufacturers.

What can be done to prevent problems?

- How dry is dry enough?
  - Roofing industry is not sure yet
  - Multiple entities wanting to do research
    - Money has not materialized
- Read the Specs (Not just Division 7)
  - Division 03-3300 Cast-in-Place Concrete or 03-3310 Structural Concrete
  - Look for mention of light weight aggregates and or a unit weight around 110-120 pounds per cubic foot.
- LEED project should be a big red flag
- Typically too late in design process to affect a change to regular weight concrete by the time bids go out.

What can be done to prevent problems?

- Light Weight Structural Concrete is in the design now what can I do?
- First and foremost this is a design issue
- The designer of record should be confronted about the issue
  - IN WRITING
  - Paper trail can be the difference between a good nights sleep and an expensive lawsuit

What can be done to prevent problems?

- Light Weight Structural Concrete is in the design now what can I do?
  - If possible get a heavy vapor retarder in the system
    - Manufacturers starting to require one with concrete decks
    - Bid it as an Alternate = “temporary roof”
  - Shot blast the concrete slab and seal it with an epoxy coating at considerable cost per square foot.
    - Flooring industry solution at large expense
    - To date this has met with mixed success in roofing industry

What can be done to prevent problems?

- Provide Designer / Client / General contractor / Project Manager industry information on moisture risks
- Example: 2011 GP DensDeck Prime data sheet
  - “When roofing systems are installed on new poured concrete or light weight concrete decks or when re-roofing over a wet existing concrete deck, a venting base sheet or vapor retarder should be installed above the concrete to retard the migration of water from the concrete into the roof assembly.”

What can be done to prevent problems?

- Provide Designer / Client / General contractor / Project Manager industry information on moisture risks
- Example: 2014 GAF Technical Advisory Bulletin TAB-C 2014-24
  - GAF concurs with ARMA's position: *"The selection of the deck material and its suitability for use is the responsibility of the designer of record, who must make appropriate design accommodations to address high moisture content encountered in lightweight structural concrete decks."*

What can be done to prevent problems?

- Table from GAF TAB-C 2014-24

The following chart summarizes these recommendations and requirements:

System Type	Poured in Place Structural Concrete Non-vented substrate or metal form that remains	
	Lightweight Aggregate	**Standard Concrete**
MB/BUR	Deck not acceptable	Deck not acceptable
TPO/PVC	Vapor Retarder Required	Vapor Retarder Recommended

GAF is not responsible for moisture related problems associated with any deck material.

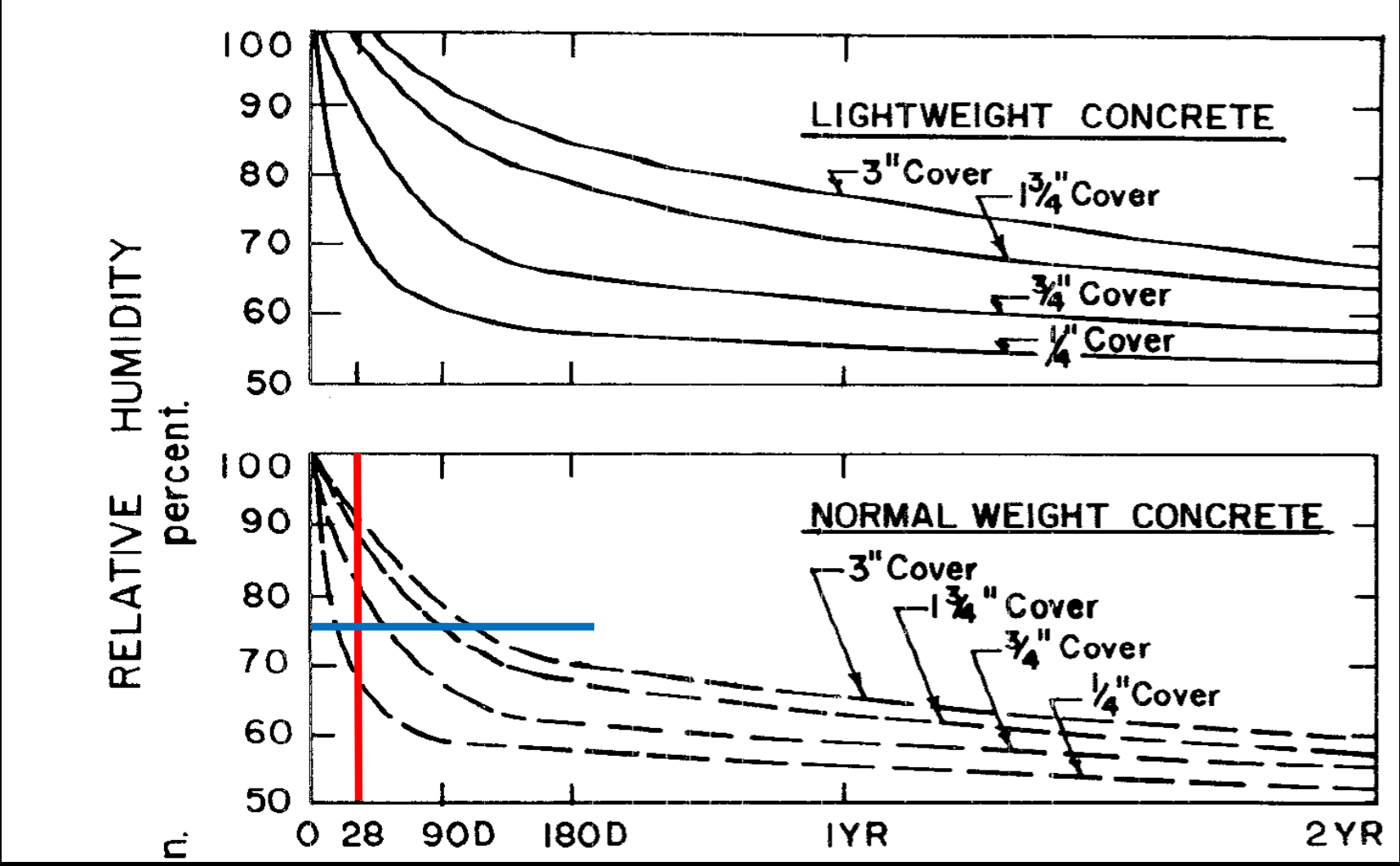
What can be done to prevent problems?

- Provide Designer / Client / General contractor / Project Manager industry information on moisture risks
- MRCA Technical Bulletin 1-2011
- NRCA Industry Issue Update 2012

What can be done to prevent problems?

- At this point in the Roofing Industry ASTM F-2170 is the only proven method for determining moisture levels in poured concrete roof decks.
  - 75% RH requirement was hypothesized by Dr. Rene Dupuis as a safe level based on decades of BUR roofing over RWSC after 28 days

What can be done to prevent problems?



Effects of Curing and Drying Environments on Splitting and Tensile Strength of Concrete - Hanson

What can be done to prevent problems?

- At this point in the Roofing Industry ASTM F-2170 is the only proven method for determining moisture levels in poured concrete roof decks.
  - While 75% RH is admittedly very conservative and may be impossible to achieve in some environments, it is the only data point out there.
  - No other recommendations for when it is safe to roof are known to exist.
  - Hygrothermal modeling is not useful (if possible) as actual current weather is needed and hygrothermal properties of concrete change constantly while it chemically cures
    - It may help predict long term survivability (moisture content) of the roof system. But does nothing to help roofing contractor determine when to put the roof down.

Summary

- Historical 28 day period for concrete is for strength not moisture content
- Light Weight Structural Concrete takes much longer than Regular Weight Concrete to achieve acceptable moisture levels
- Watch out for new manufacturer requirements for installing their systems over concrete decks

Summary

- Flooring industry has settled on ASTM F-2170 test to determine when they can apply flooring
- Roofing industry has a vastly larger problem to tackle here
  - Research and specific guidelines are a work in progress at best
- If you (general contractor) can't wait for the deck to dry, keep the concrete moisture out of <u>your</u> roof system.
  - Get a vapor retarder in the system.

Field Examples

Field Example

- Hospital in the upper Midwest
- Roof deck intended to be a floor for future vertical expansion
- Light Weight Structural Concrete on metal deck
- Fully adhered EPDM with tapered ISO
  - Low rise foam adhesive ribbon

Field Example

- Top floor unoccupied
- No leaks reported
- First indication was fully adhered membrane billowing in wind
- Manufacturer denied warranty coverage due to trapped moisture

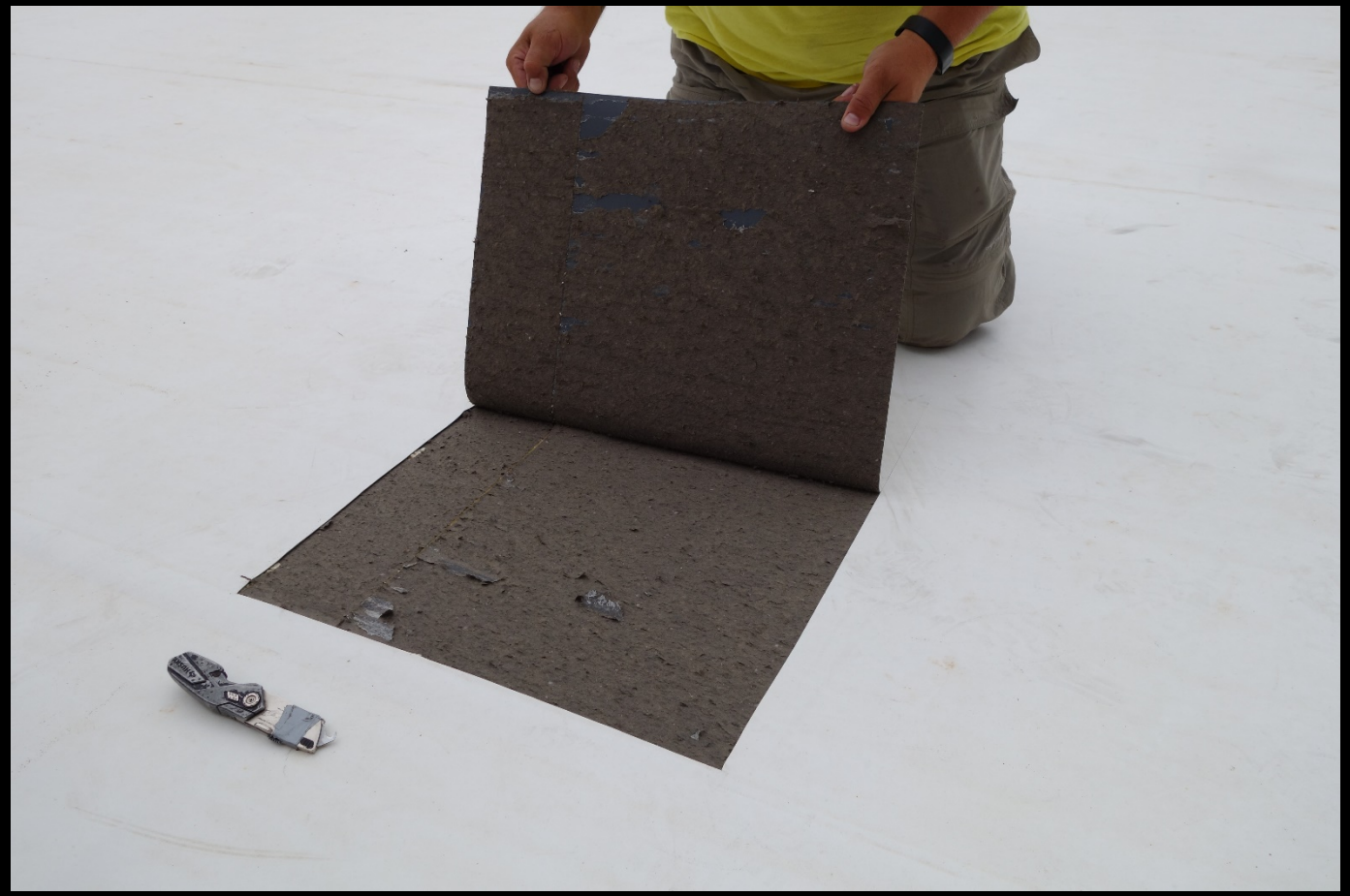

SAND IN A TUBE


SAND IN A TUBE


LYNYRD
SKYNYRD

Field Example

- Hospital in Central Plains
- New construction
  - Roof levels 1 and 2 were RWSC
  - Roof levels 3 – 10 were LWSC
- Adhered TPO over tapered ISO in low rise adhesive
- Roof membrane disbondment at relatively low wind speeds




%H2O Wood
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COMPARATIVE
TRAMEX™
Moisture Encounter Plus
Scale 1. - Wood, Timber
Scale 2. - Drywall, Roofing
Scale 3. - Plaster, Brick


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Scale 1. - Wood, Timber
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Scale 3. - Plaster, Brick
ON
SCALE
HOLD
Non-Destructive Moisture Detection
Made in Ireland
COMPARATIVE
%H2O Wood

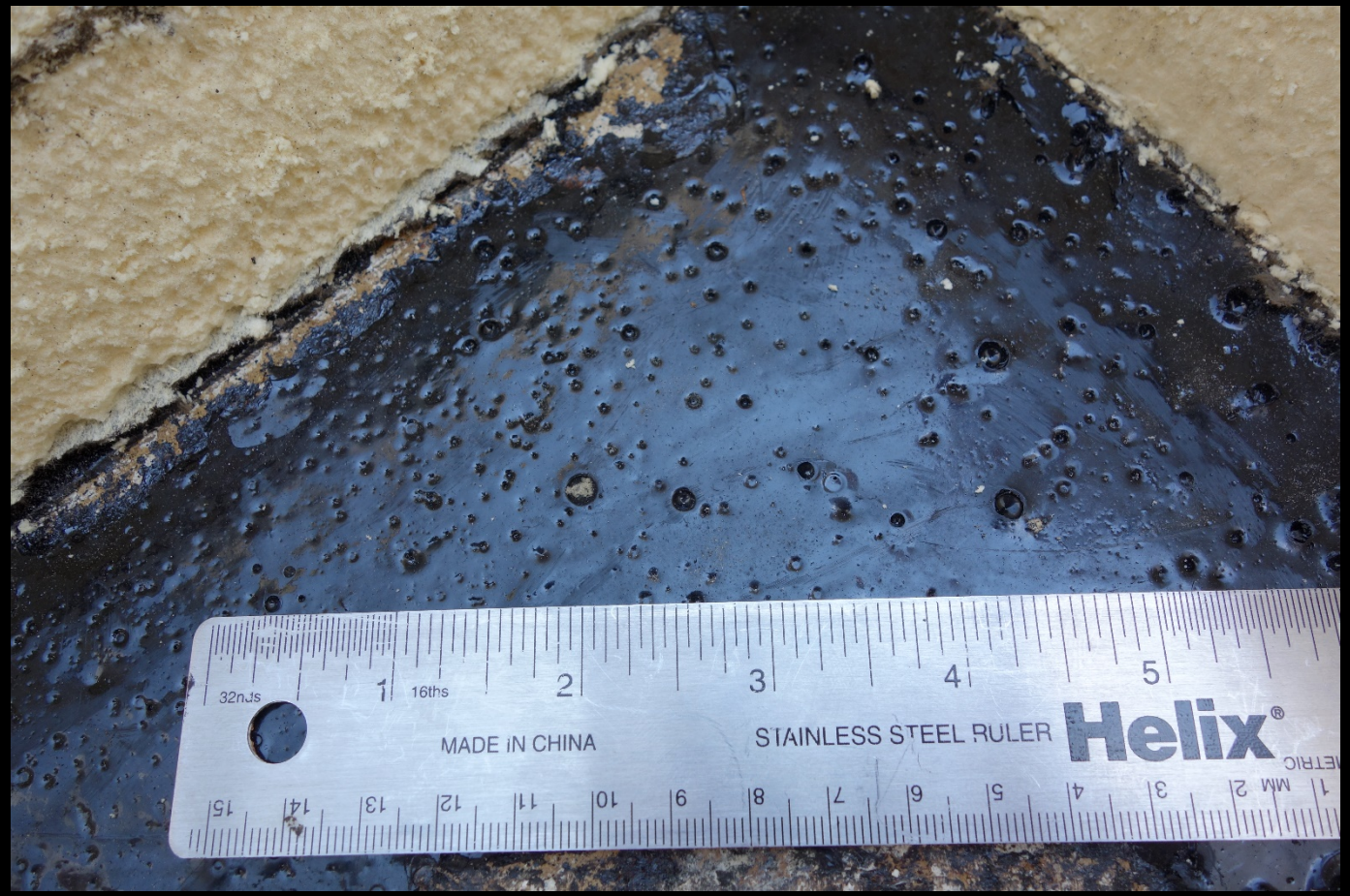
Field Example

- Research Center / Office Building on East Coast
- New construction
  - LEED Project
  - LWSC
- Adhered TPO over tapered ISO (deep) in mopped asphalt
- Roof membrane disbondment at relatively low wind speeds


SP-1


Wagner Meters
99
Made in USA


Do Not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STAINLESS STEEL RULER
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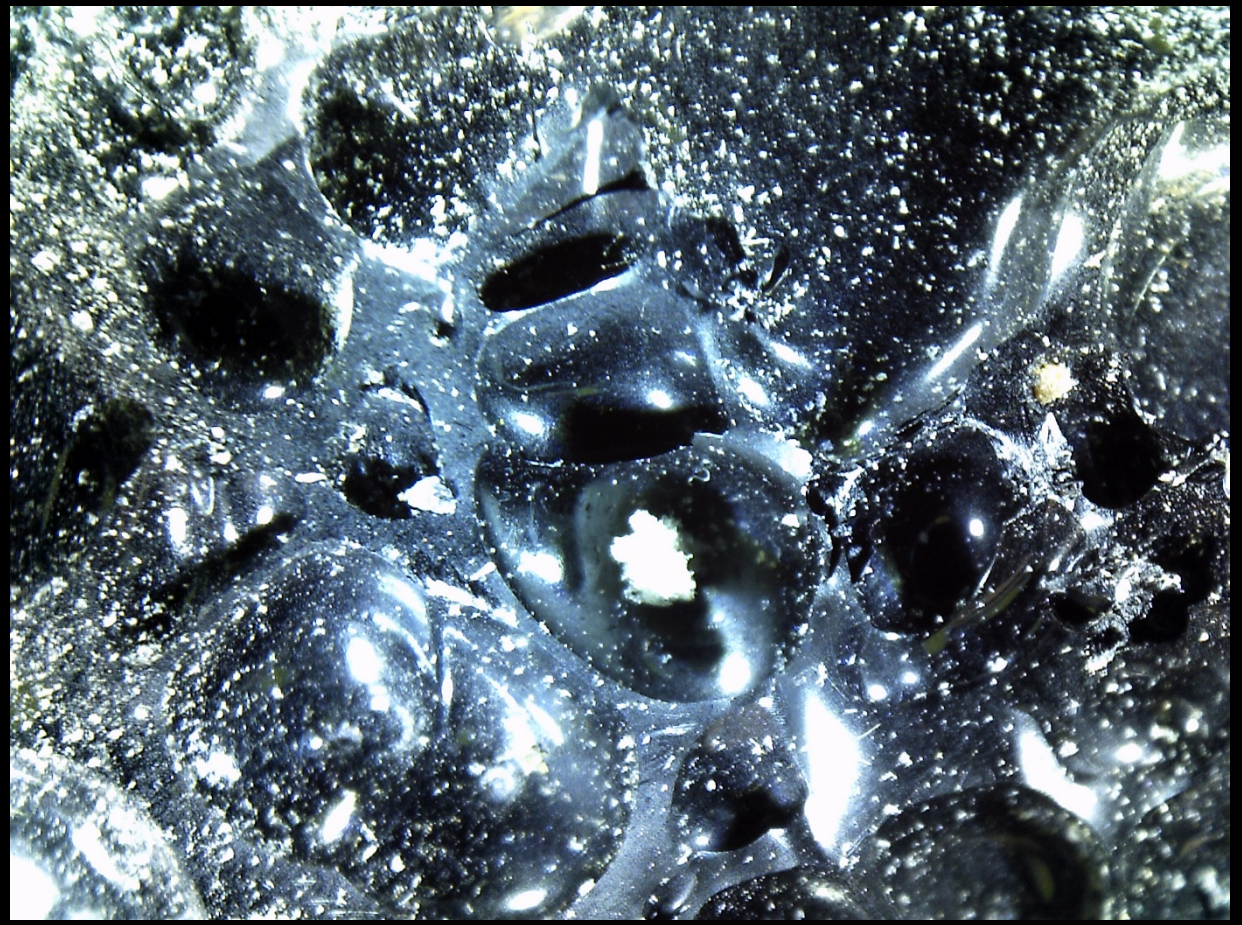

Field Example

- Hospital in Southeast
- New construction
  - LEED Project
  - LWSC
  - Under construction
  - Manufacturer’s Technical Staff recognized problem early and advised designer to include a vapor retarder, and it was.
- Adhered TPO over tapered ISO (deep) in low rise foam
- Cold and wet weather was hampering construction
- Still had moisture indications in finished roof


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Plaster, Brick
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Non-Destructive Moisture Detection


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Thank You