HOW DO HIGH MOISTURE RESISTANT ADHESIVES WORK IN HIGH MOISTURE CONDITIONS AND HOW CAN THEY STILL FAIL WITH ALL THE CLAIMS MADE?

A LOOK INTO THE SCIENCE OF POLYMER COALESCENCE, CONCRETE COMPOSITION AND SALT PUMPS

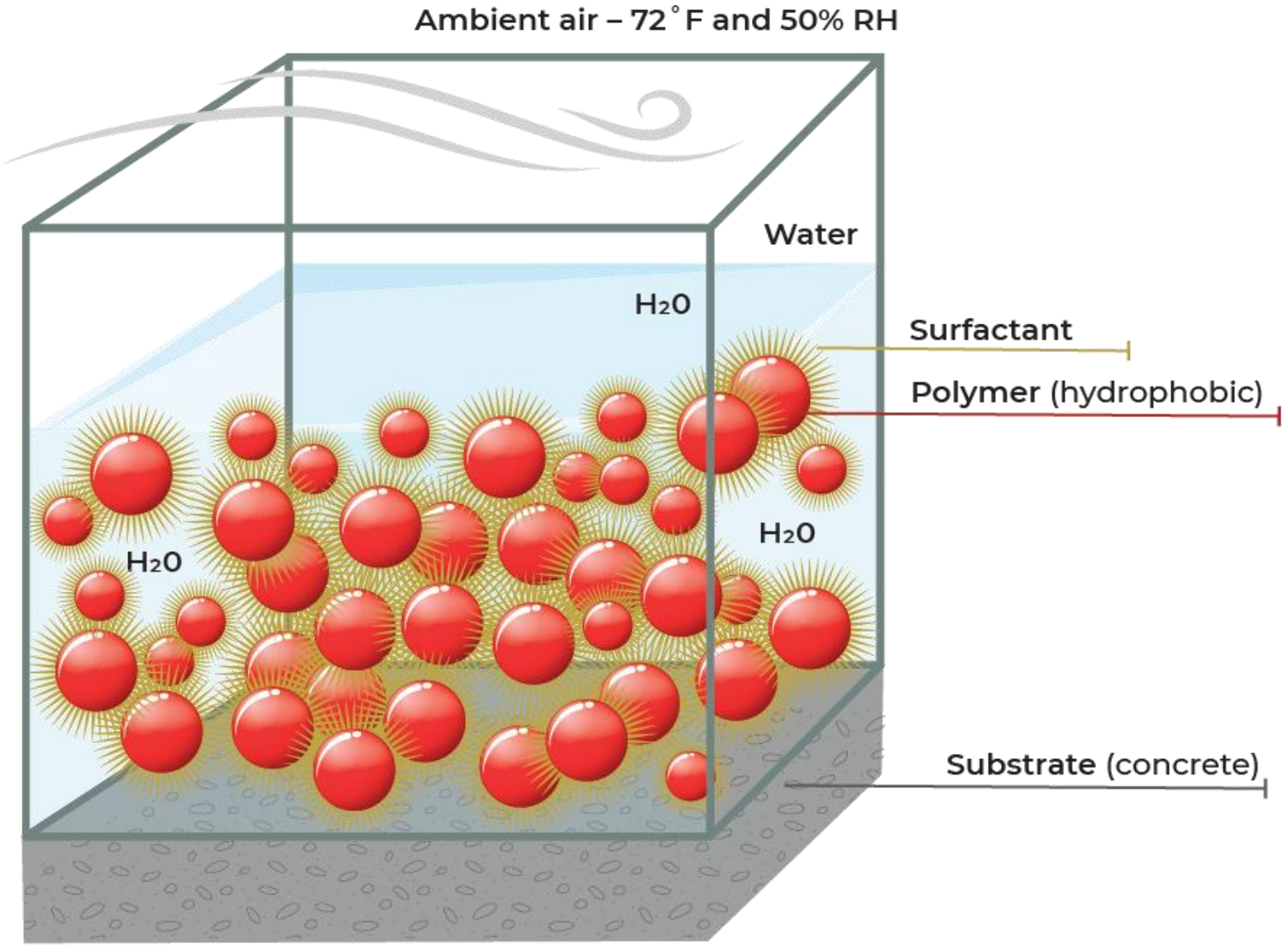
Sponsored by FCICA

The Flooring Contractors Association

Presented by: Jeffrey B Johnson

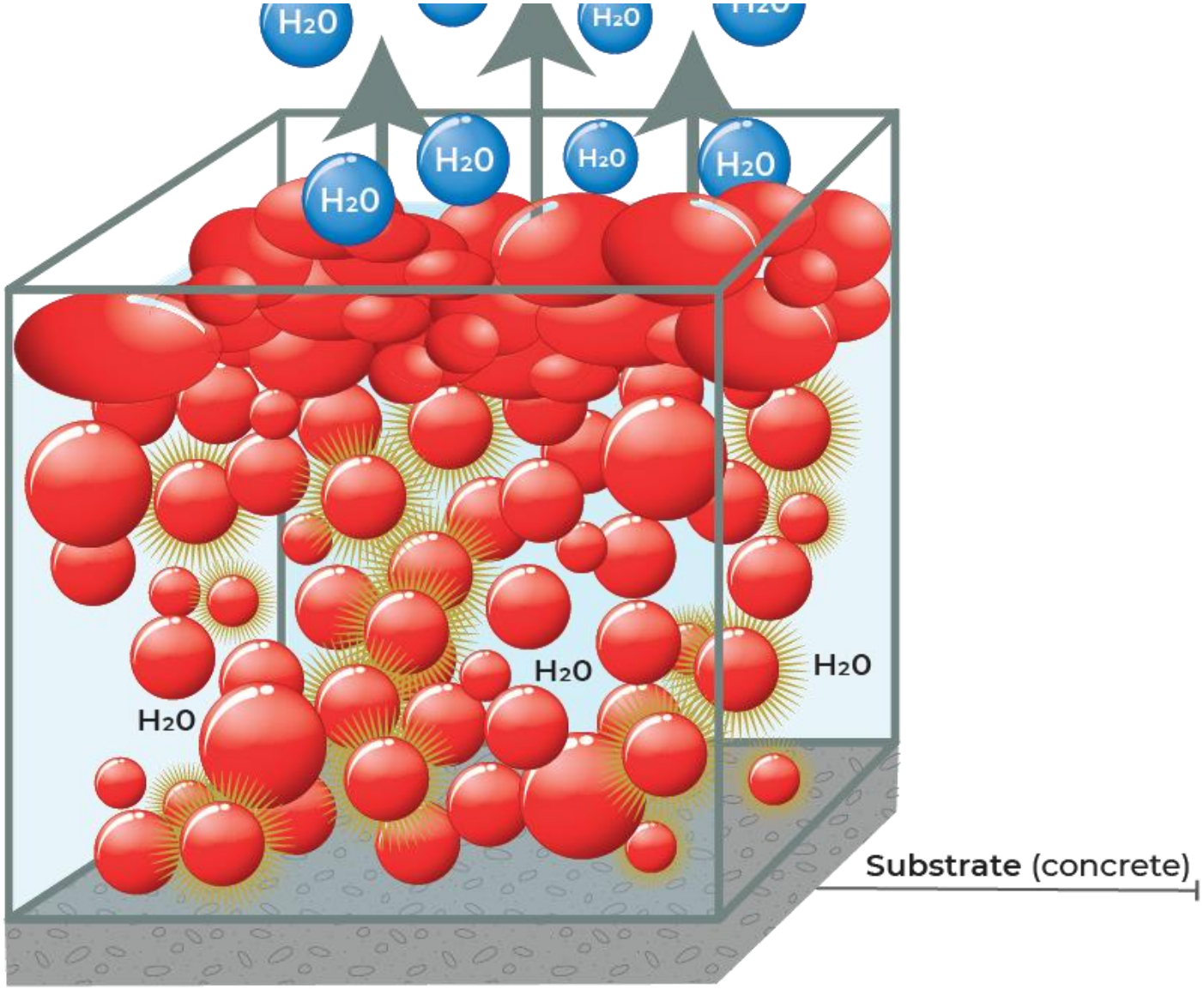
COURSE OBJECTIVES

- Learn about the process of coalescence and why this is important for high moisture resistant adhesives
- Discuss factors that influence high moisture resistant film formation
- Review the basic principles of pH values
- Outline concrete chemical composition and curing
- Discuss the process of carbonization.
- Discuss osmosis and how this is relative to a concrete slab
- Propose mechanism for moisture generation under flooring installations due to osmotic action
- Discuss techniques and practices to avoid moisture related failures



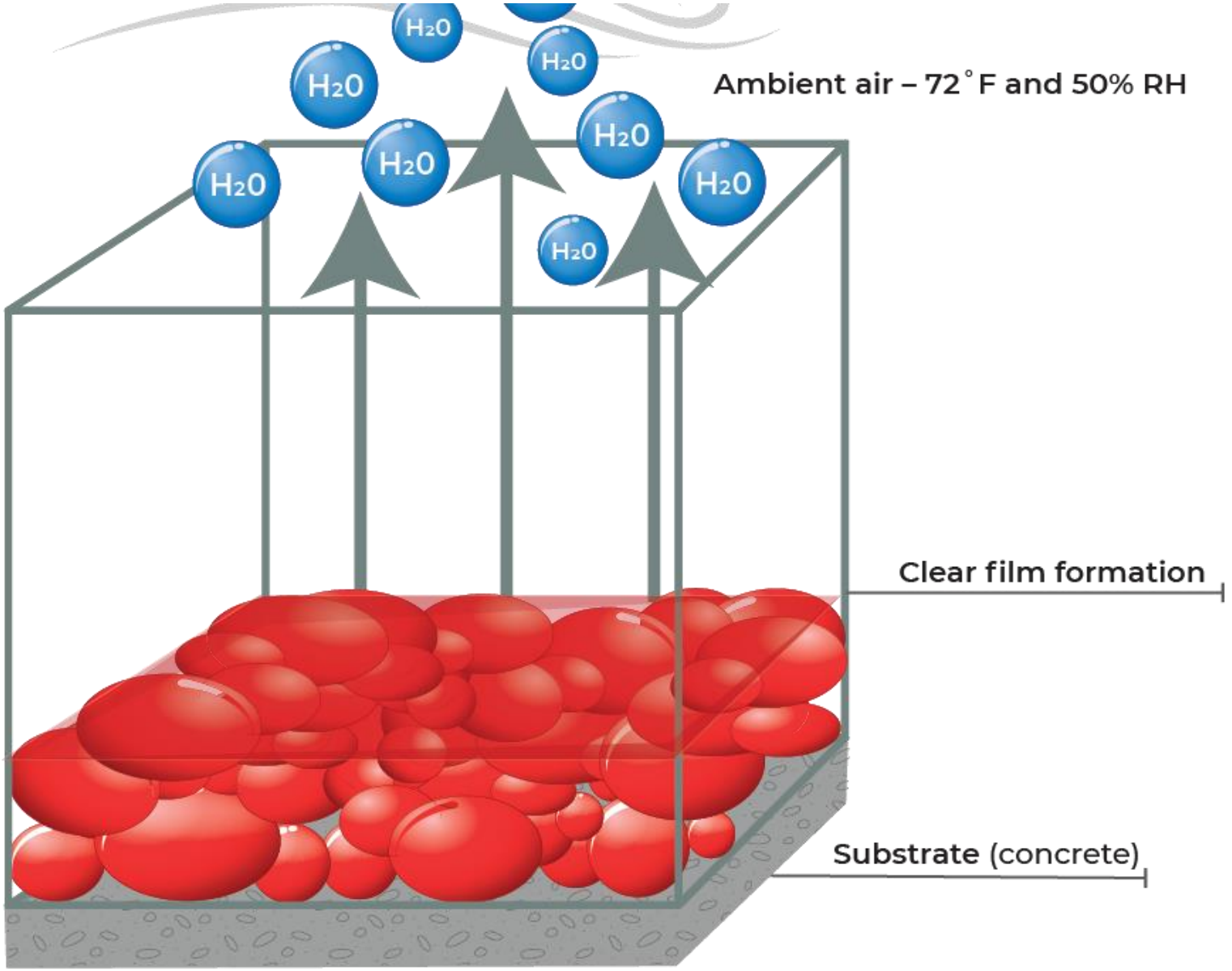
HOW HIGH MOISTURE ADHESIVES WORK

WATER-BASED ADHESIVES BEGIN WITH AN ACRYLIC LATEX POLYMER.



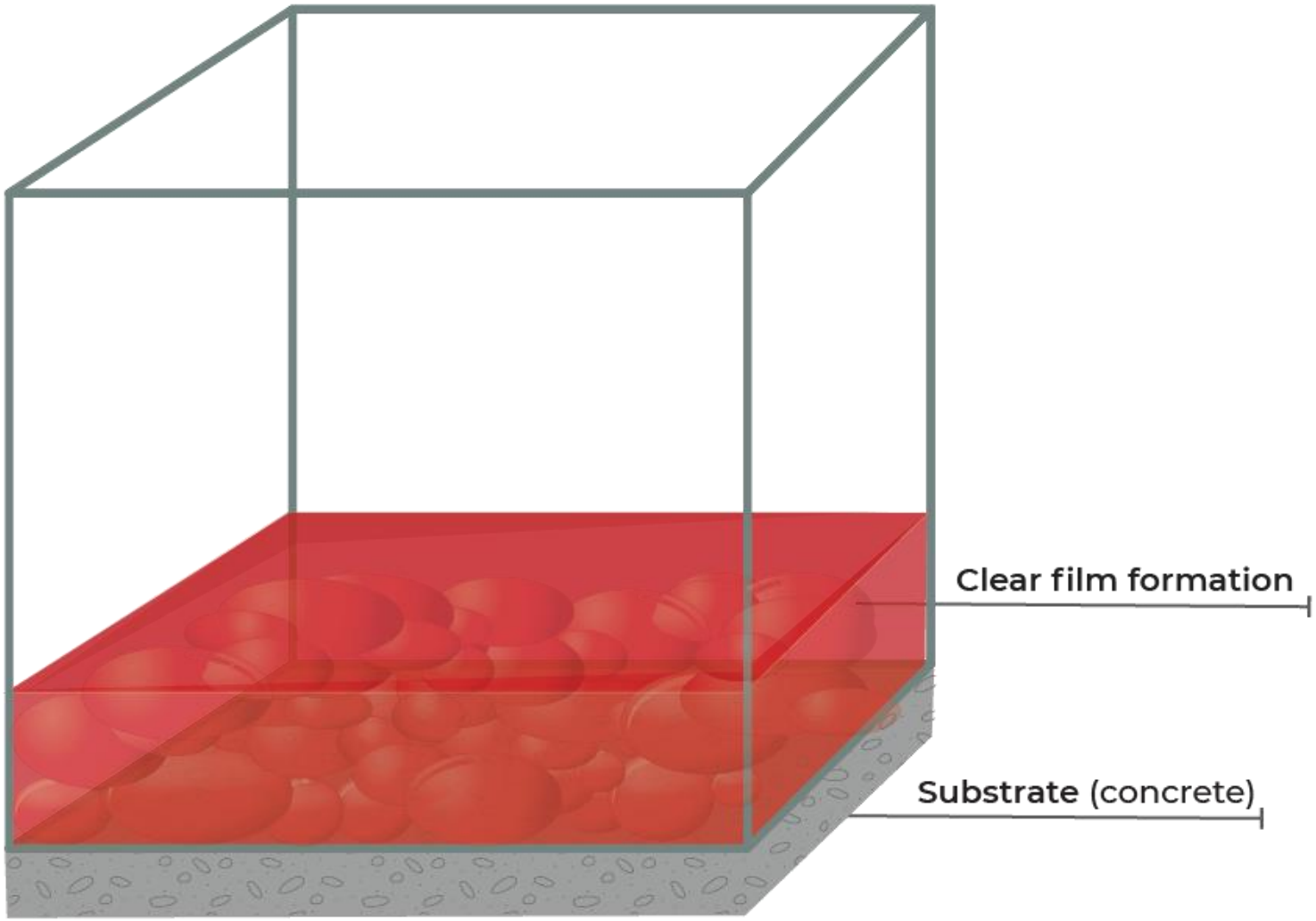
HOW HIGH MOISTURE ADHESIVES WORK

COALESCENCE



HOW HIGH MOISTURE ADHESIVES WORK

COALESCENCE

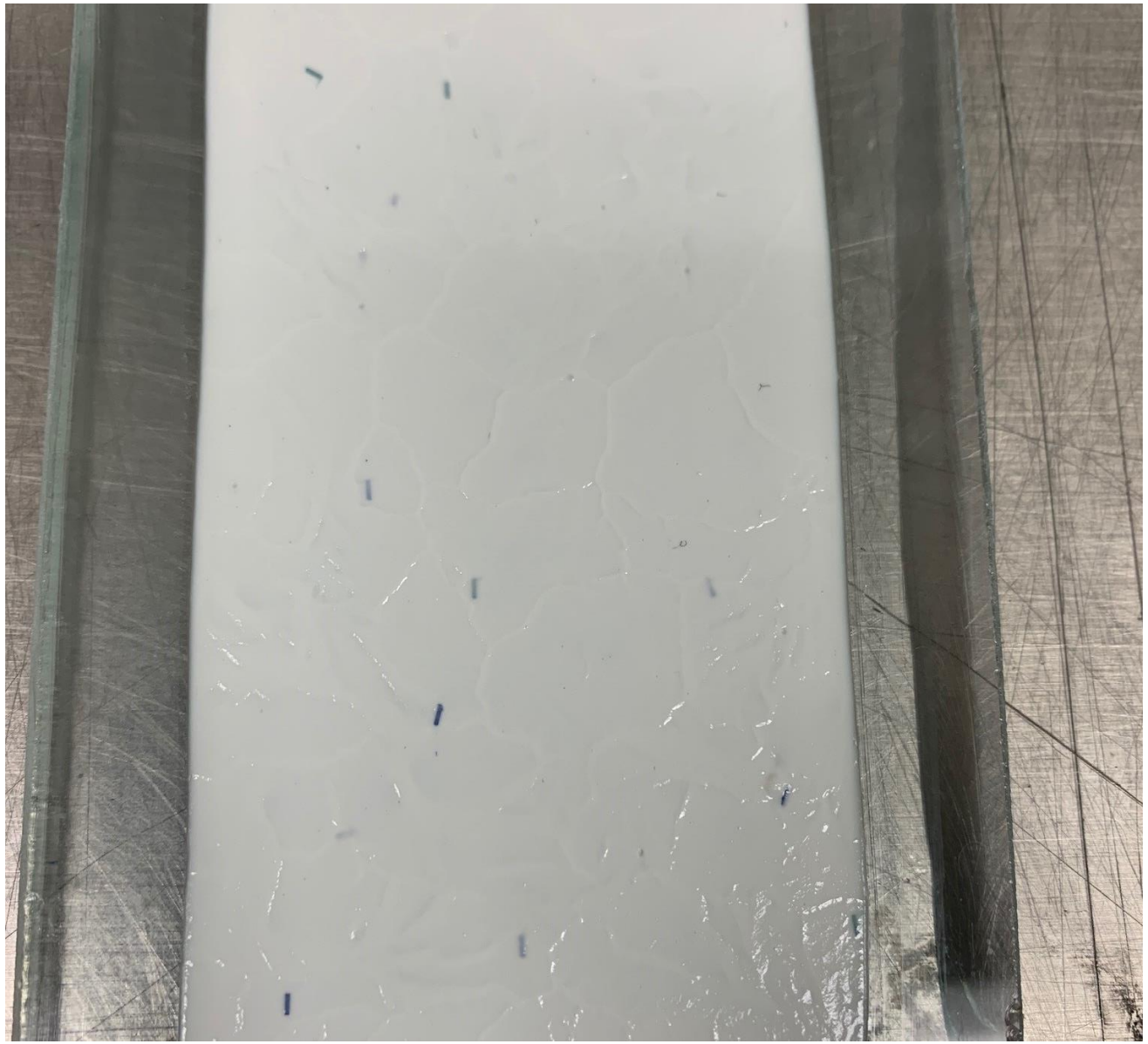


HOW HIGH MOISTURE ADHESIVES WORK

COALESCENCE

HOW HIGH MOISTURE ADHESIVES WORK

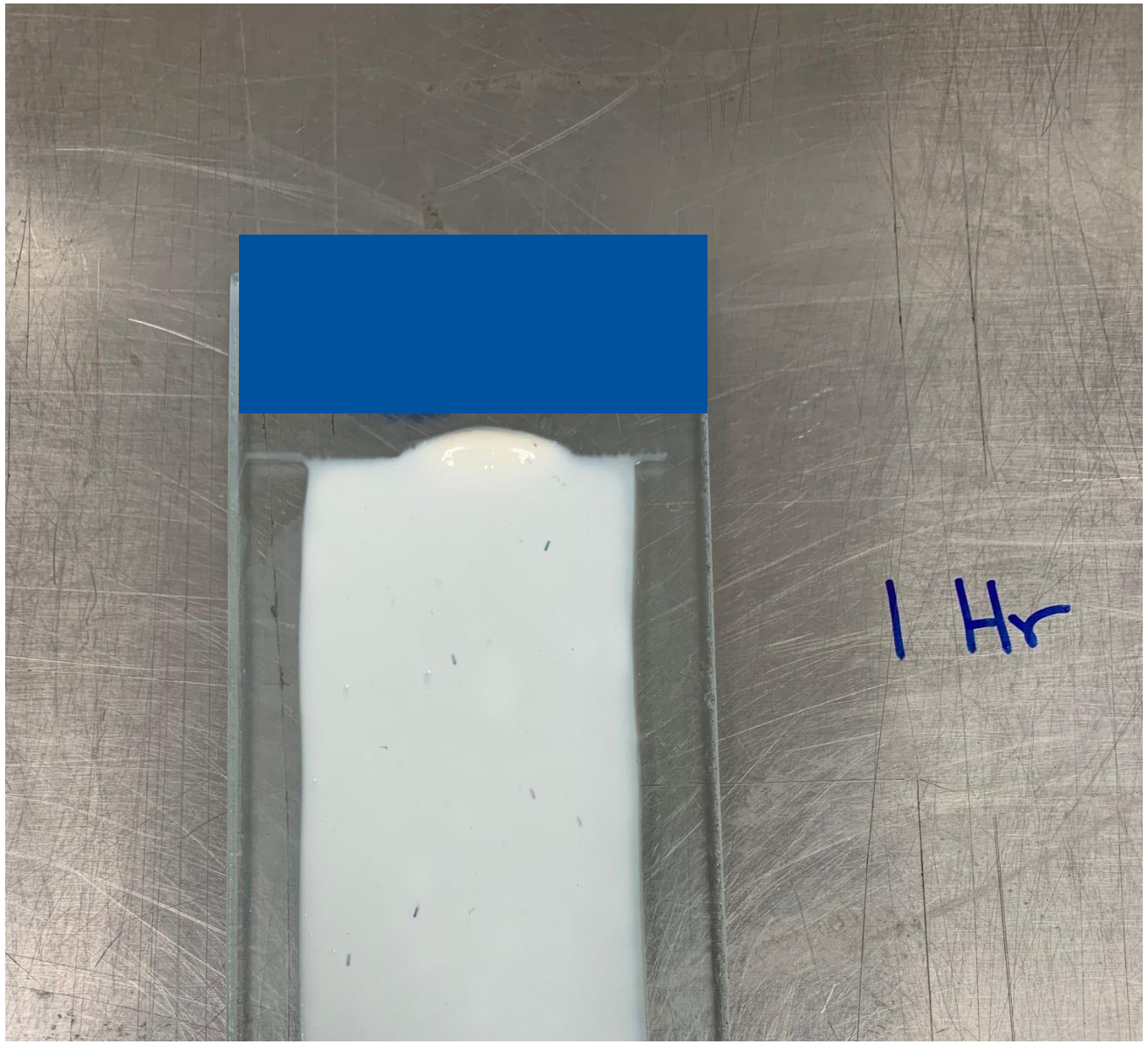
ONCE THE FILM HAS COALESCED YOU HAVE MOISTURE RESISTANCE



THINGS THAT INTERFERE WITH COALESCENCE

TEMPERATURE

- FREEZING TEMP CREATES FILM CRAZING
- HIGH TEMP FLASH DRIES SURFACE TRAPPING MOISTURE UNDERNEATH



THINGS THAT INTERFERE WITH COALESCENCE

MOISTURE

- MOISTURE FROM CONDENSATION (DEW POINT) DILUTES FILM AND WEAKENS PERFORMANCE

NUMBER GENERATION

- Testing methods:
  - ASTM D1151-00
    - Standard Practice for Effect of Moisture and Temperature on Adhesive Bonds
  - Proprietary Methods
    - Immersion
    - On slab
    - In field

ASTM D1151-00

- **1. Scope**
- 1.1 This practice defines conditions for determining the performance of adhesive bonds when subjected to continuous exposure at specified conditions of moisture and temperature. The performance is expressed as a percentage based on the ratio of strength retained after exposure to the original strength.
- 1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

ASTM F-1151 – TEST CONDITIONS

- Substrate and adherend specified by adhesive selection
- Flooring adhesives typically tested on cement boards that are conditioned to the requisite RH levels
- Adhesives allowed to cure at high RH and then bonded

TABLE 1 Standard Test Exposures

Test Exposure Number	Temperature[A] °C	Temperature[A] °F	Moisture Conditions
1	–57	–70	as conditioned
2	–34	–30	as conditioned
3	–34	–30	presoaked[B]
4	0	32	as conditioned
5	23	73.4	50 % RH
6	23	73.4	immersed in water
7	38	100	88 % RH
8	63	145	oven, uncontrolled humidity
9	63	145	over water[C]
10	63	145	immersed in water
11	70	158	oven, uncontrolled humidity
12	70	158	over water[C]
13	82	180	oven, uncontrolled humidity
14	87	188	oven, uncontrolled humidity
15	82	180	over water[C]
16	100	212	oven, uncontrolled humidity
17	100	212	immersed in water
18	105	221	oven, uncontrolled humidity
19	149	300	oven, uncontrolled humidity
20	204	400	oven, uncontrolled humidity
21	260	500	oven, uncontrolled humidity
22	316	600	oven, uncontrolled humidity

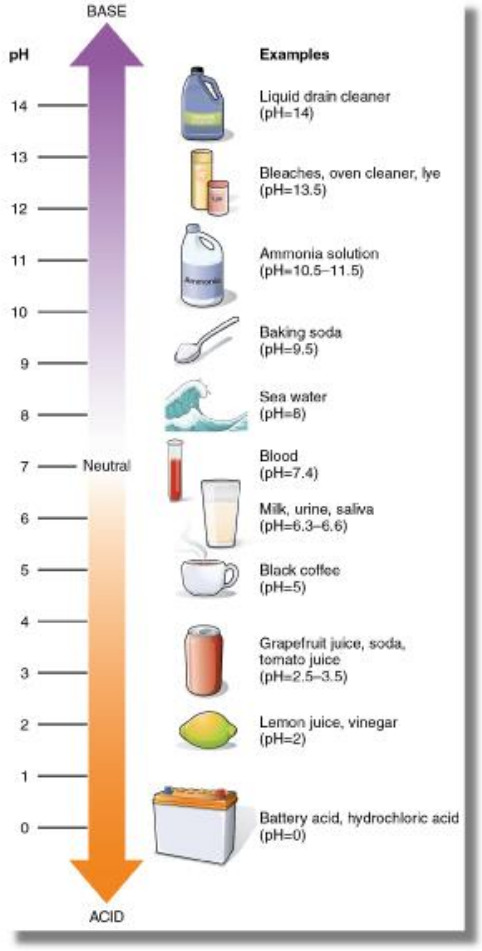
[A] The tolerance for test temperature shall be ±1°C or 1.8°F up to 82°C or 180°F, and ±1 % for temperatures above 82°C or 180°F.
[B] Presoaking shall consist of submerging specimens in water and applying vacuum at 51 cm (20 in.) of mercury until weight equilibrium is reached.
[C] The relative humidity will ordinarily be 95 to 100 %.

QUESTION

- Are we really dealing with “pure” water?

THINGS THAT INTERFERE WITH COALESCENCE

- pH
  - pH is a measure of how acidic/basic water is. The range goes from 0 to 14, with 7 being neutral. pH's of less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base.
  - pH measurement is a logarithmic scale.



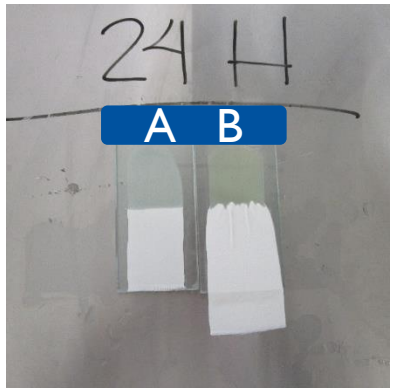
LAB TESTING OF MOISTURE RESISTANCE OF ADHESIVES

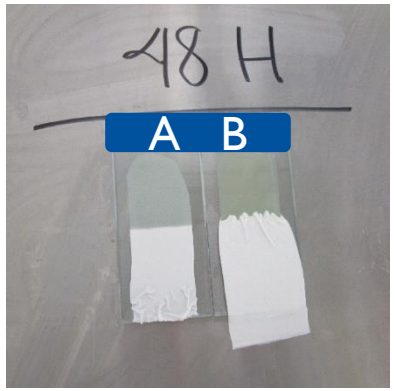
- pH Resistance
  - Water immersion testing

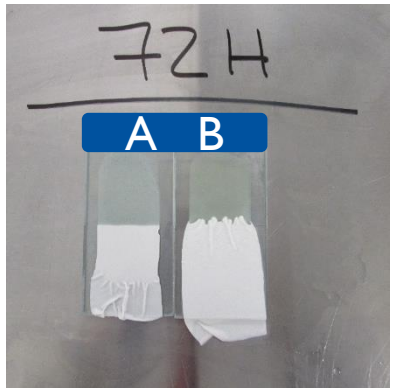
Grades	Percentage
5	90-100
4+	85-89
4	70-84
3+	65-69
3	50-64
2+	45-49
2	30-44
1+	25-29
1	0-24

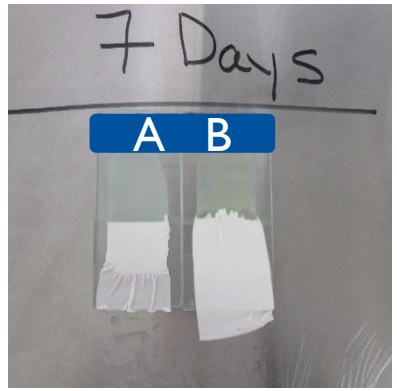
Symbol	Failure	Weighting
W(1-3)	Whitening	1%
B(1-3)	Bubbling	16.00%
FW(1-3)	Weak Film	26.00%
SW(1-3)	Swelling	16.00%
DL(3)	Delamination	10.00%
PDL(1-3)	Partial Delamination	4.00%
AC(1-3)	Adhesive Curling	5.00%
MB(1-3)	Minor Bubbling	5.00%
MFW(1-3)	Minor Weak Film	12.00%
MSW(1-3)	Minor Swelling	5.00%

THINGS THAT INTERFERE WITH COALESCENCE





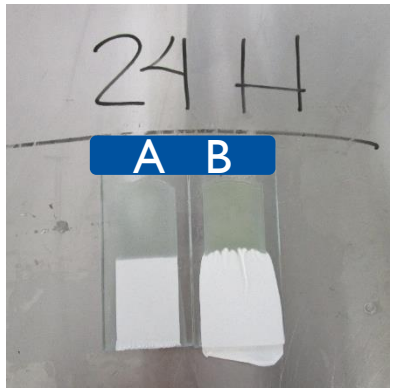


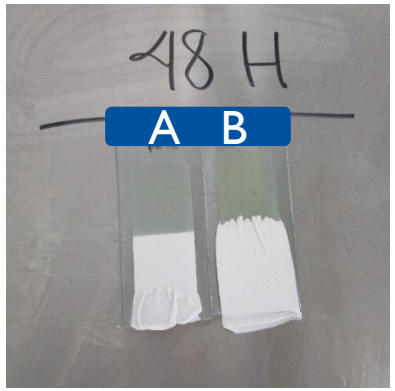


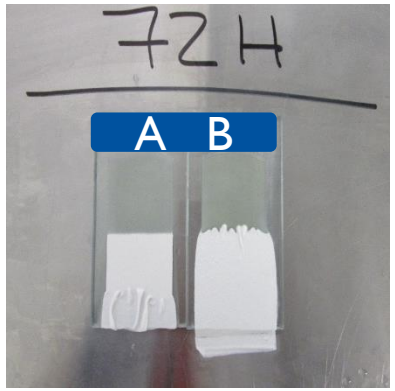
pH 7				
	Time	Rating	% Rating	Comments
Adhesive A	24Hrs	5	99.00%	W(3)
Adhesive B	24Hrs	3	57.00%	W(3)DL(3)SW(3)B(3)
Adhesive A	48 Hrs	5	94.66%	W(3)PDL(2)MSW(1)
Adhesive B	48 Hrs	3	57.00%	W(3)DL(3)SW(3)B(3)
Adhesive A	72 Hrs	5	94.66%	W(3)PDL(2)MSW(1)
Adhesive B	72 Hrs	3	57.00%	W(3)DL(3)SW(3)B(3)
Adhesive A	7 Days	5	91.33%	W(3)PDL(2)MSW(3)
Adhesive B	7 Days	3	57.00%	W(3)DL(3)SW(3)B(3)

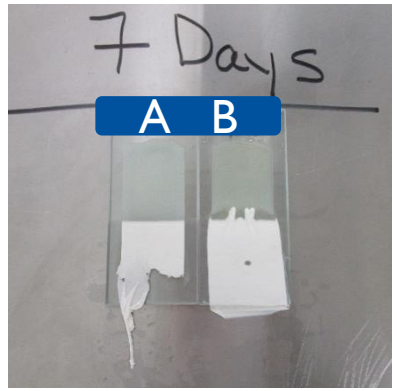
FCICA

THINGS THAT INTERFERE WITH COALESCENCE





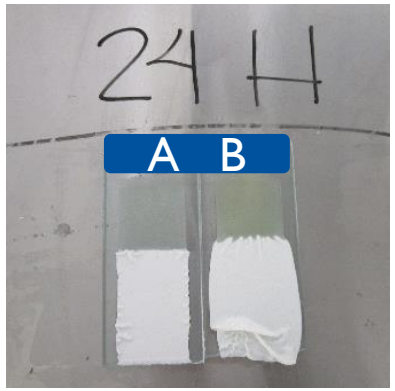


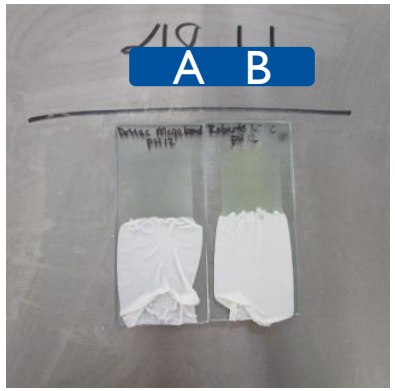


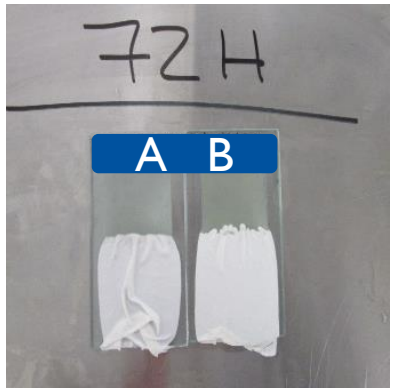
pH 10				
	Time	Rating	% Rating	Comments
Adhesive A	24Hrs	5	99.00%	W(3)
Adhesive B	24Hrs	3	62.33%	W(3)DL(3)SW(2)B(3)
Adhesive A	48 Hrs	5	94.66%	W(3)PDL(2)MSW(1)
Adhesive B	48 Hrs	3	62.33%	W(3)DL(3)SW(2)B(3)
Adhesive A	72 Hrs	5	93.00%	W(3)PDL(2)MSW(2)
Adhesive B	72 Hrs	3	53.00%	W(3)DL(3)SW(3)B(3)MFW(1)
Adhesive A	7 Days	3	65.00%	W(3)PDL(2)FW(3)SW(1)
Adhesive B	7 Days	3	53.00%	W(3)DL(3)SW(3)B(3)MFW(1)

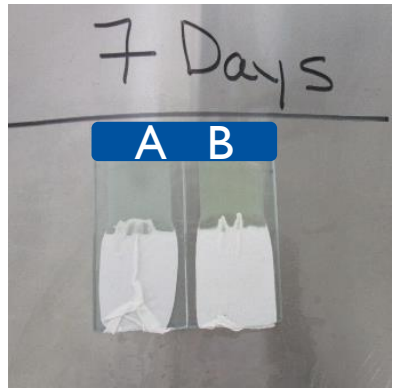
FCICA

THINGS THAT INTERFERE WITH COALESCENCE









pH 12				
	Time	Rating	% Rating	Comments
Adhesive A	24Hrs	5	96.33%	W(3)PDL(2)
Adhesive B	24Hrs	3	51.00%	W(3)PDL(3)B(3)SW(2)FW(2)
Adhesive A	48 Hrs	4	84.33%	W(3)PDL(3)SW(2)
Adhesive B	48 Hrs	3	51.00%	W(3)PDL(3)B(3)SW(2)FW(2)
Adhesive A	72 Hrs	4	79.00%	W(3)PDL(3)SW(3)
Adhesive B	72 Hrs	2	42.33%	W(3)PDL(3)B(3)SW(2)FW(3)
Adhesive A	7 Days	3	61.00%	W(3)DL(3)SW(3)MFW(3)
Adhesive B	7 Days	2	36.33%	W(3)DL(3)B(2)SW(3)FW(3)

FCICA

WHERE DOES THE HIGH PH COME FROM IN CONCRETE?

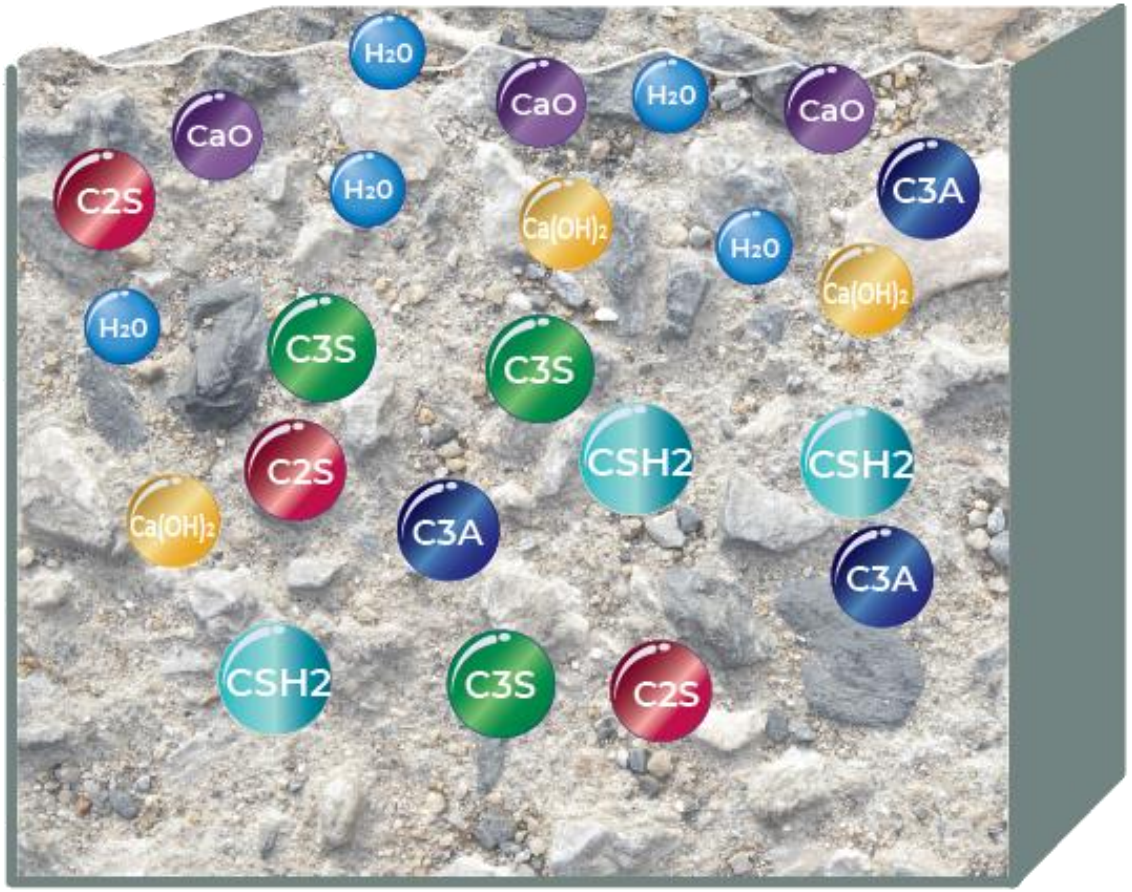
- Components of dry concrete:
  - Tricalcium silicate, C3S
  - Dicalcium silicate, C2S
  - Tricalcium aluminate, C3A
  - Tetracalcium aluminoferrite, C4AF
  - Gypsum, Calcium Sulfate Dihyhdrate (CSH2)

WHERE DOES THE HIGH PH COME FROM IN CONCRETE?

- Ettringite
  - 15 to 20%
- Calcium silicate hydrates, CSH
  - 50 to 60%
- Calcium hydroxide (lime)
  - 20 to 25%
- Voids
  - 5 to 6% (in the form of capillary voids and entrapped and entrained air)

WHERE DOES THE HIGH PH COME FROM IN CONCRETE?

- Fresh concrete has a pH of 12-14.



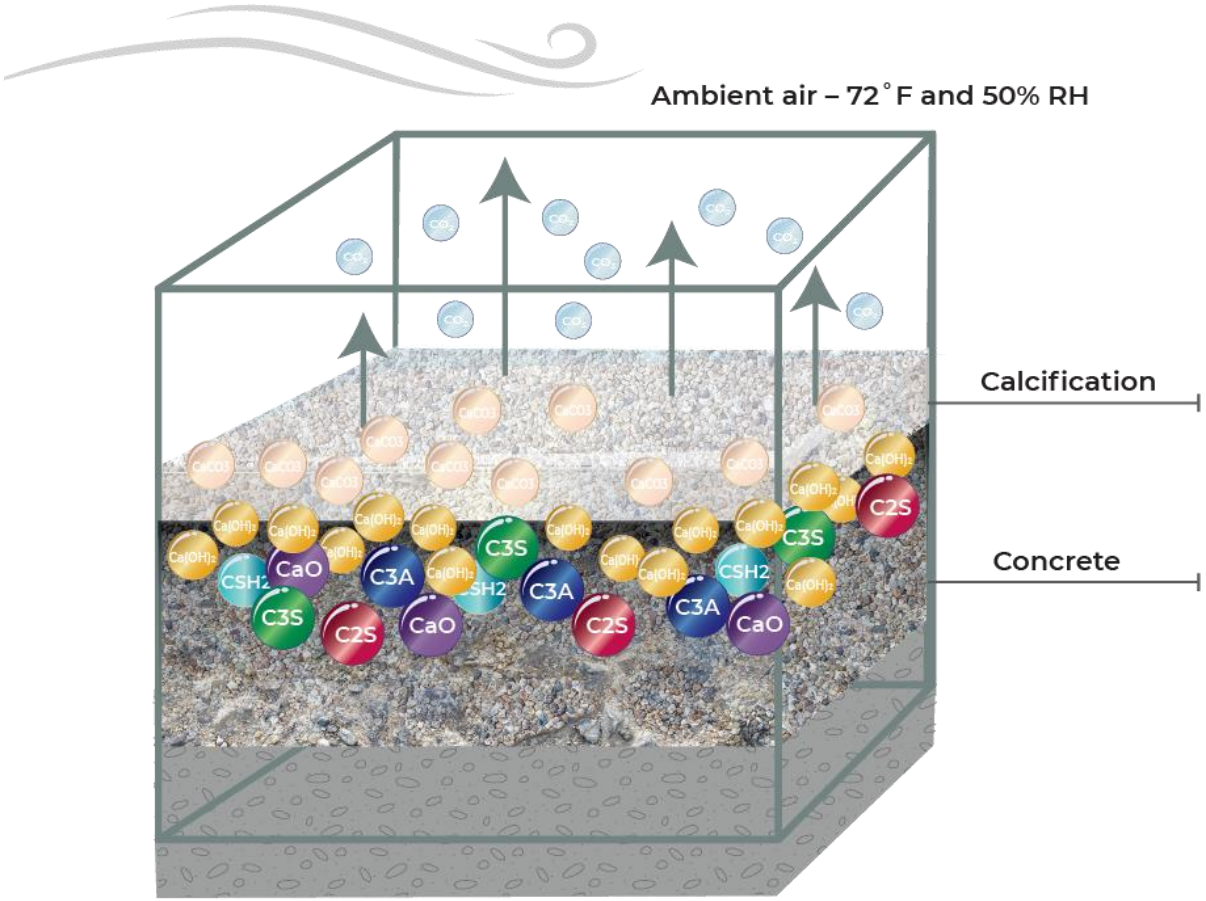
CONCRETE CHEMICAL REACTIONS

Tricalcium silicate, C3S
Dicalcium silicate, C2S
Tricalcium aluminate, C3A
Tetracalcium aluminoferrite, C4AF
Gypsum, CSH2

CHEMICAL CONCRETE REACTIONS

FINISHING THE SURFACE

STEEL TROWELING BRINGS BLEED WATER TO THE SURFACE COMPACTING AGGREGATE LEAVING FINES AT THE SURFACE



CONCRETE CHEMICAL REACTIONS

CARBONIZATION

THE NORMAL REACTION OF CO_2 IN THE ATMOSPHERE WITH THE CALCIUM HYDROXIDE TO CREATE CALCIUM CARBONATE AND LOWER THE PH OF THE SURFACE

WHERE DOES THE WATER COME FROM?

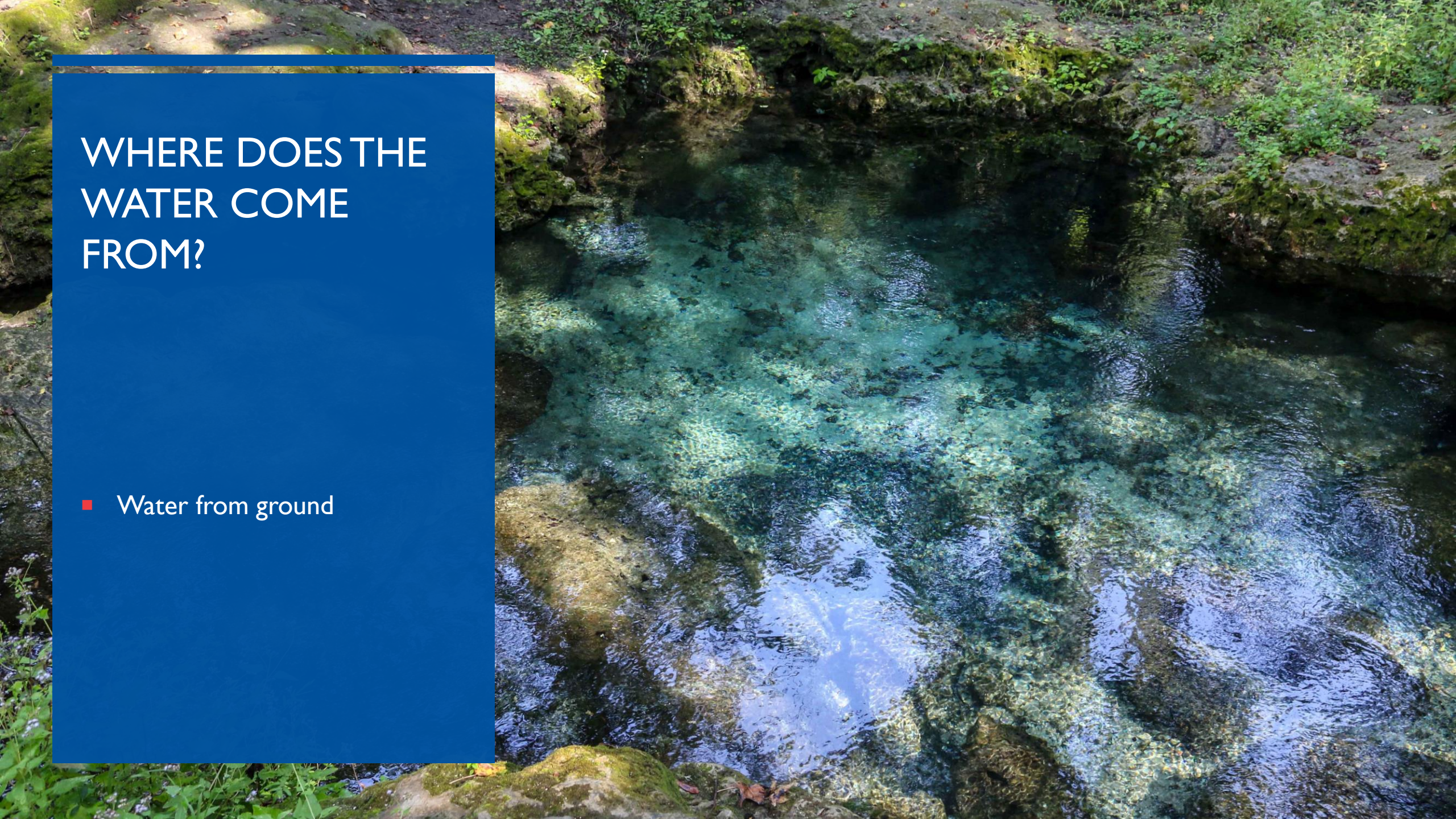
- Water of hydration

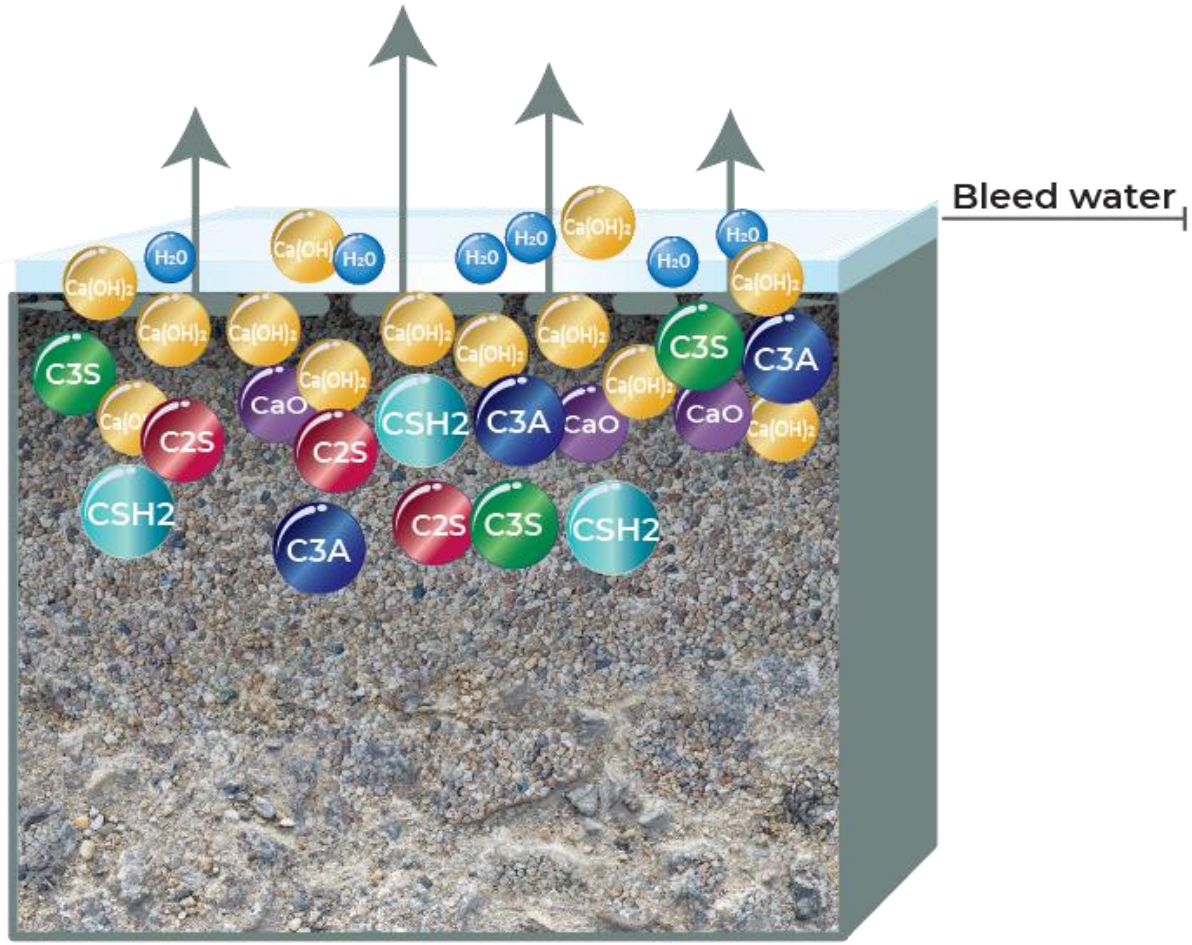
WHERE DOES THE WATER COME FROM?

- Water of convenience

WHERE DOES THE WATER COME FROM?

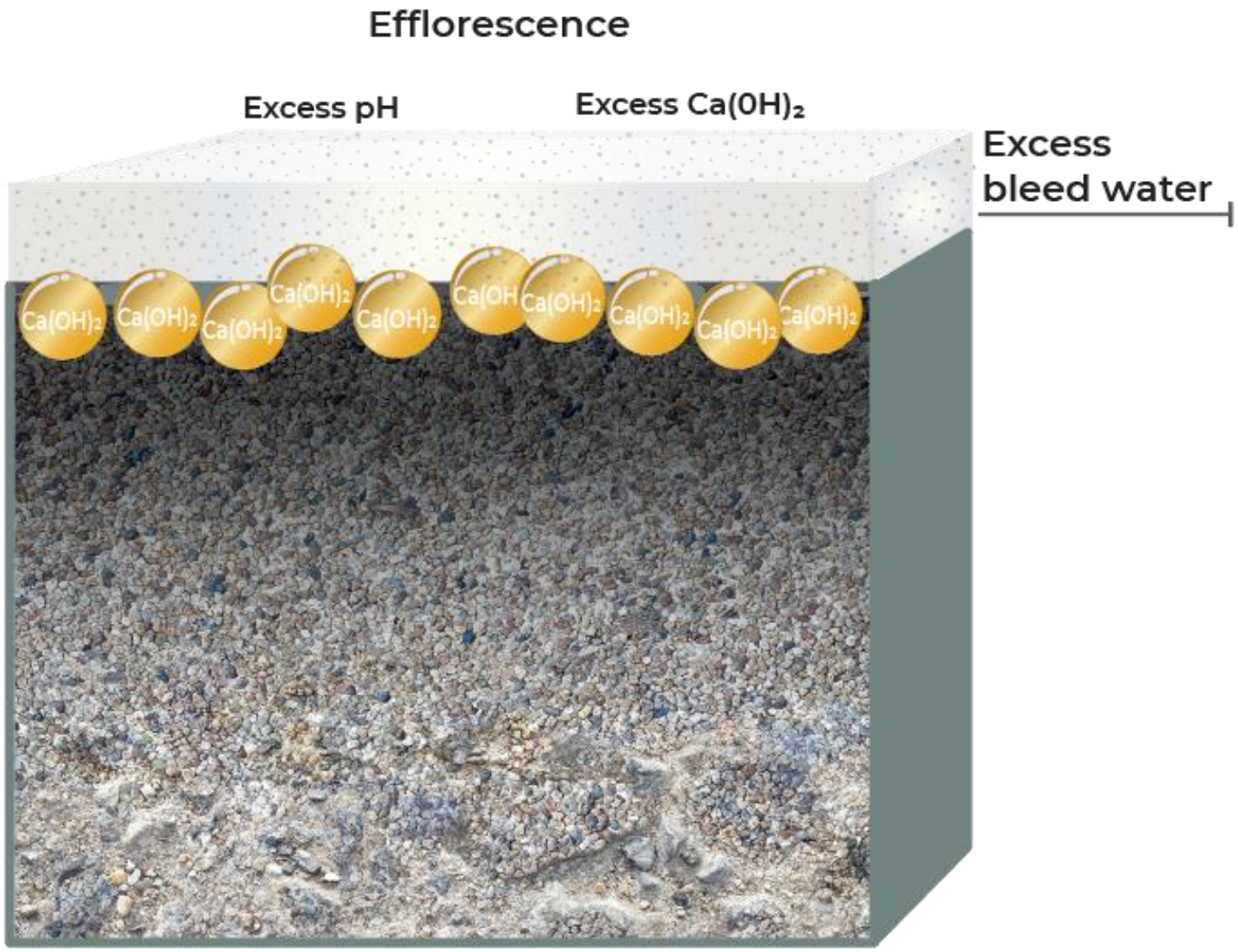
- Water from ground





WHAT IS IN BLEED WATER

MIX OF CALCIUM, SODIUM, HYDROXIDE AND SULFATE IONS



WHAT IS EFFLORESCENCE

DEPOSITS OF CALCIUM SALTS ON THE SURFACE IN THE FORM OF WHITE CRYSTALS.

HOW DO WE KNOW IF THE SLAB IS SALTED

- Visual inspections do not always show signs of salt deposits

PH TESTING

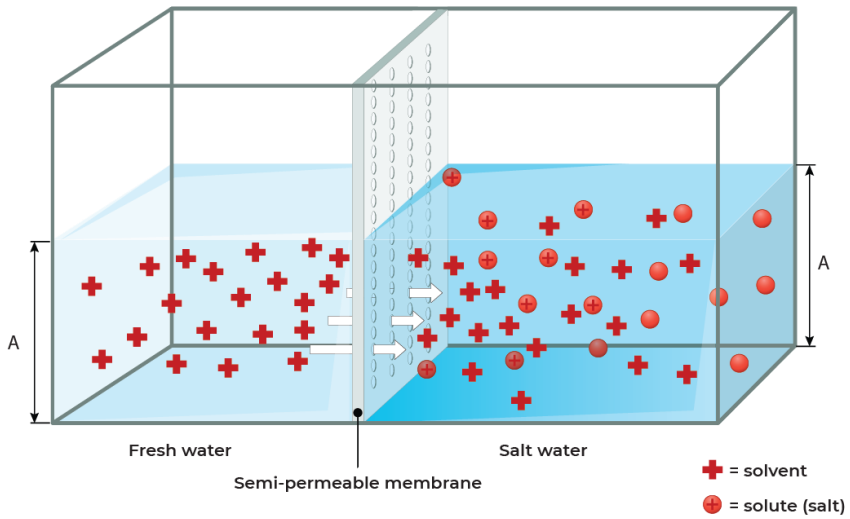
- Why do we test concrete slabs for pH?

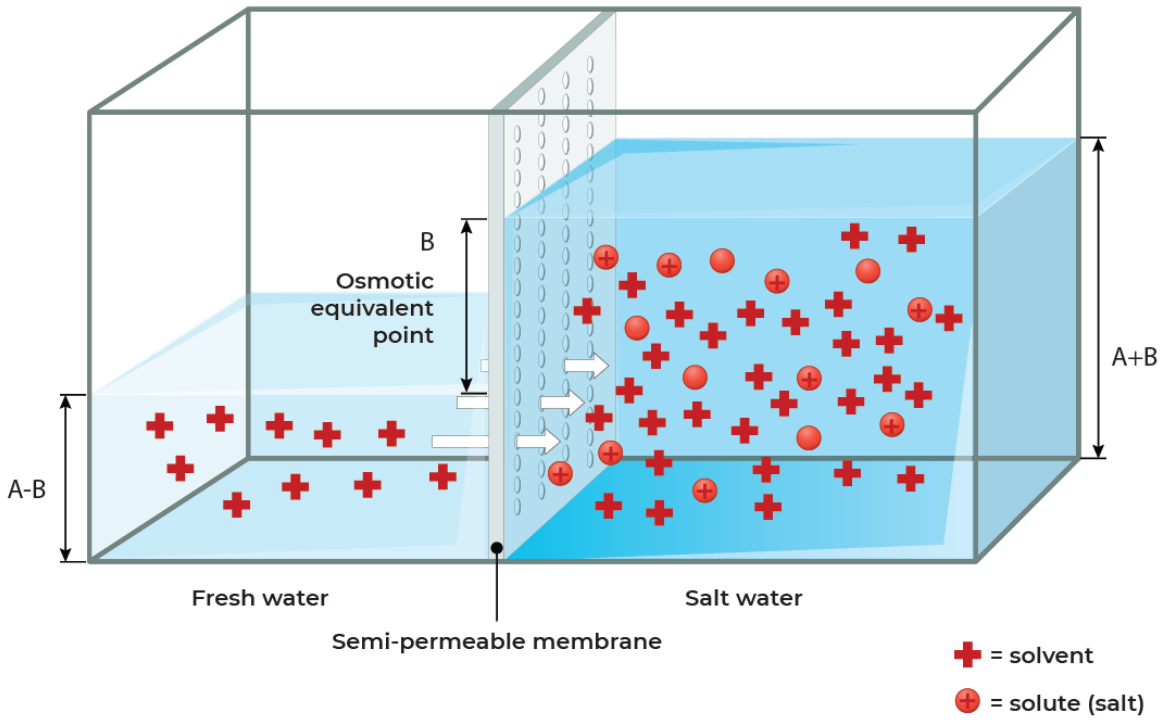
QUESTION

- So what's all this talk about salt deposits on the surface of a concrete slab have to do with floor installation?
- Salts are hygroscopic and absorb moisture
  - Zinc chloride, sodium chloride, and sodium hydroxide crystals are hygroscopic, as are silica gel, honey, nylon, and ethanol.

WHAT IS OSMOSIS

A process by which molecules of a solvent tend to pass through a semipermeable membrane from a less concentrated solution into a more concentrated one, thus equalizing the concentrations on each side of the membrane





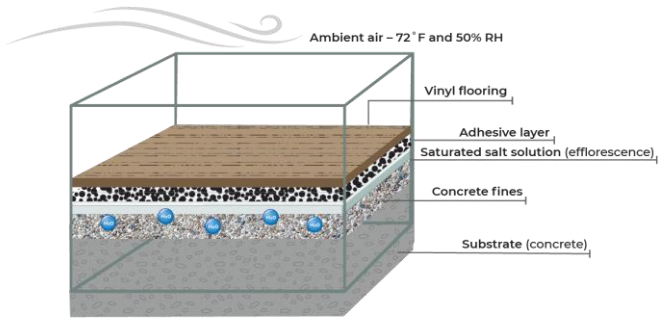
WHAT IS OSMOSIS

SEMI PERMEABLE MEMBRANES AND HIGH SALT CONCENTRATIONS CREATE A SALT PUMP BRINGING WATER FROM ONE SIDE INTO THE AREA OF HIGH SALT CONCENTRATION.

OSMOSIS IS USED IN DIALYSIS MACHINES

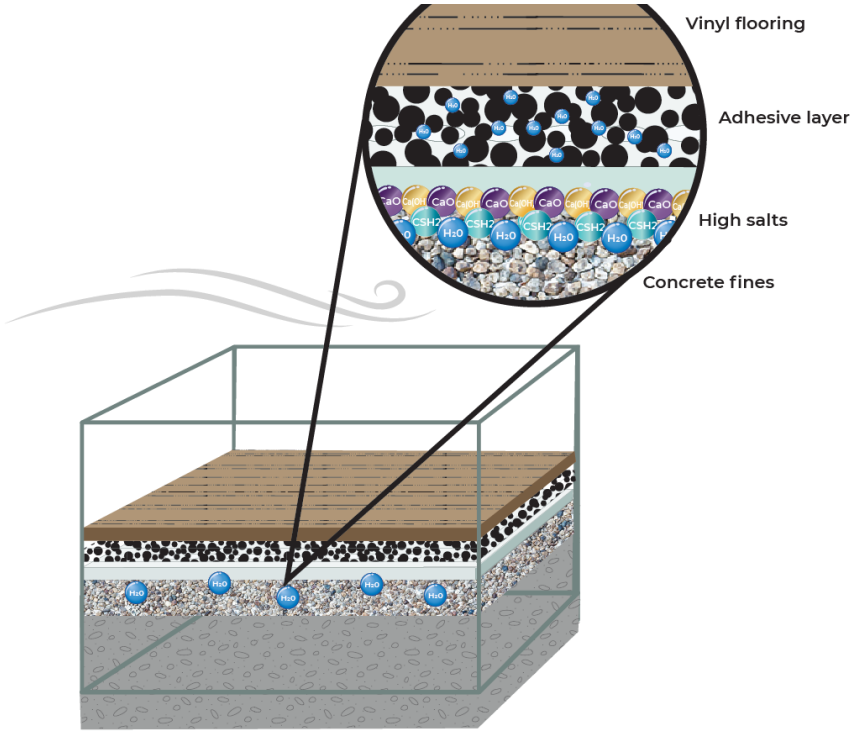
SEMI PERMEABLE MEMBRANES ALLOW FOR SPECIFIC TOXIN REMOVAL LEAVING GOOD MATERIALS BEHIND.

WHAT ARE THE CAUSES OF OSMOTIC BLISTERING



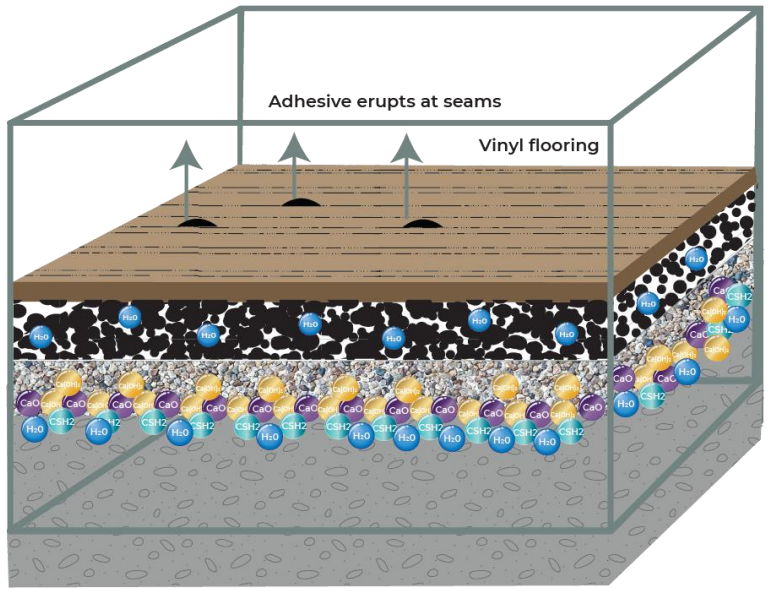
- High concentration of soluble salts on the surface create the potential for osmotic action
- Cement fines act as the semi permeable membrane
- Water is pulled from the concrete to dilute the salt concentration but since it cannot go back down into the concrete a build up of salt solution is created

HOW DOES OSMOSIS RELATE TO RESILIENT FLOORS

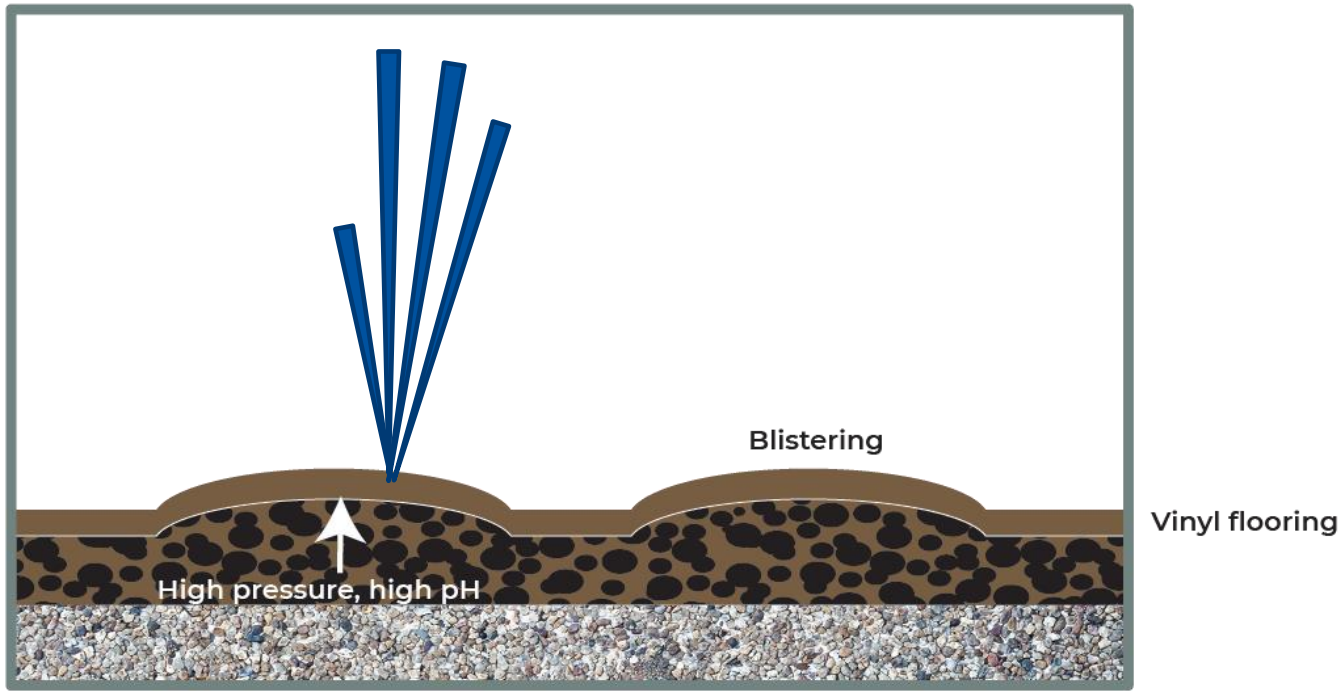


- Osmotic action will only stop when the water source runs out.
- Solution created is high pH which is detrimental to adhesives and patching compounds.
- Excessive pressure can be generated due to the action of the salt pump

HOW DOES OSMOSIS RELATE TO RESILIENT FLOORS



- Liquid accumulates in the adhesive layer forcing blisters or causing liquified adhesive to ooze up through seams



HOW DOES OSMOSIS AND CONCRETE RELATE

OSMOTIC BLISTERING OCCURS UNDER EPOXY COATINGS AND RESILIENT FLOORING

HOW DOES OSMOSIS EFFECT HIGH MOISTURE ADHESIVES?

HIGH PH CAUSES SIGNIFICANT IMPACT ON ADHESIVE INTEGRITY

HOW TO AVOID OSMOTIC ACTIVITY

PERFORM PH TEST

HOW TO AVOID THESE SITUATIONS

- Do a pH test
- Do a petrographic analysis of the slab

Inorganic Surface Chemistry

Client:	[redacted]	MI#:	20212
Project:		P.O.#:	N/A
Location:		Method:	Ion Chromatography

Sample ID		Depth BTC*	Sodium	Potassium	Chloride	Sulfate
			(ppm)			
Core 1	20212–01A	0-3 mm	2330	2520	70	3930
	20212-01B	3-6 mm	130	240	50	3030

**BTC = Below Top Surface of the Core*

Data Anomaly

In the presence of elevated levels of concrete relative humidity, near-surface concentrations of inorganic salts (e.g., metasilicate, chloride, and/or sulfate-rich compounds) and/or organic contaminants (e.g., oils & cleaning product residues) have the potential to adversely effect the bond integrity between the flooring system and the concrete substrate. Specialized surface preparation methods may help to diminish the influence of the surface contaminants, thereby contributing to improved adhesion of the flooring system.

SUMMARY

- High moisture adhesives need proper conditions in order to coalesce into final film
- Temperature, moisture and pH can affect coalescence
- High pH conditions are unavoidable on fresh concrete
- Excess bleed water creates potential for osmotic activity

- Always perform pH test
- Always understand internal concrete RH levels

FCICA

THANK YOU FOR YOUR ATTENTION

Jeffrey B Johnson, FCIS Business & Marketing Manager

jbjohnson@mapei.com

FCICA