PCA

Concrete Technology and Codes

Chemical Admixtures

Admixtures

- DEFINITION:
  Admixtures are any ingredients in concrete other than:

  Water

  Aggregates

  Cement

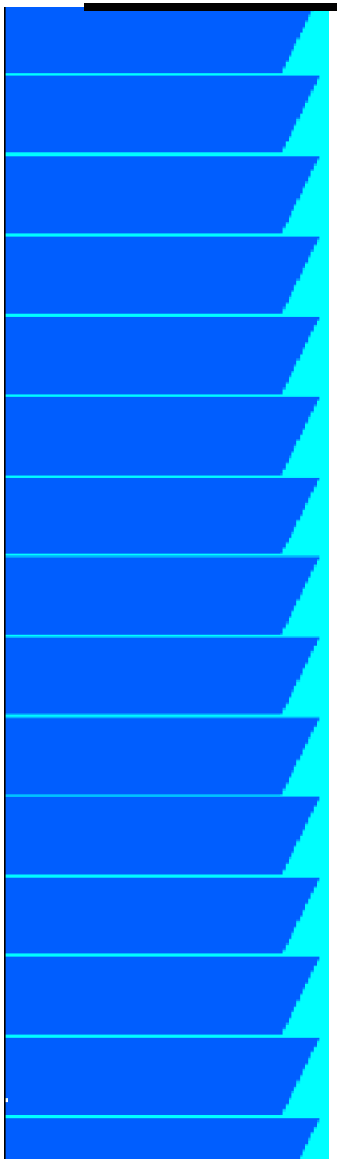
  & Fibers

  Added to the batch immediately before or during mixing

(ACI)

Why Use Admixtures?

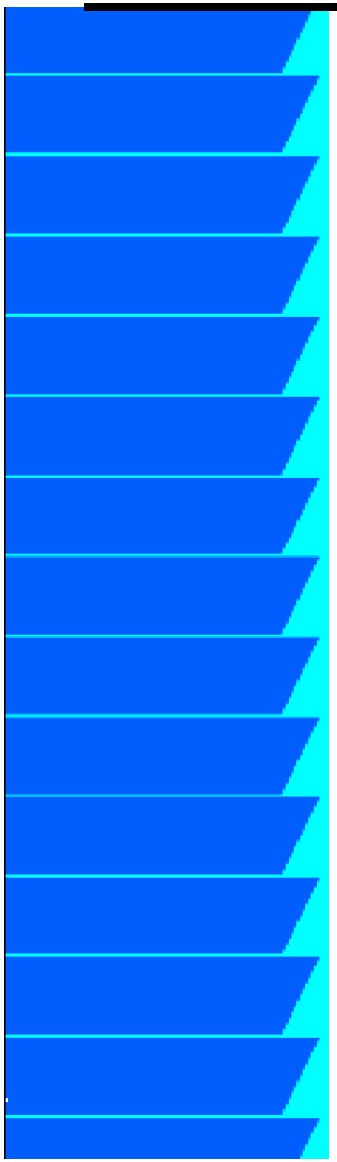
To Modify fresh concrete properties



- decrease water content
- increase workability
- retard or accelerate setting time
- reduce segregation
- reduce the rate of slump loss
- improve pumpability, placeability, finishability
- modify the rate and/or capacity for bleeding

Why Use Admixtures?

To Modify hardened concrete properties



- improve impact and abrasion resistance
- inhibit corrosion of embedded metals
- reduce plastic shrinkage cracking
- reduce long term drying shrinkage
- produce colored concrete
- produce cellular concrete

Current Admixture Standards

- Air Entraining ASTM C260
- Chemical ASTM C494
- Calcium Chloride ASTM D98
- Foaming Agents ASTM C869
- Admixtures for shotcrete ASTM C1141
- Flowing Concrete ASTM C1017
- Grout Fluidifier ASTM C937
- Pigments ASTM C979

Air Entrainment

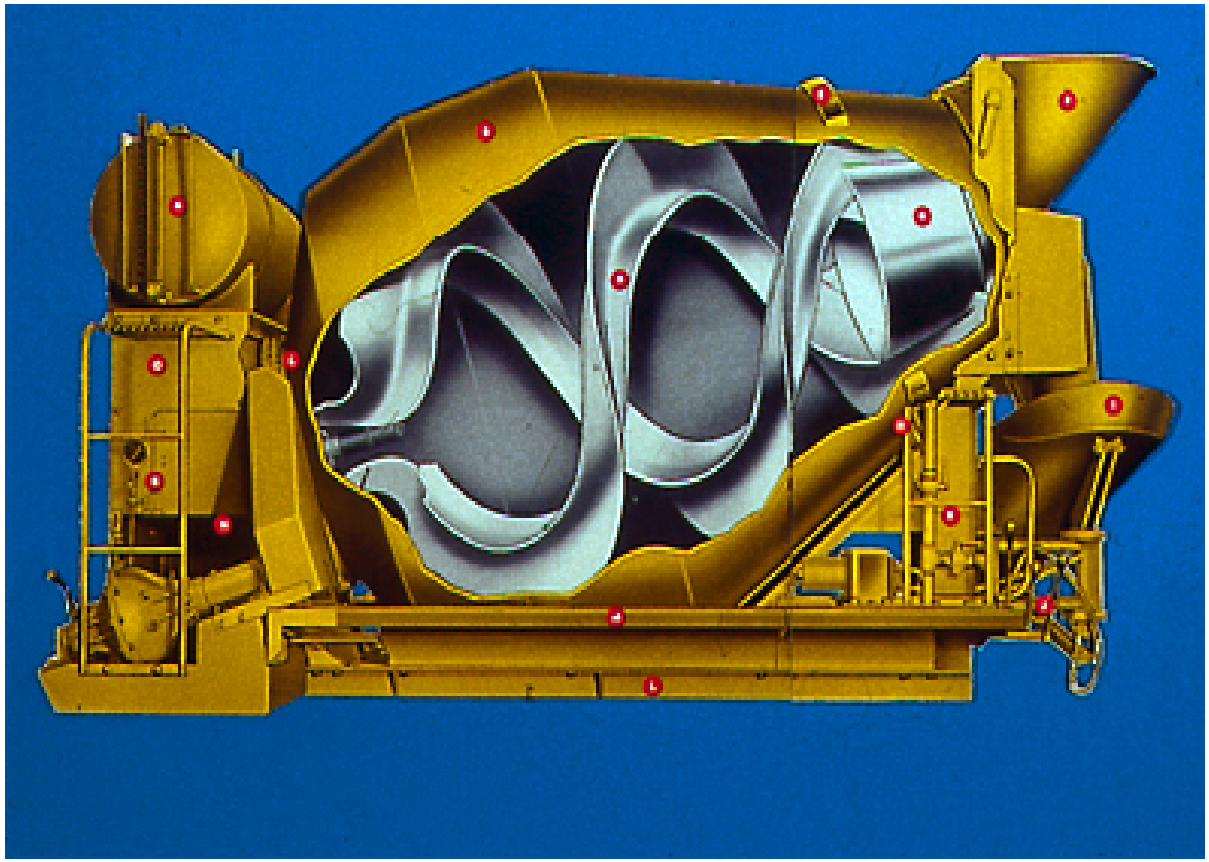
- **Air-Entraining Agents are primarily used to stabilize tiny bubbles generated in concrete to protect against freezing and thawing cycles.**

Air-Entraining Agents

- 4 Categories:
  1. Wood Derived Products:
     Vinsol® resin, Tall oil, Wood rosin
  2. Synthetic Materials:
     Alky-aryl sulfonates and sulfates
  3. Vegetable Acids:
     Coconut fatty acids, Alkanolamine salt
  4. Miscellaneous:
     Alkali/alkanolamine acid salts, Animal tallows
- Must pass ASTM C260

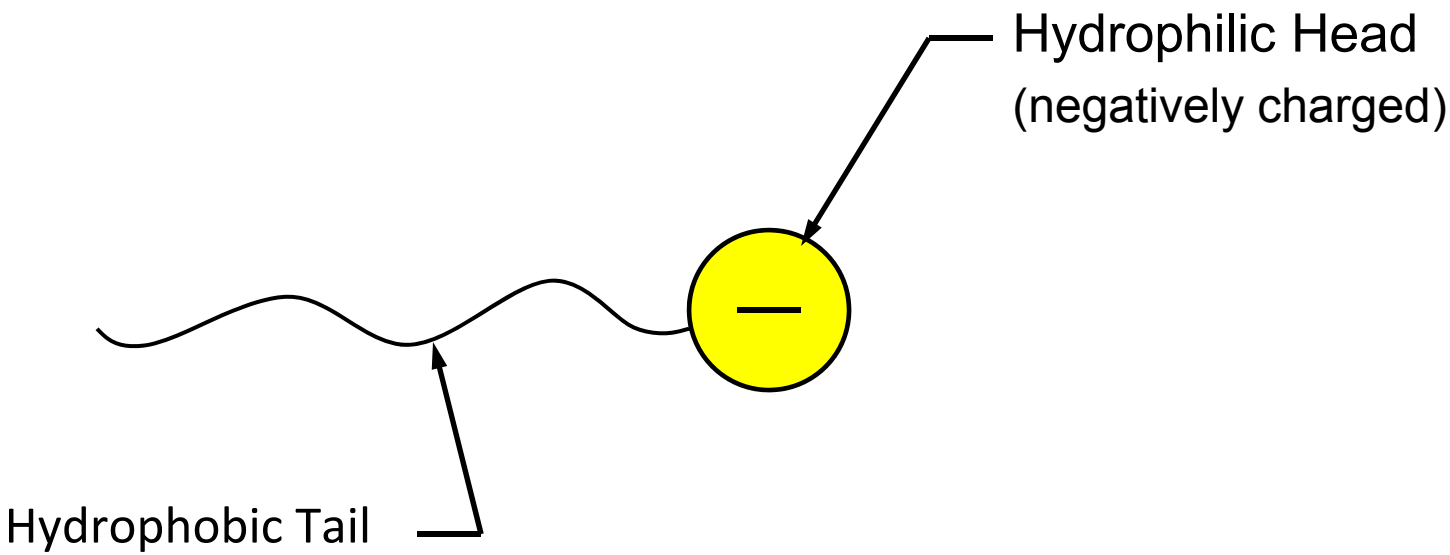
Mechanism of Air-entrainment

- Air is Generated into Concrete During the Mixing Process

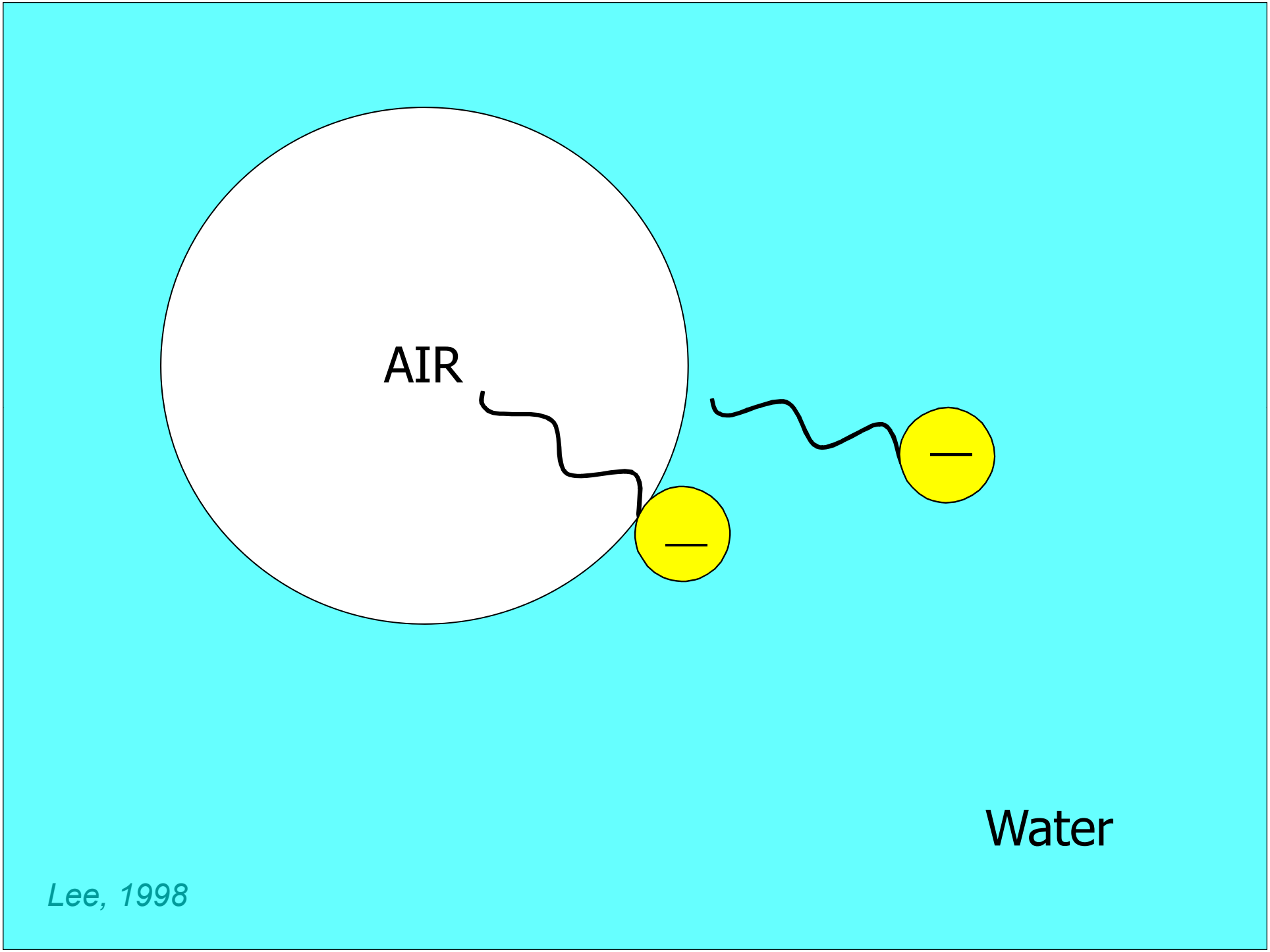


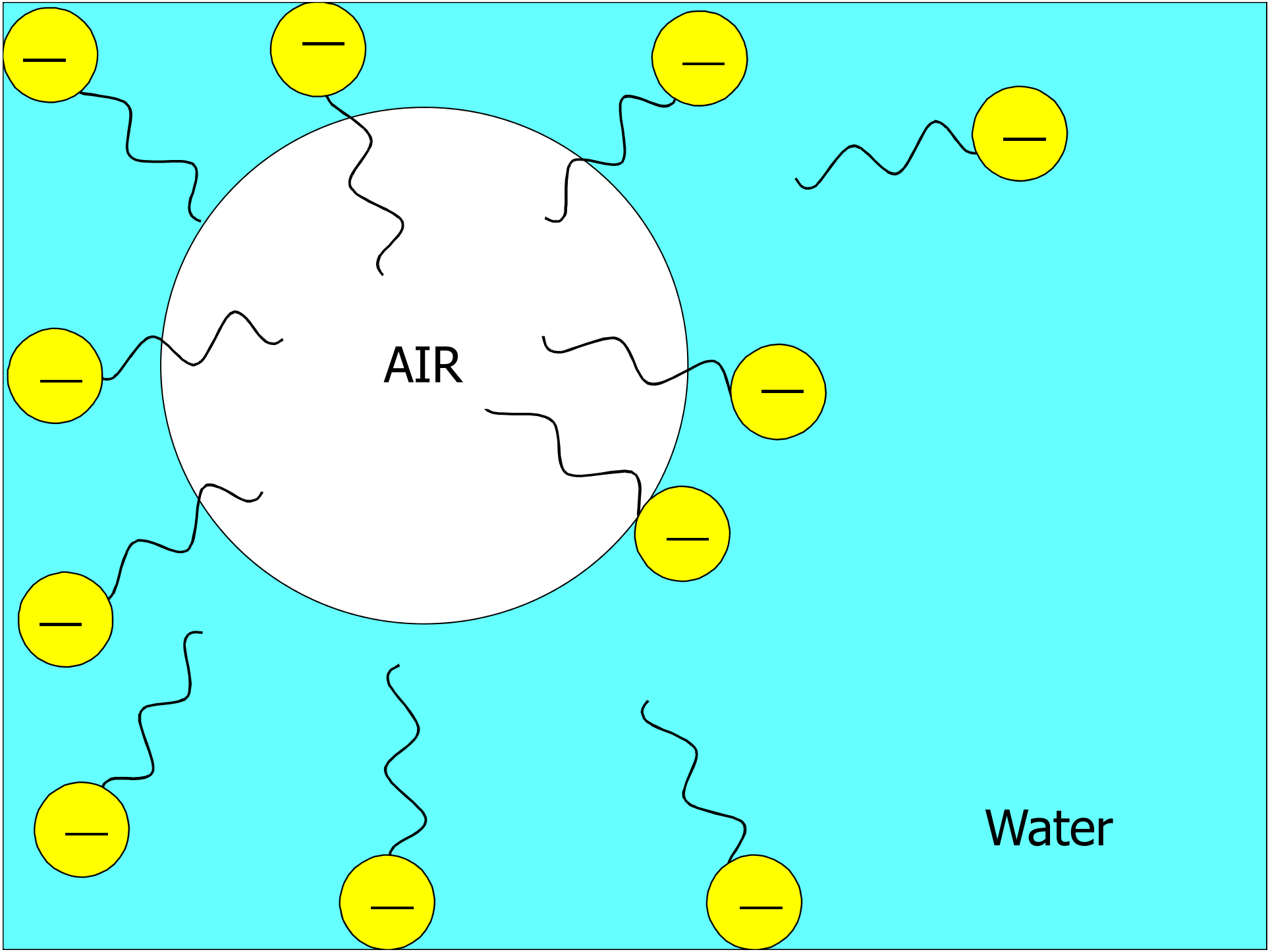
  - Entrapped vs. Entrained Air...

Typical Anionic Surfactant



Air-Entraining Admixtures are typically surfactants that have a negatively charged head which is hydrophilic, and a hydrophobic tail.


AIR
Water
Lee, 1998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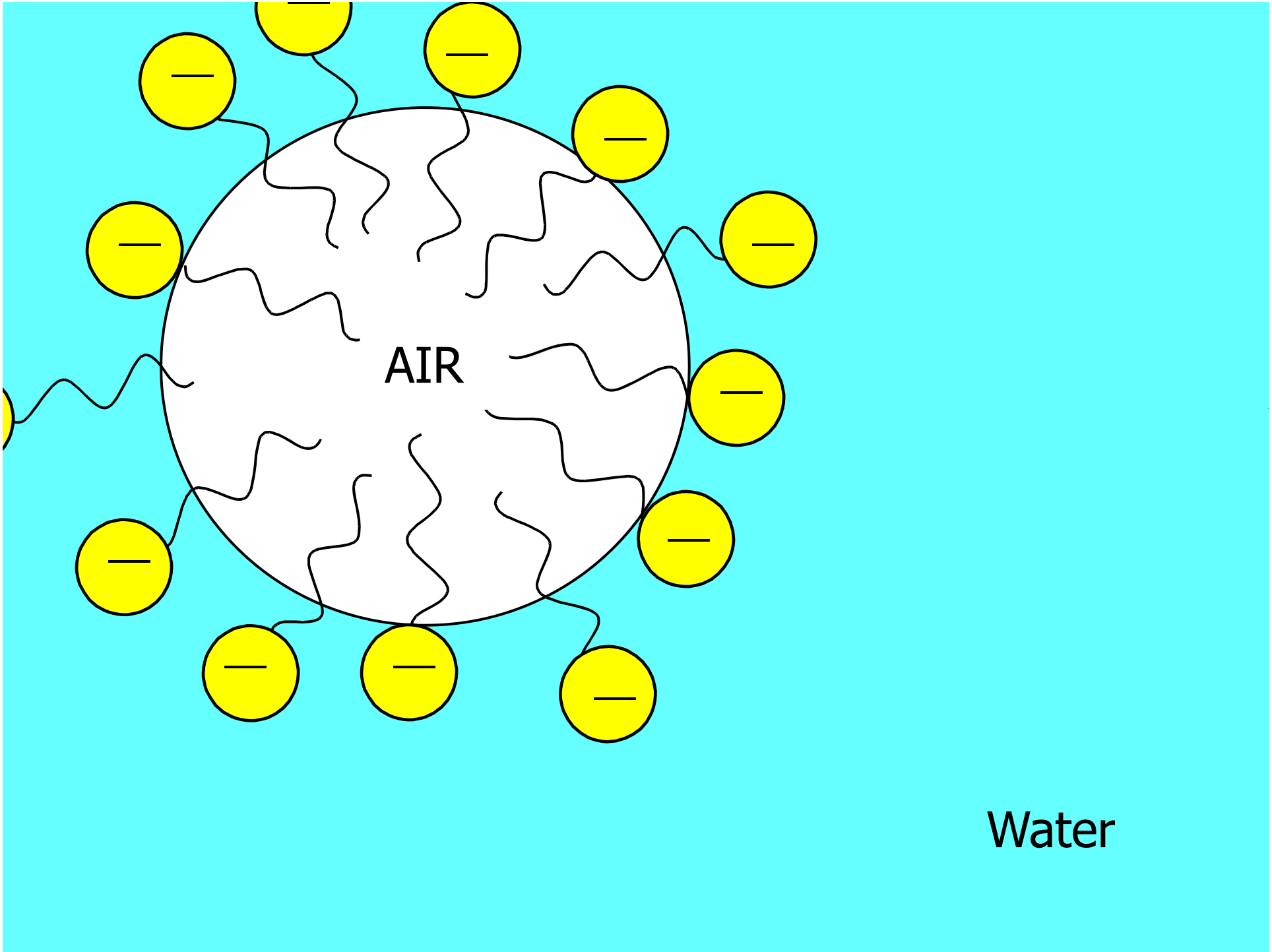
Water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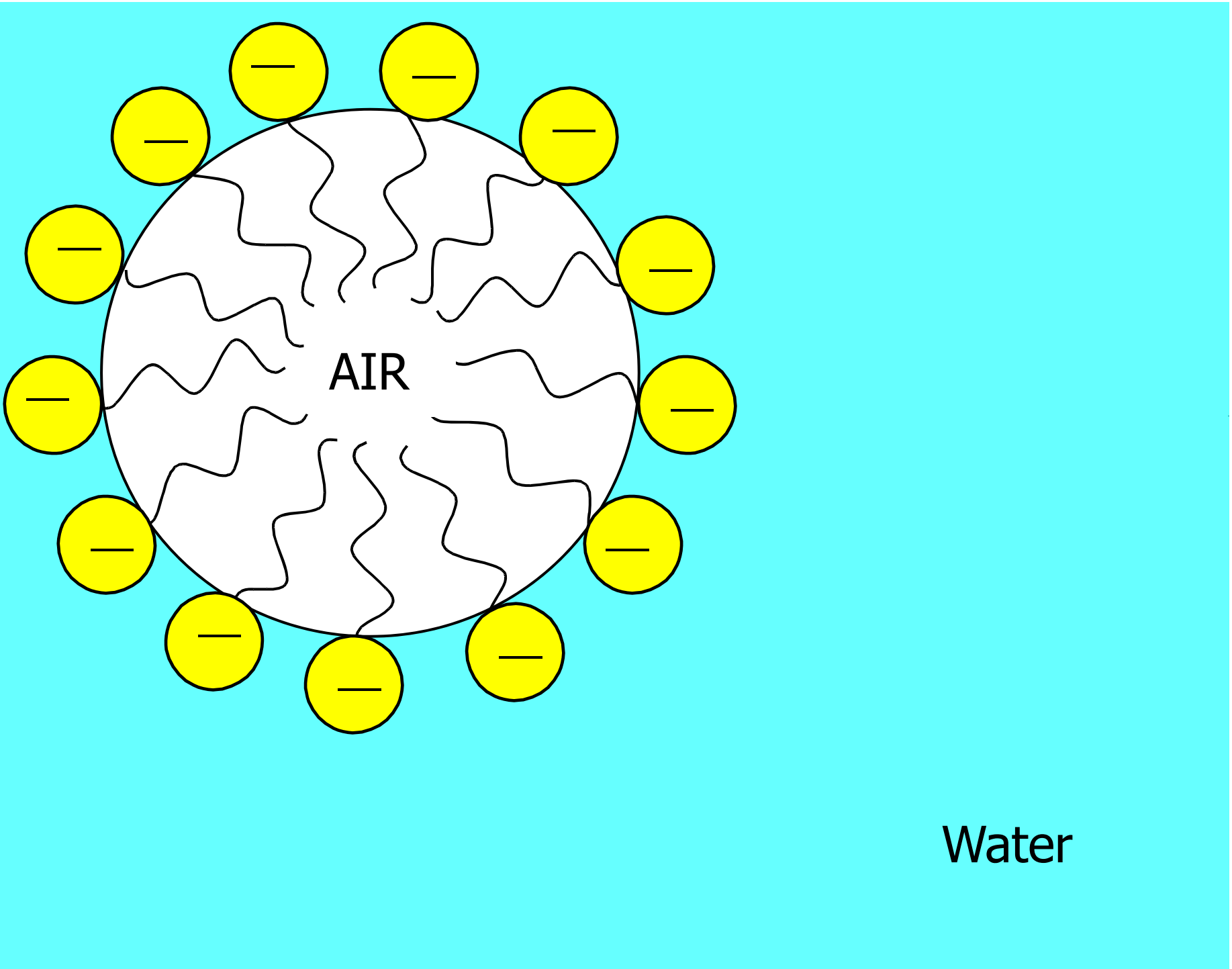
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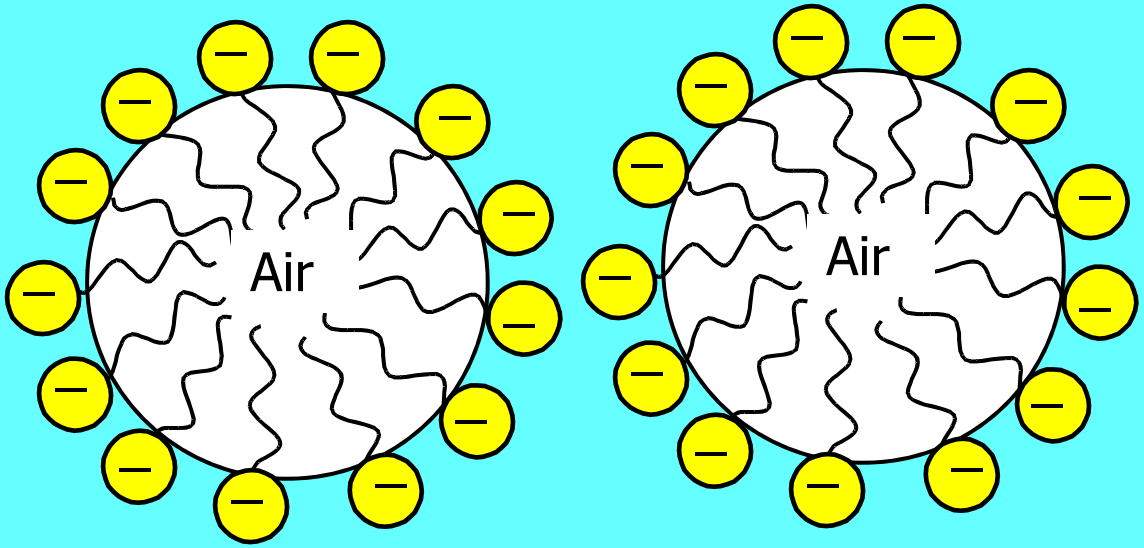
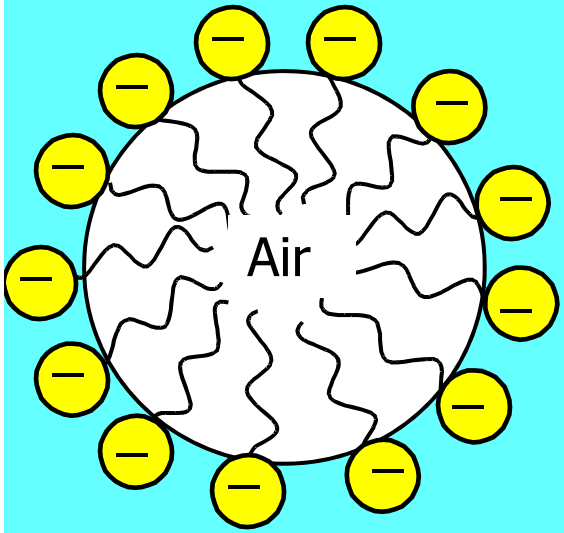
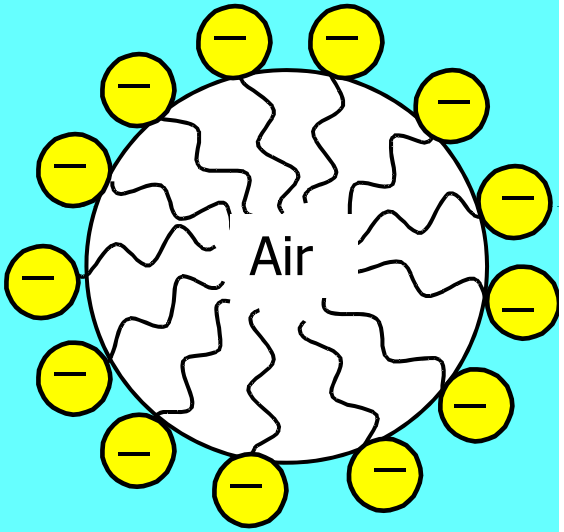


Water





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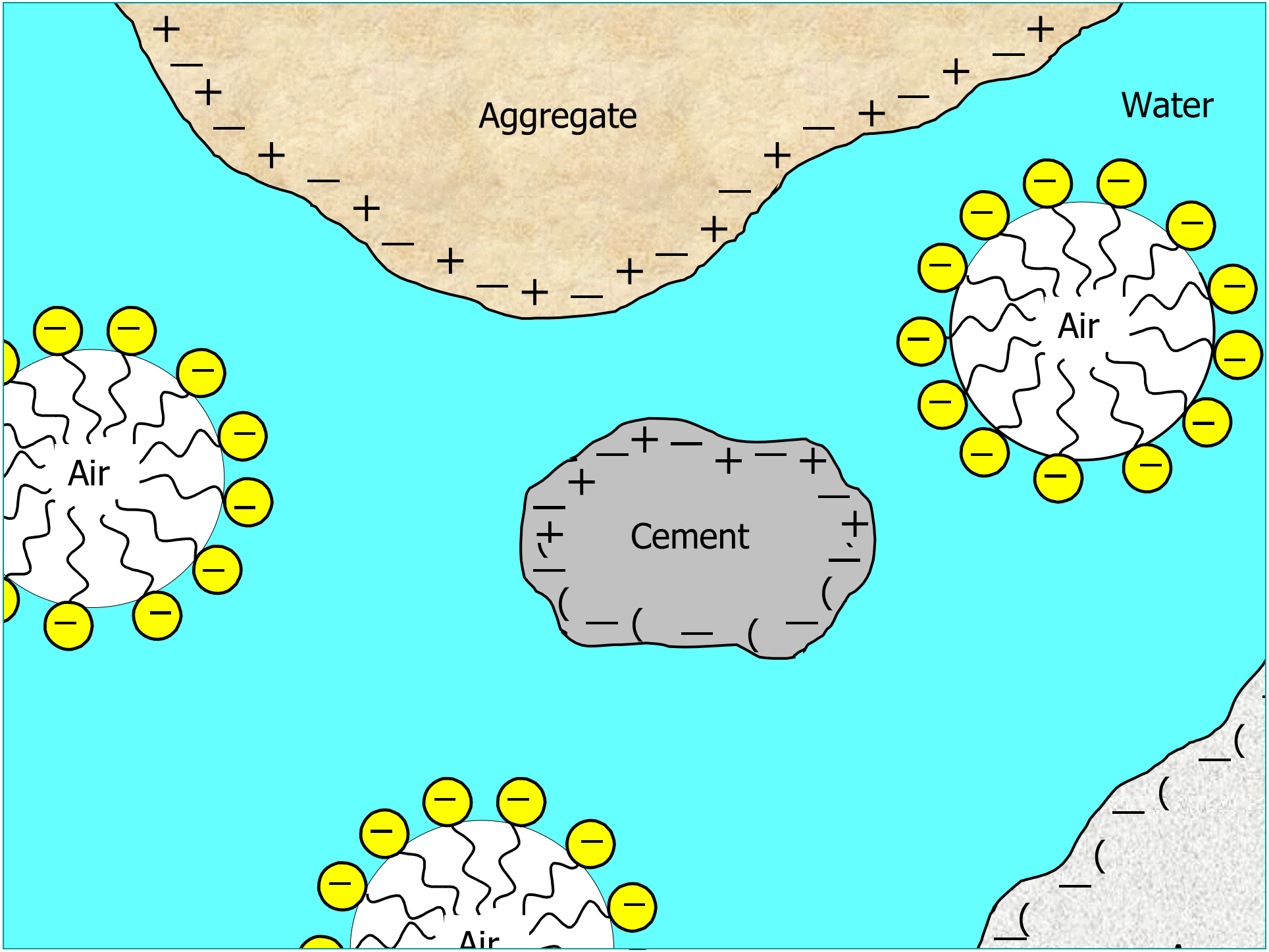
Aggregate
Water
Air
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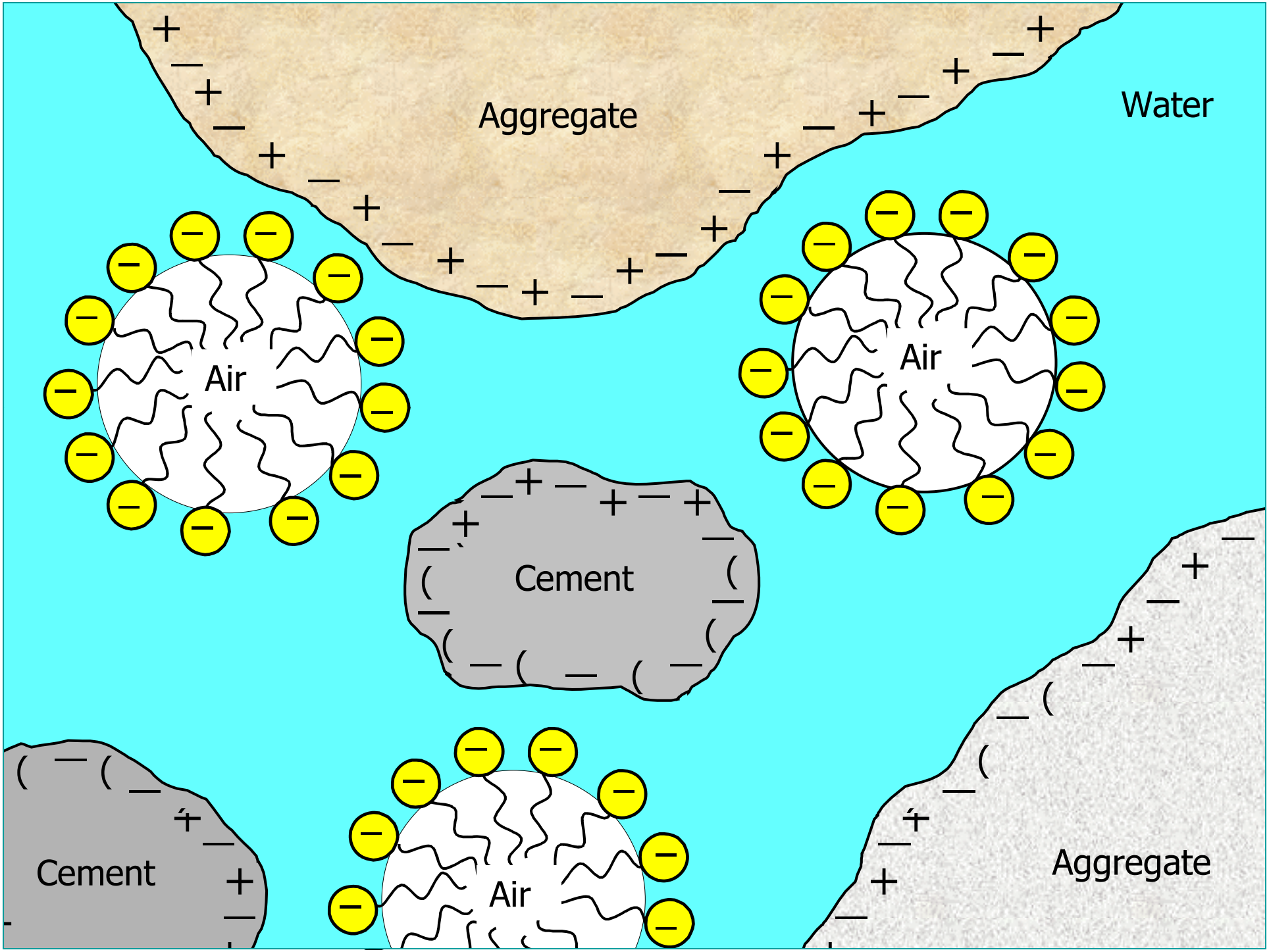
Cement
Air


Aggregate
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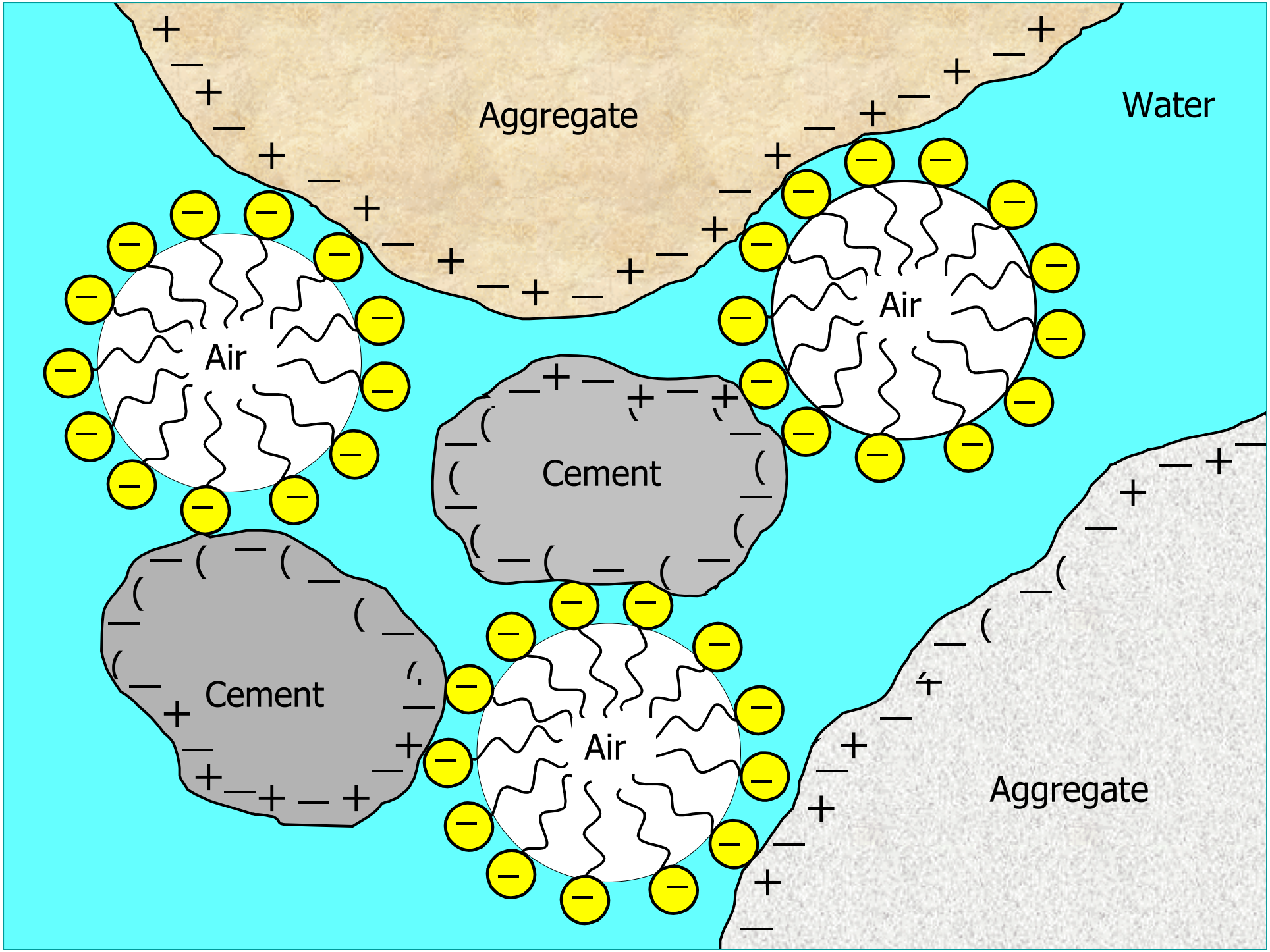
Aggregate


Aggregate
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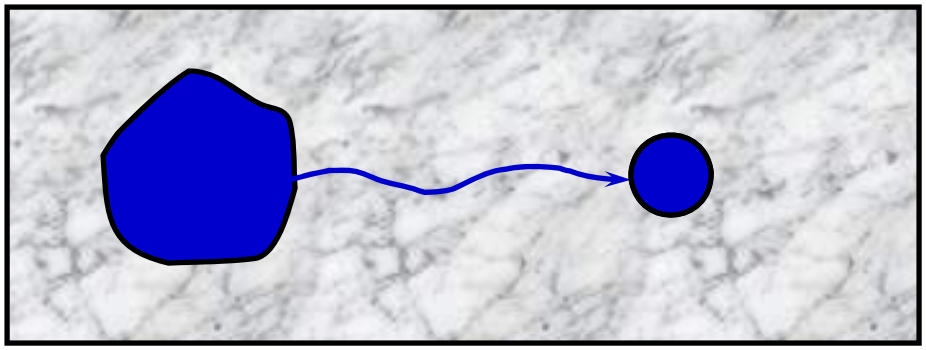
Aggregate



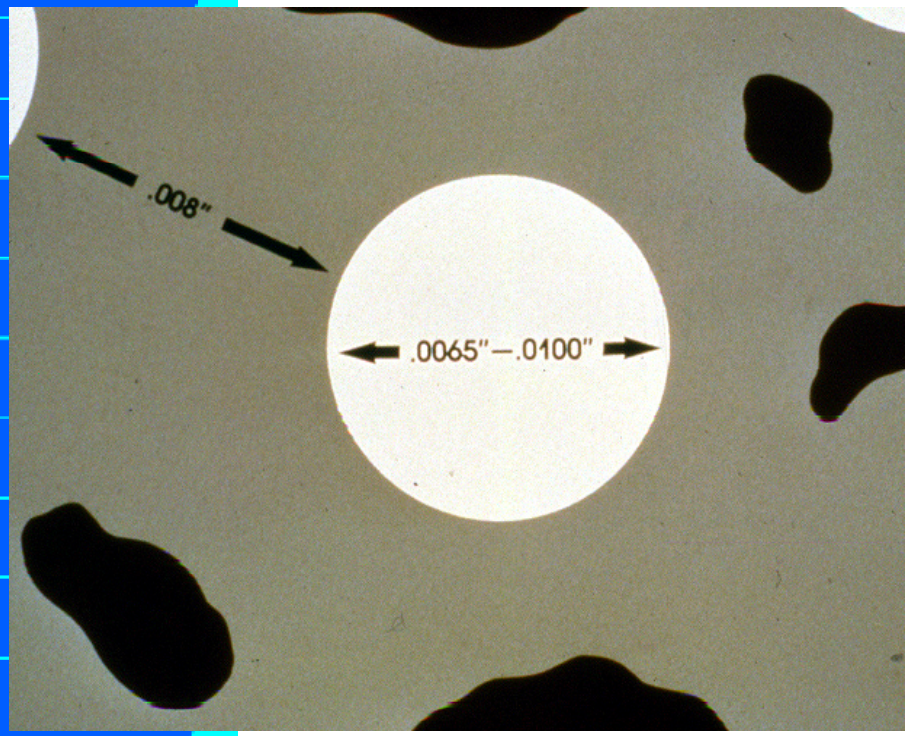
The amount of hydraulic pressure generated as a result of the water in the void (or capillary) being expelled depends on:

- the degree of saturation
- the rate of freezing
- the permeability of the surrounding paste
- the distance to the nearest empty bubble

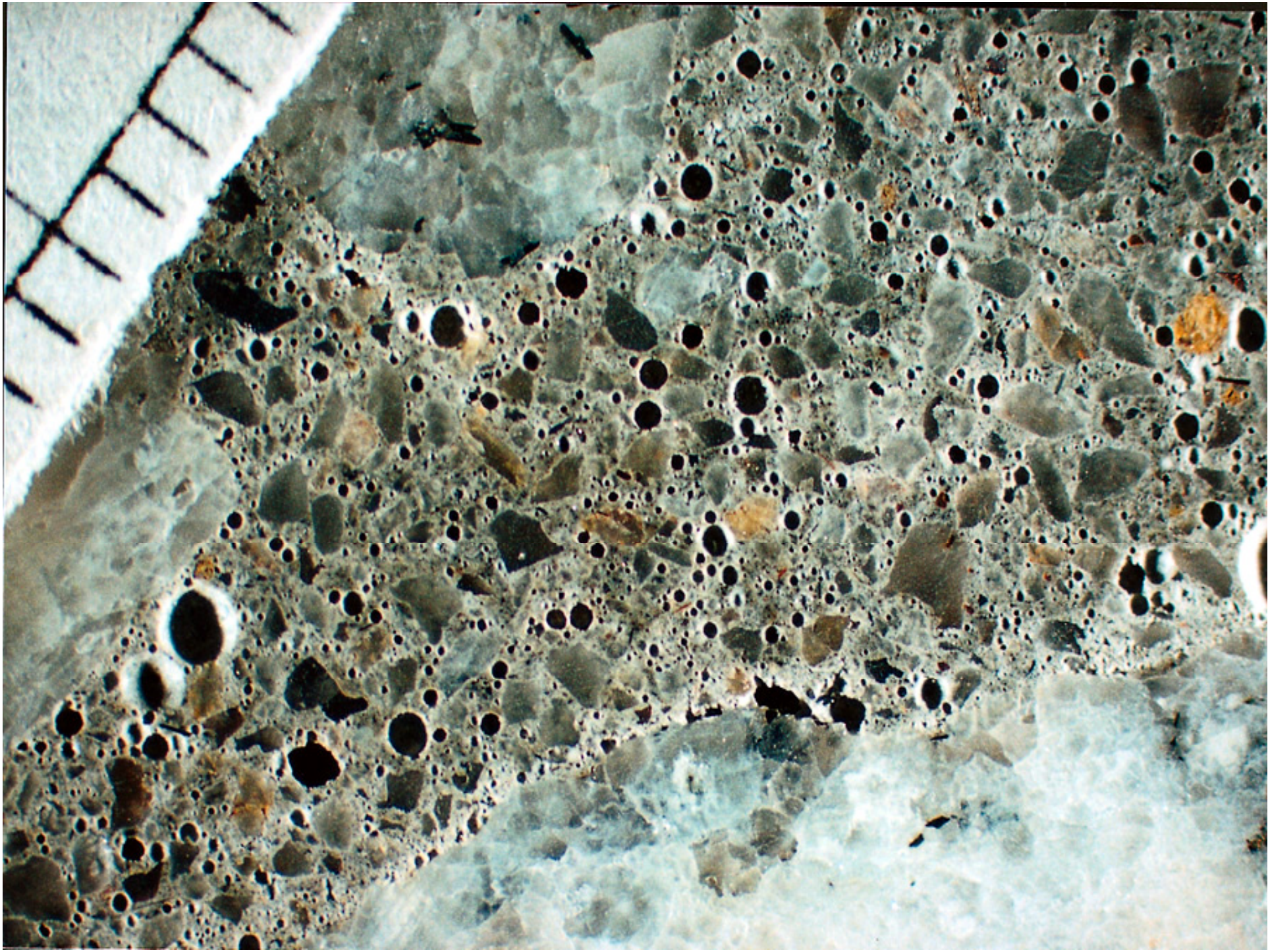
For Durability

ASTM C457

- Spacing factor $\leq$ 0.008 in (0.203 mm)
- Specific surface $\geq$ 600 in^2/in^3 (24 mm^2/mm^3)
- Voids per linear inch: 1.5 - 2 times % air



Spacing Factor and Specific Surface are More Important than Total Volume (%) of Air



Why Do We Focus on Volume of Air Content? (%Air)

Measuring Air Content

Pressure Method – ASTM C231

(not suitable for lightweight aggregate)

Volumetric Method – ASTM C173

(suitable for all types of aggregate)

Measuring Air Content

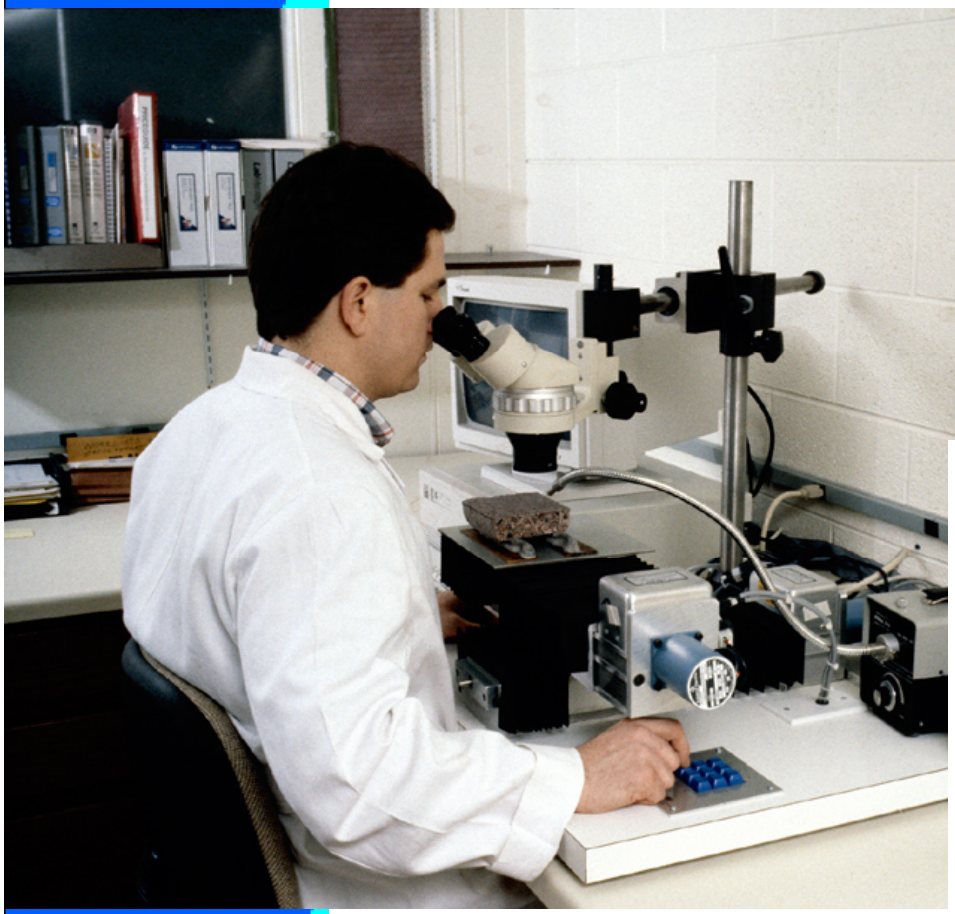
Chace Air Indicator – AASHTO T 199

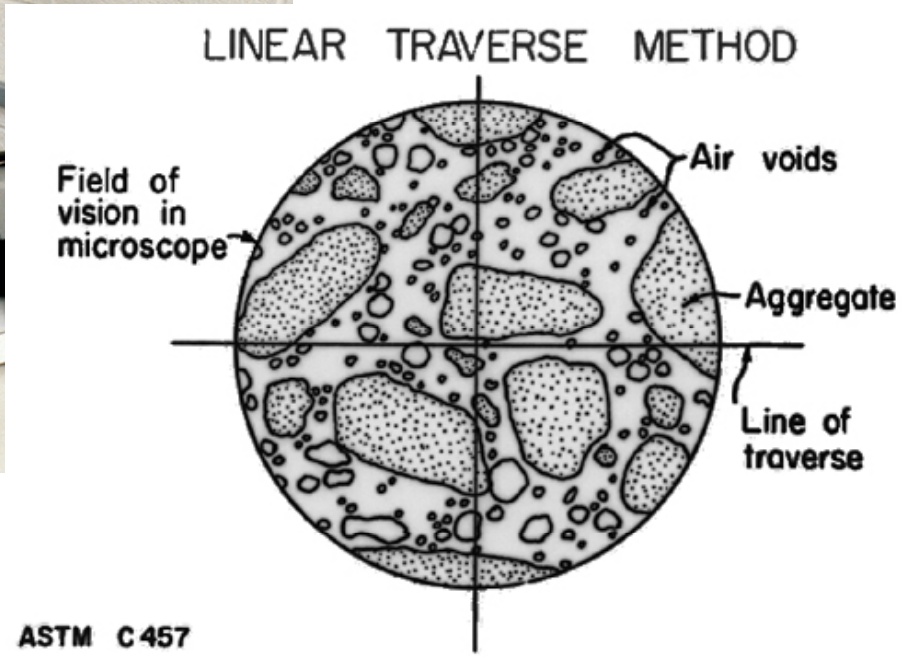
(uses mortar sample from concrete)

Gravimetric Method – ASTM C138

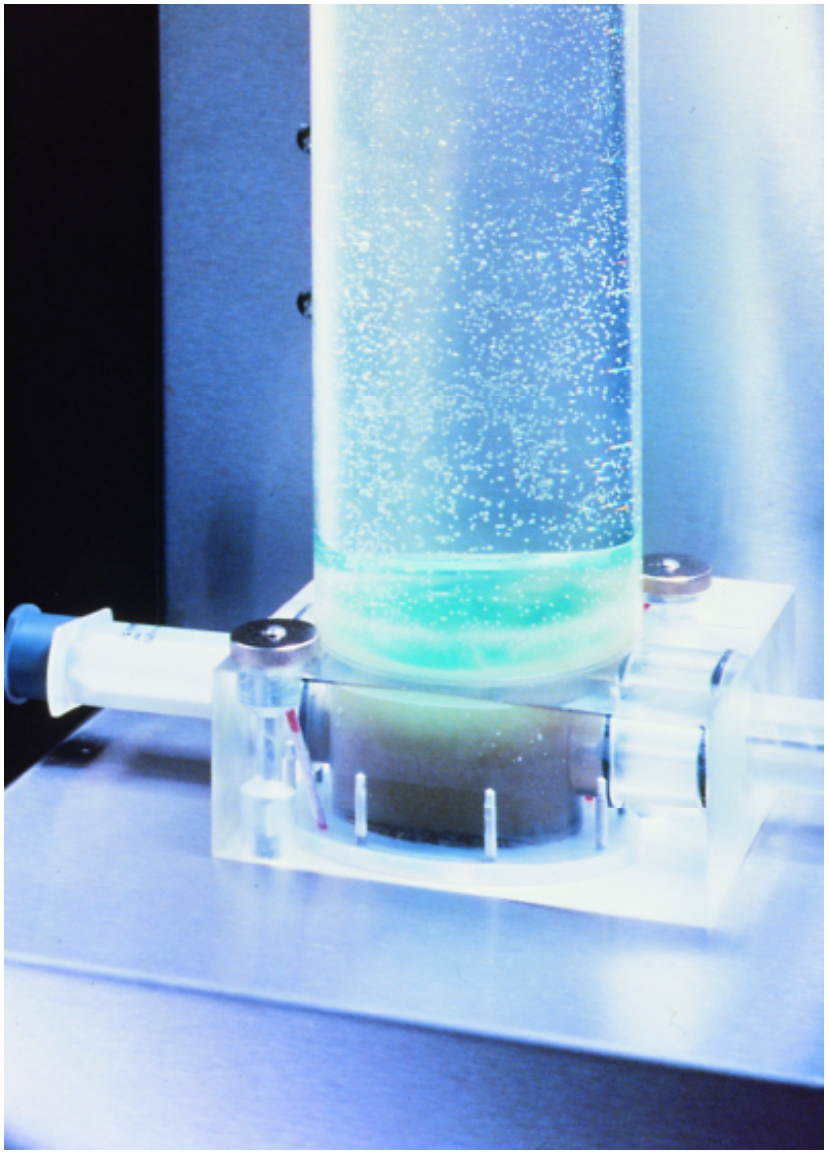
(requires accurate knowledge of relative density and absolute volumes of concrete ingredients)

Measuring Air in Hardened Concrete

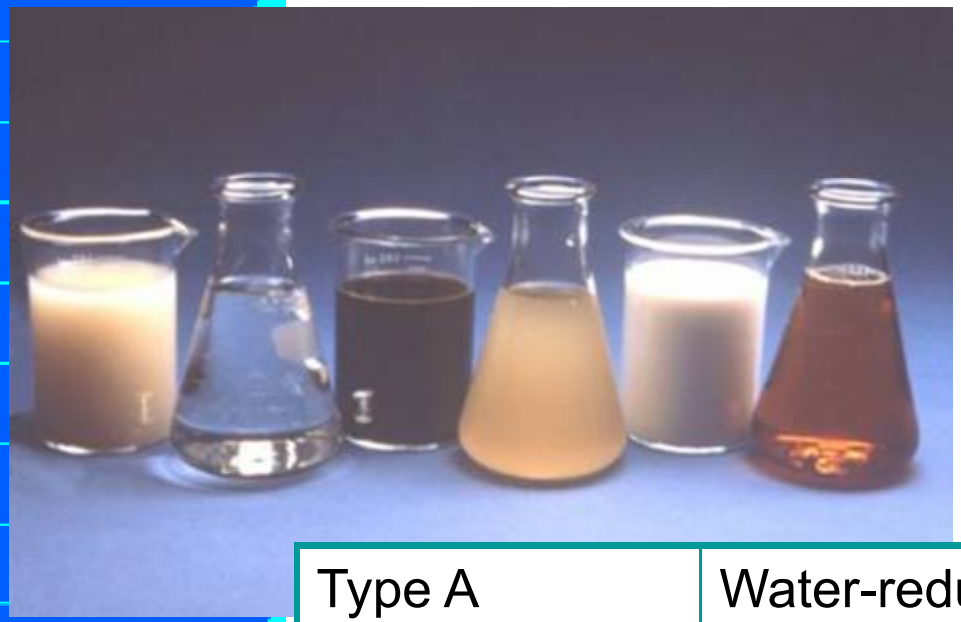




Fresh Concrete Air Void Analyzer



Chemical Admixtures



ASTM C494 (AASHTO M 194)

<u>Classification</u>

Water Reducing &

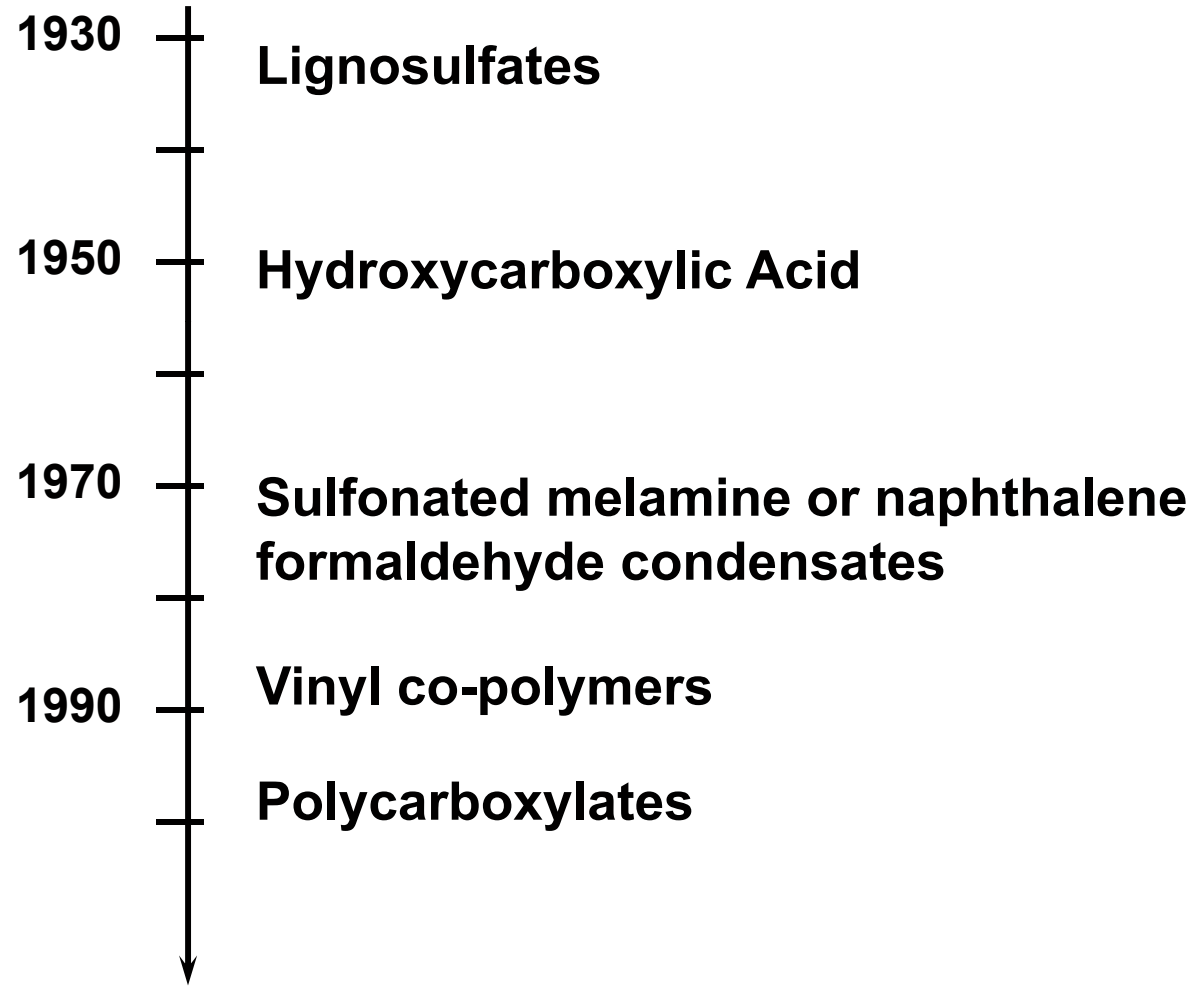
Set Control Admixtures

Type A	Water-reducer
Type B	Retarding
Type C	Accelerating
Type D	Water-reducing & retarding
Type E	Water-reducing & accelerating
Type F	Water-reducing, high range
Type G	Water-reducing, high-range & retarding

Water Reducers

- **Water Reducers are used for the purpose of reducing the quantity of mixing water required to produce a concrete of given consistency.**

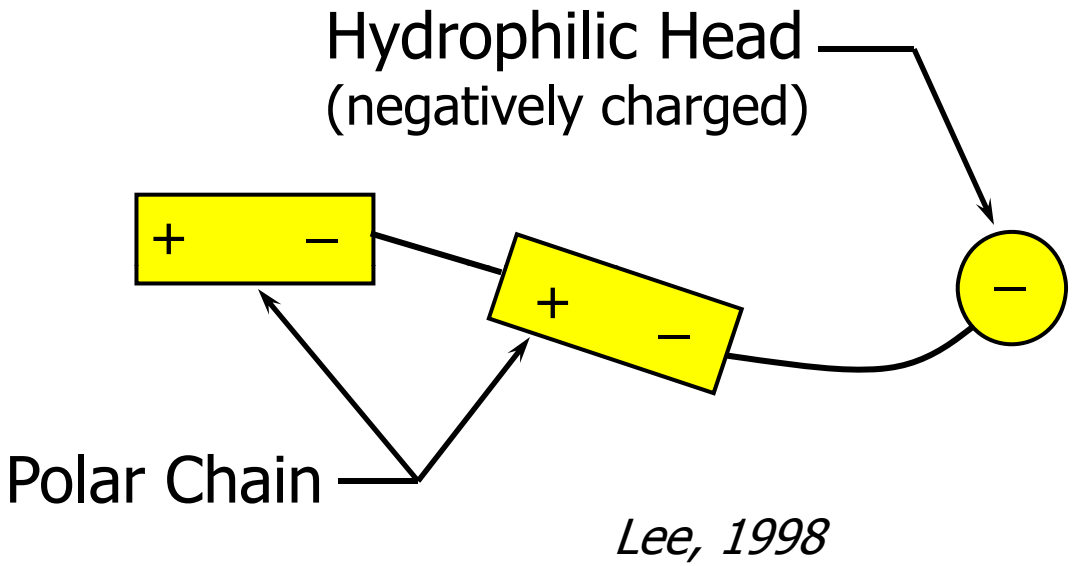
Types of Water Reducers



Classification

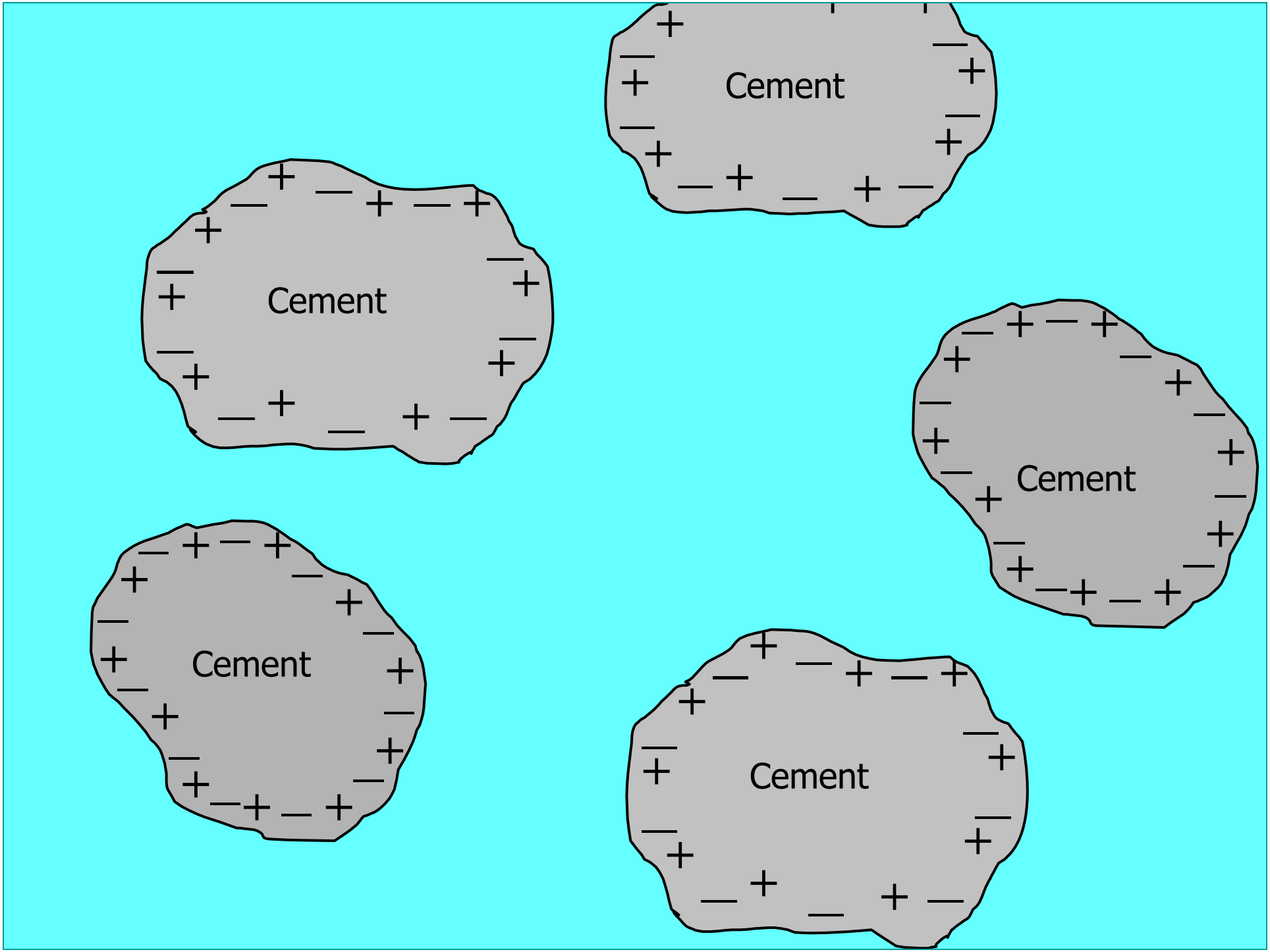
	% Water Reduction	or	Increased Workability
Conventional water-reducing admixtures (WRA)	5 - 10		
Mid-range water-reducing admixtures	6 - 12		
High-range water-reducing admixtures (HRWR) or Superplasticizers	12 - 30		

Typical Water Reducer



Lee, 1998

Water Reducers are typically hydrophilic surfactants which consist of a polar chain and a negatively charged head.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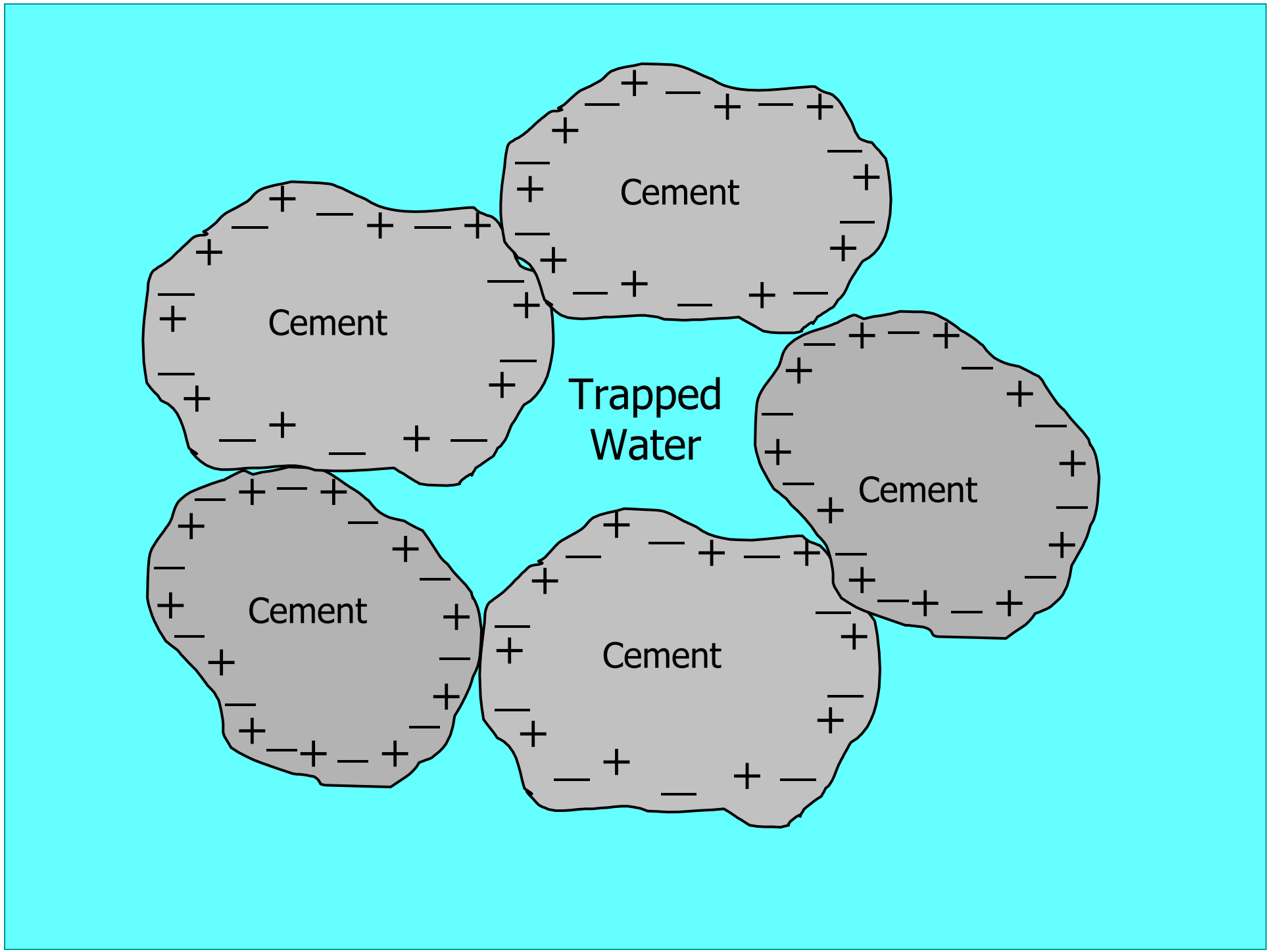
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Trapped
Water
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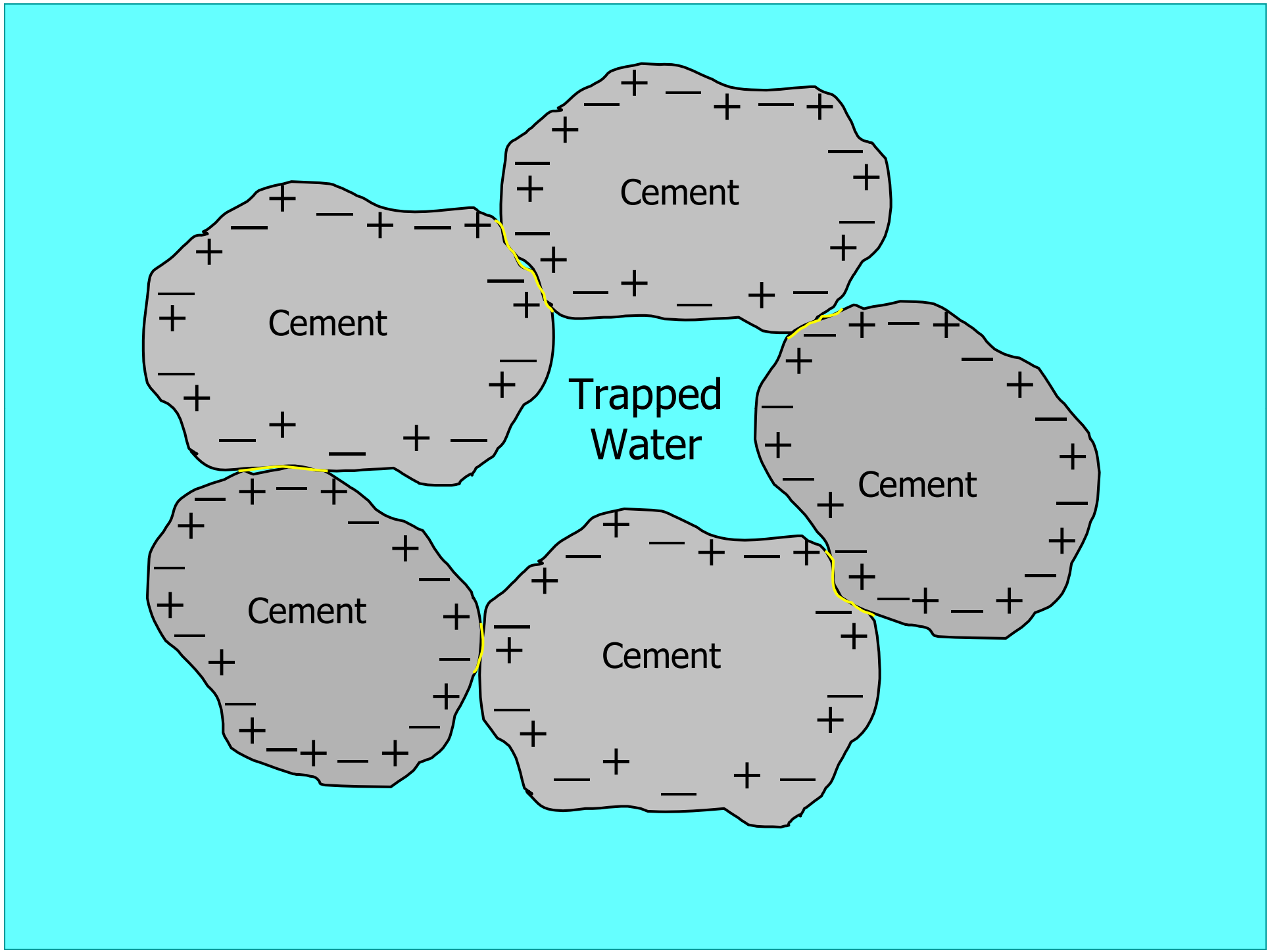
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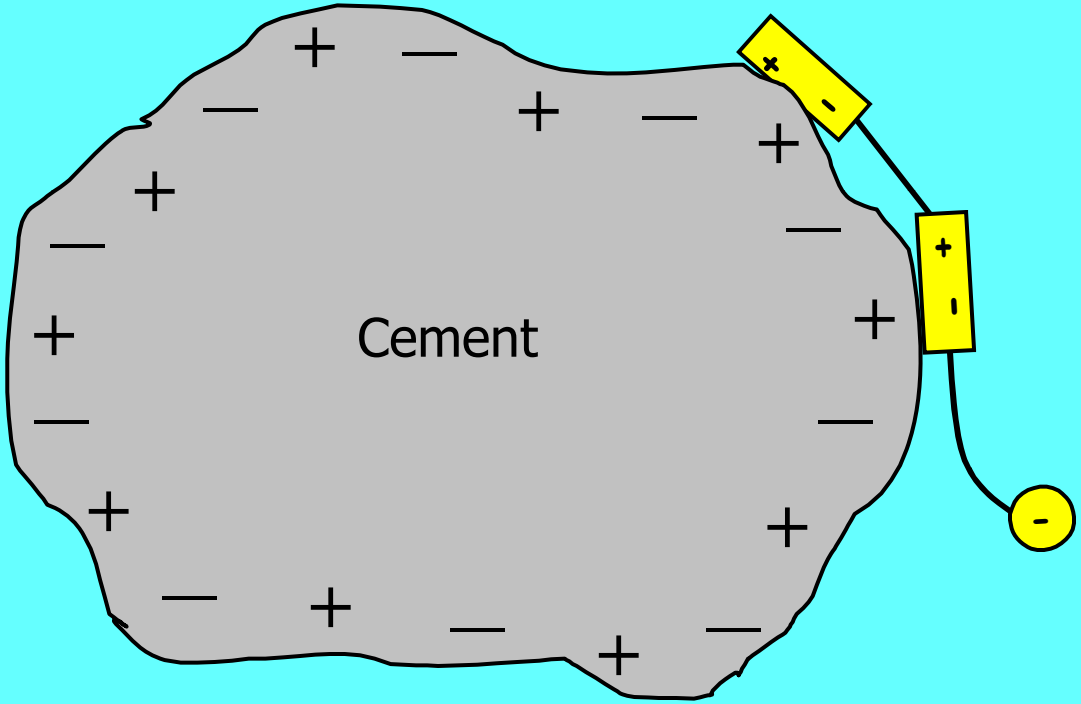
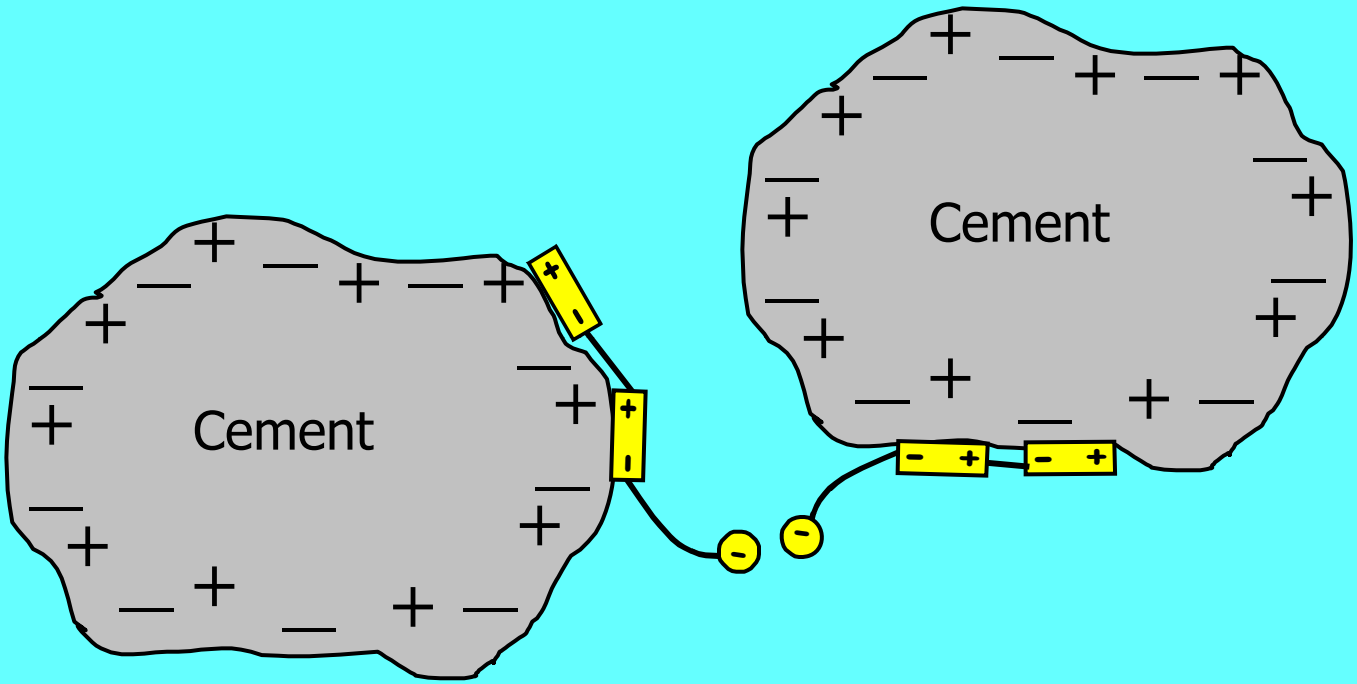


Lee, 1998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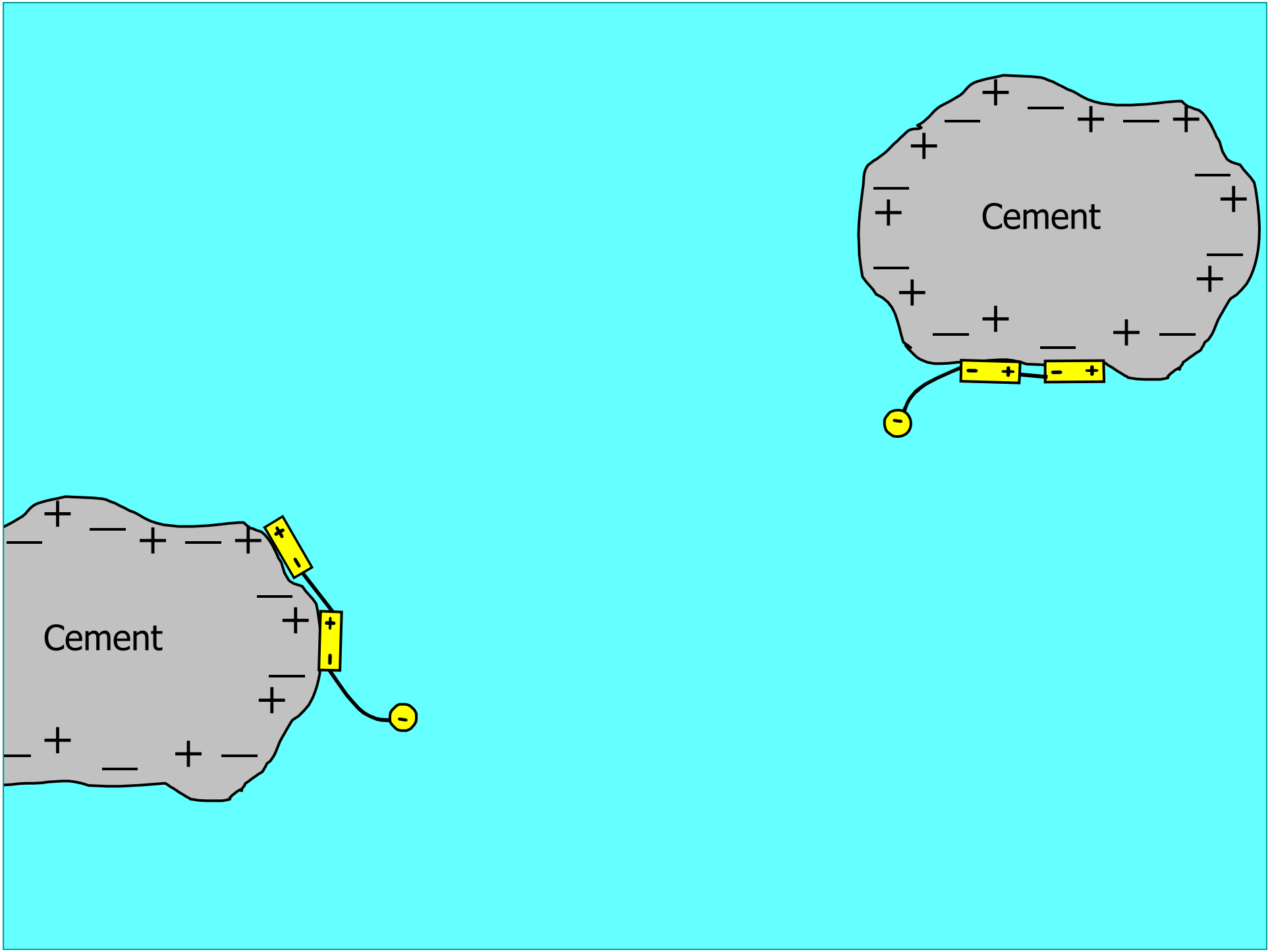
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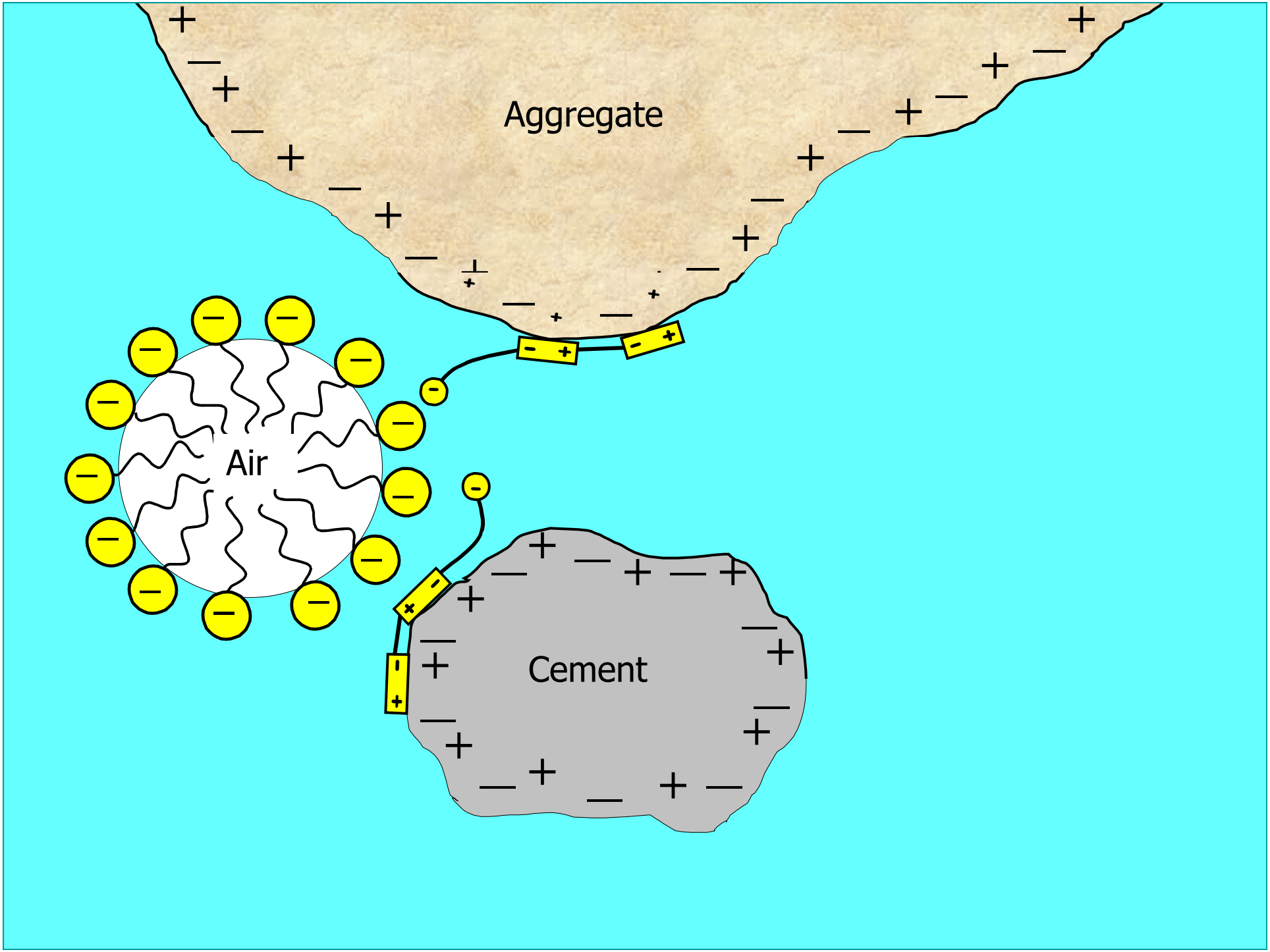
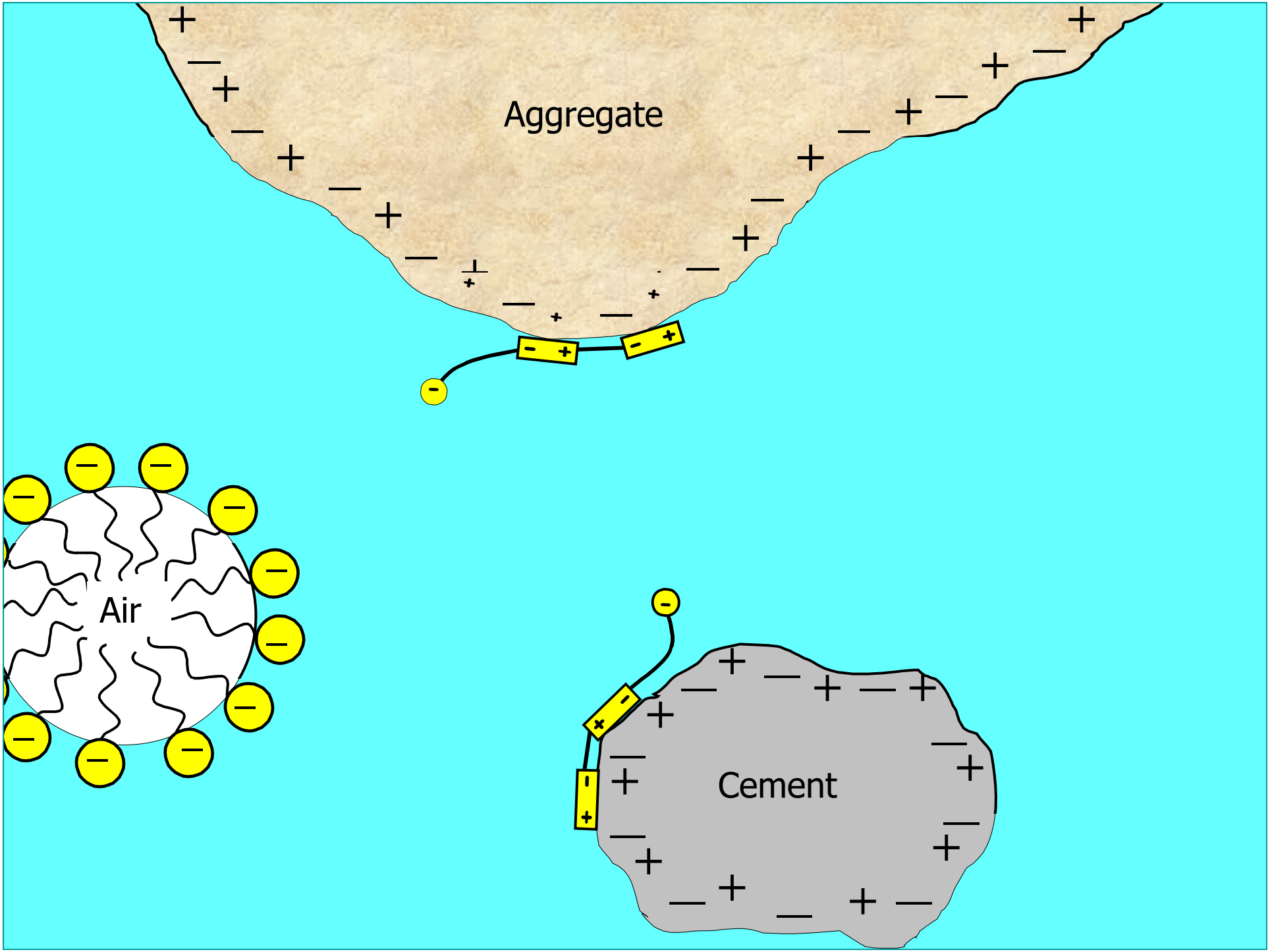
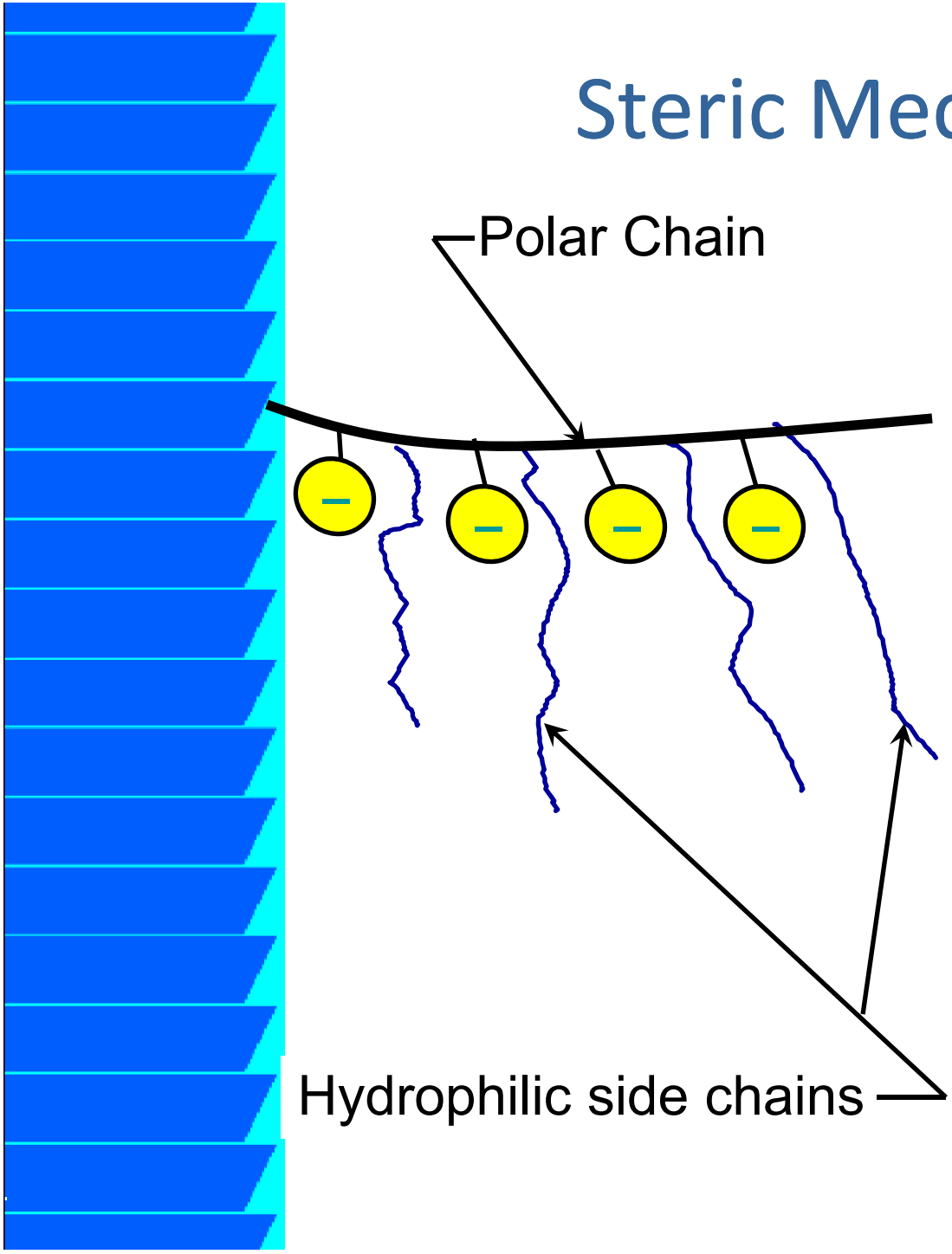

Aggregate
Air
Cement

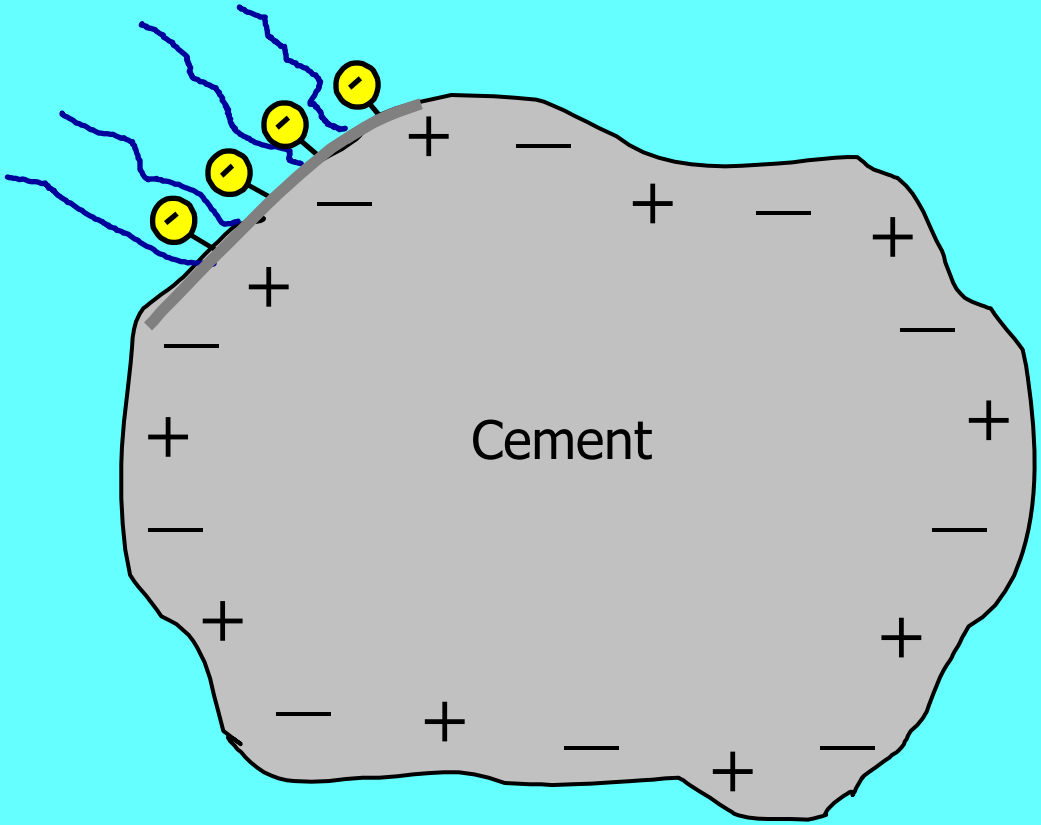

Aggregate
Air
Cement

Steric Mechanism



Unlike traditional superplasticizers, molecules of polycarboxylate consist of ether with a very flexible polar chain carrying negative functional groups and long hydrophilic side chains

BASF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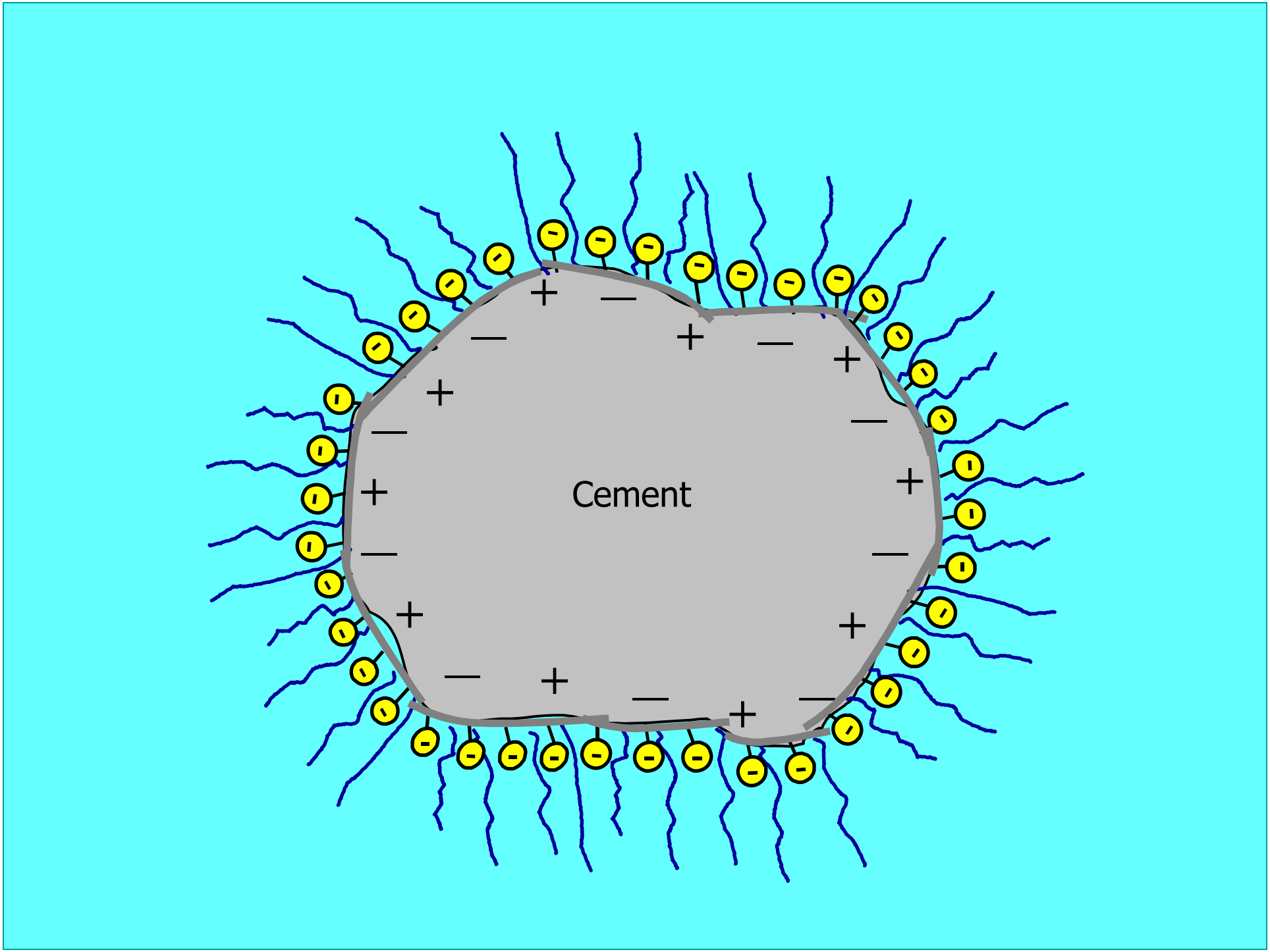
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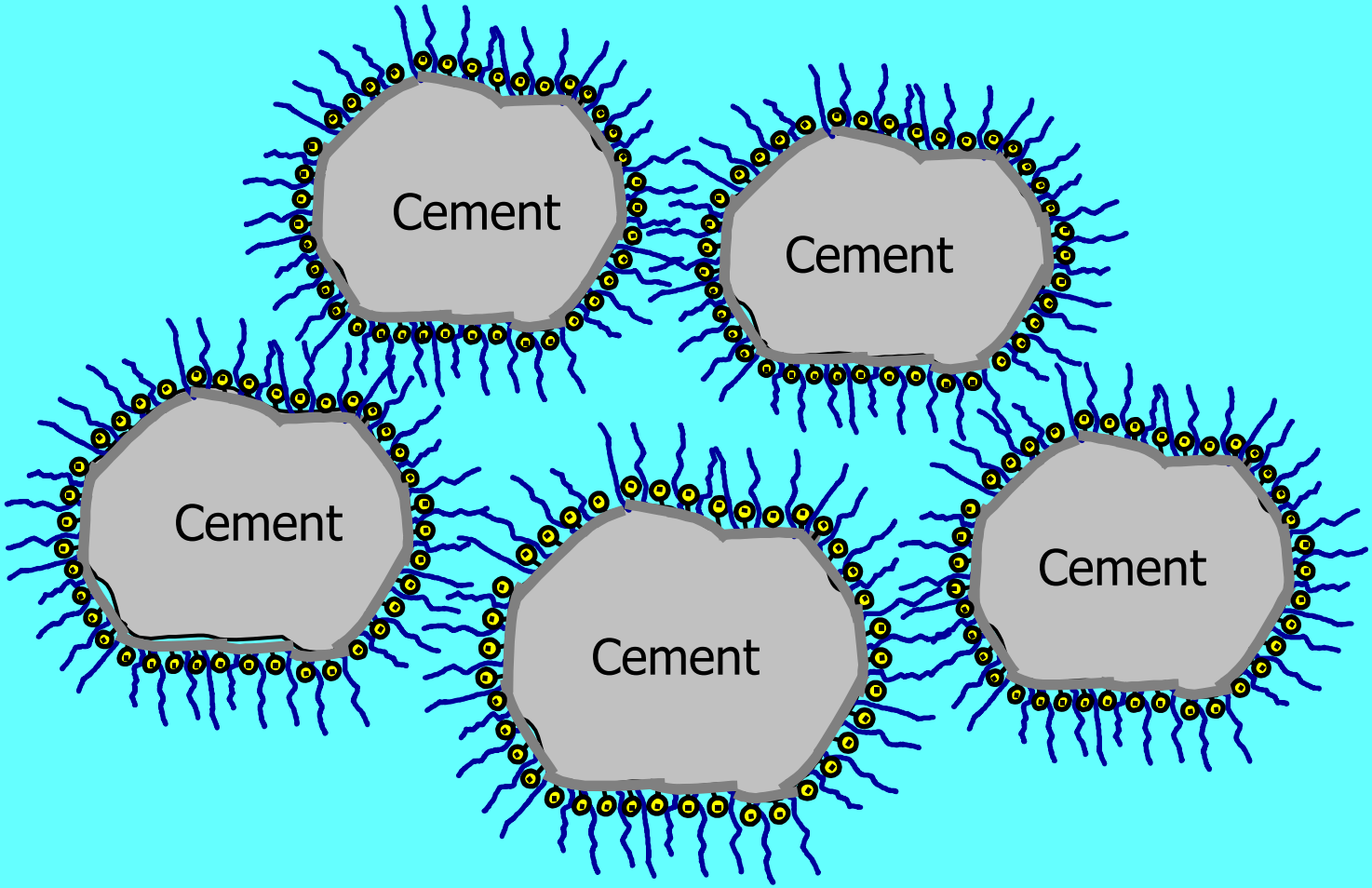
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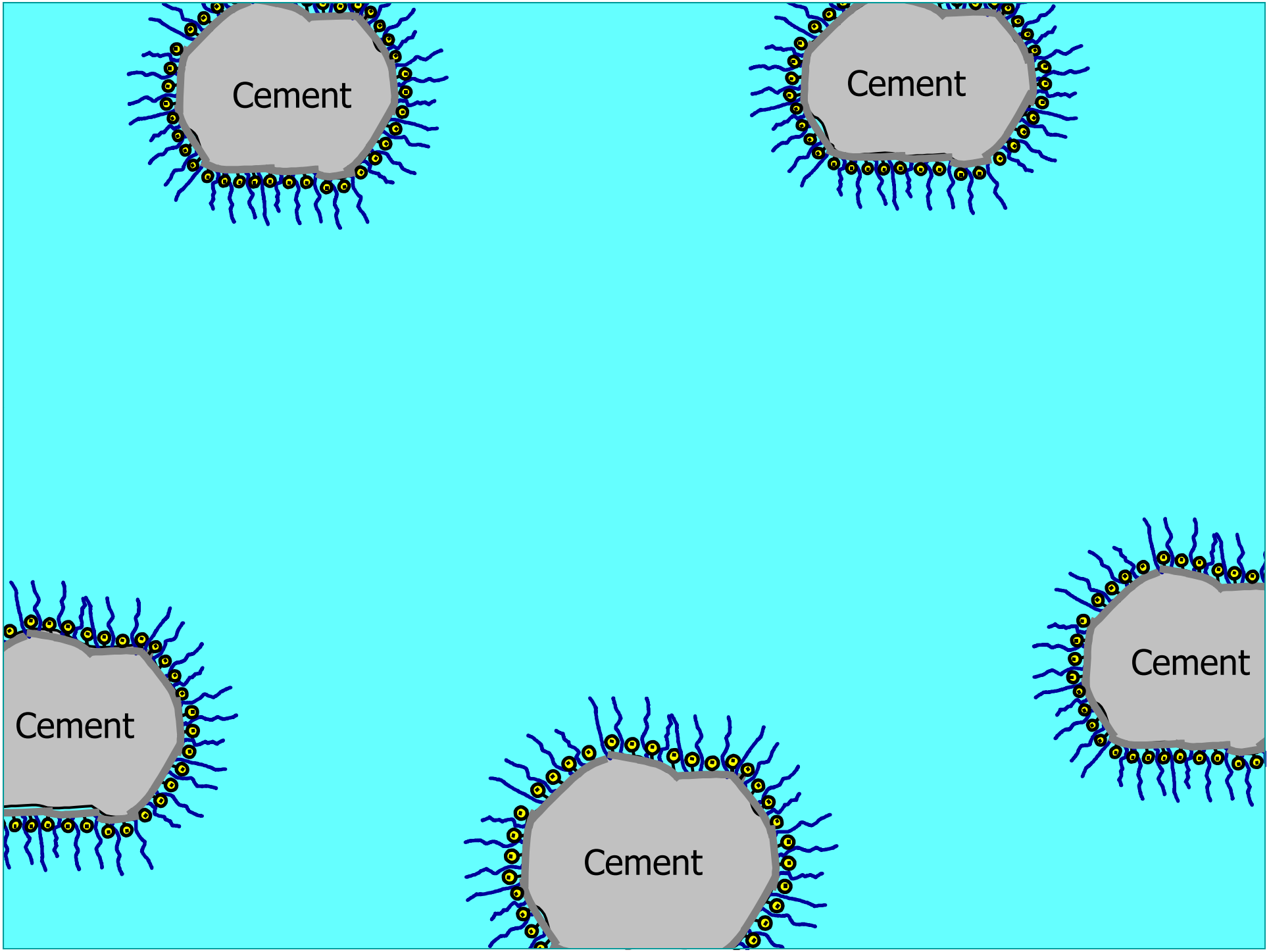
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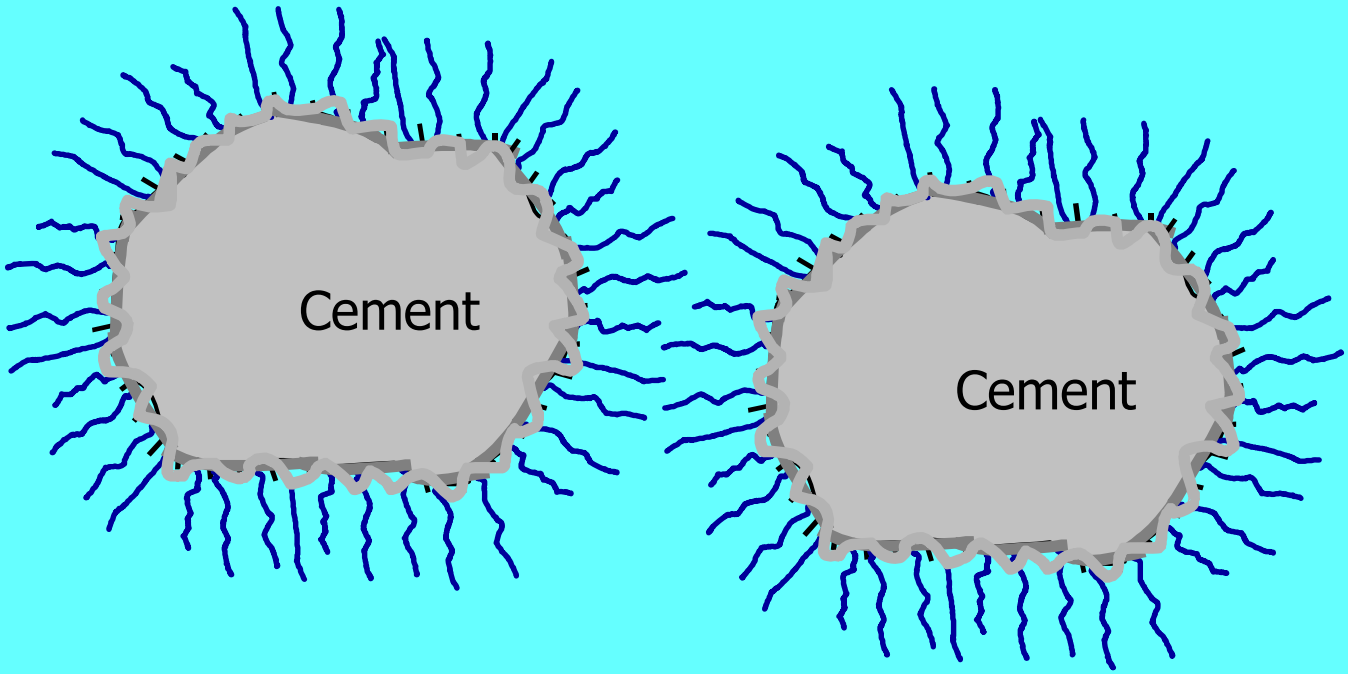

Cement
Cement

Effect of Plasticizers on Properties of Fresh Concrete

- Increases slump
- Improves flow
- Improves placing
- Improved pumpability
- Improved finishability
- Improved formed surfaces

Effect on

- **Air content**
- **Setting**

Effect of Plasticizers on Properties of Hardened Concrete

As W/CM decreases:

- Compressive strength increases
- Permeability decreases
- Chloride resistance increases
- Frost resistance improves
- Increases sulfate resistance
- Abrasion

Accelerators

- **Accelerating admixtures are added to concrete for the purpose of shortening set time and accelerating early strength development.**

Types of Accelerators

Calcium chloride:

- Regular flake (ASTM D98 Type 1) - 77% $CaCl_2$ (minimum)
- Pellet or granular (ASTM D98 Type 2) - 94% $CaCl_2$ (minimum)

Non-chloride accelerators:

- Wide range of soluble inorganic salts of calcium or sodium:

  - Bromides, fluorides, carbonates, thiocyanates, nitrites, nitrates, thiosulfates, silicates, aluminates, hydroxides

- Soluble organic salts

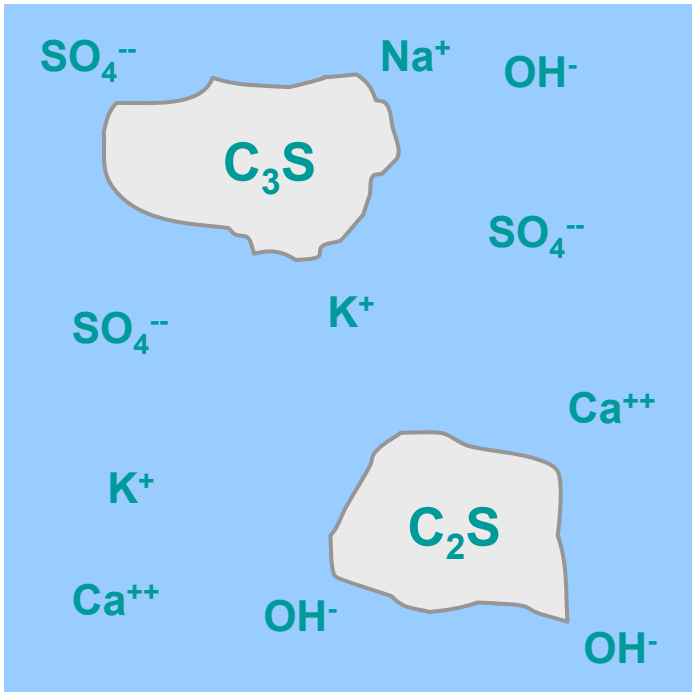
  - Triethanolamine (TEA), calcium formate

  - Calcium acetate, calcium propionate, calcium butyrate

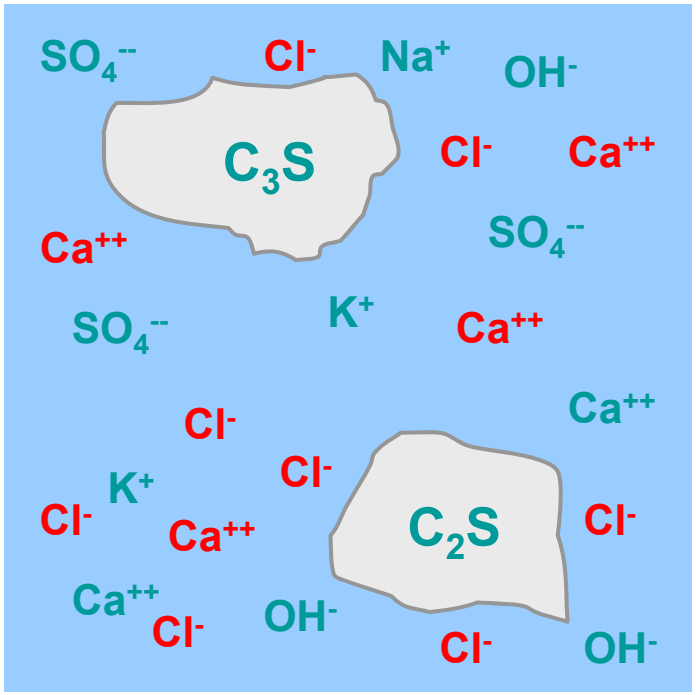
Should meet requirements for Type C or Type E in ASTM C494

Accelerators – Mechanisms

No Admixture

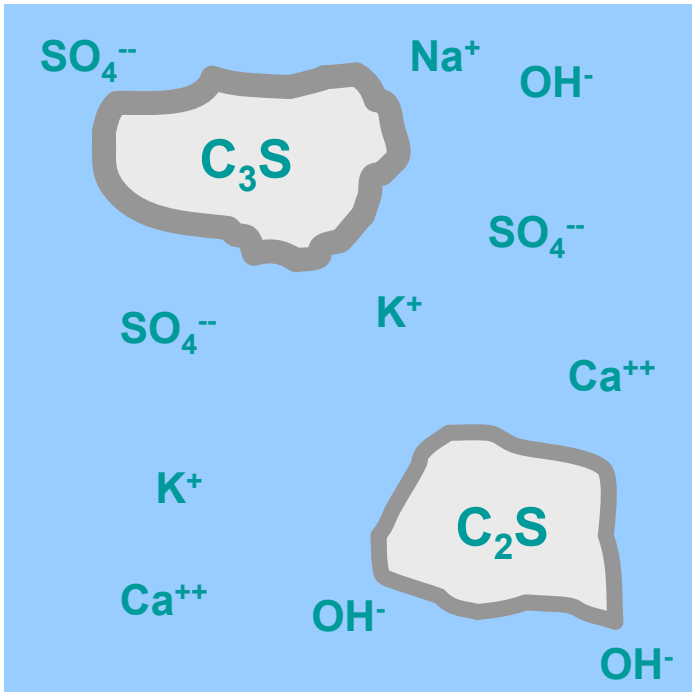


$CaCl_2$ Accelerator

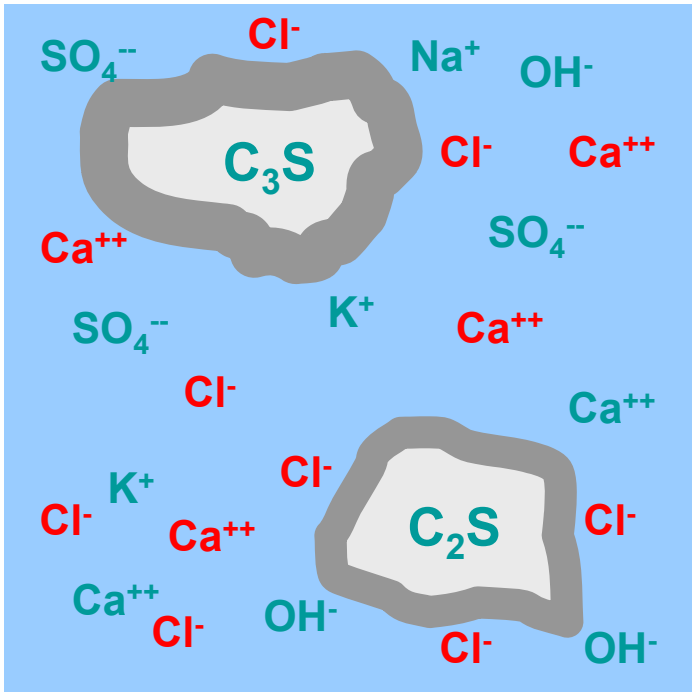


Accelerators – Mechanisms

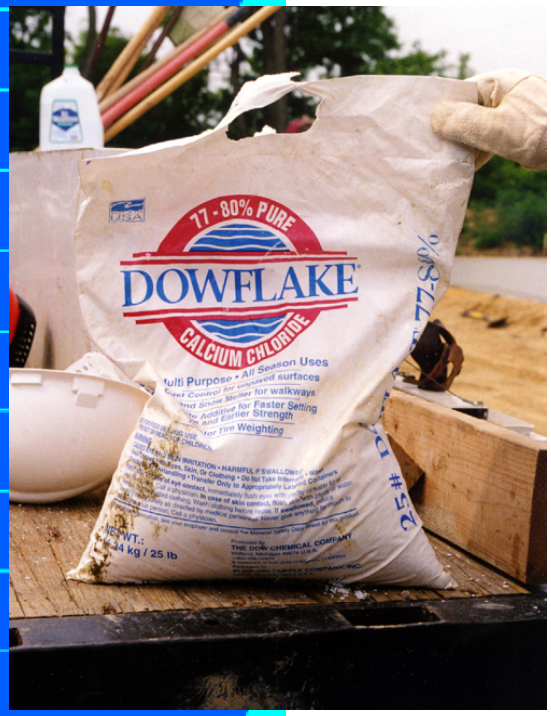
No Admixture



$CaCl_2$ Accelerator

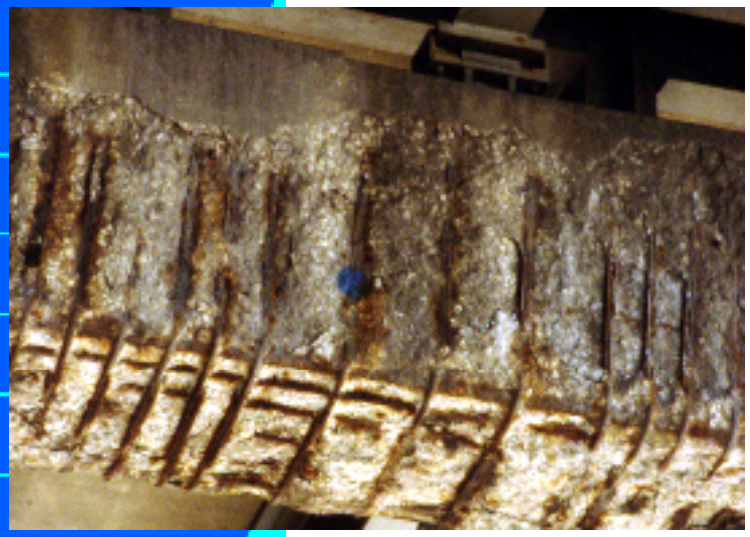


Effects on Concrete Properties



Effect of calcium chloride on other concrete properties:

- Increased slump
- Decreased bleeding
- Increased shrinkage
- Increased creep
- Reduced long-term strength
- Reduced freeze-thaw resistance (at later ages)
- Reduced resistance to sulfates
- Exacerbates alkali-silica reaction



Effects on Concrete Properties

ACI 318 Building Code limits the amount of chloride in reinforced and prestressed concrete.

	* Chloride (%)
Prestressed concrete	0.06
Reinforced concrete exposed to chloride in service	0.15
Reinforced concrete that will be dry or protected from moisture in service	1.00
Other reinforced concrete construction	0.30

* *Maximum water-soluble chloride ion expressed as a mass percentage of the cementitious material content*

Retarders

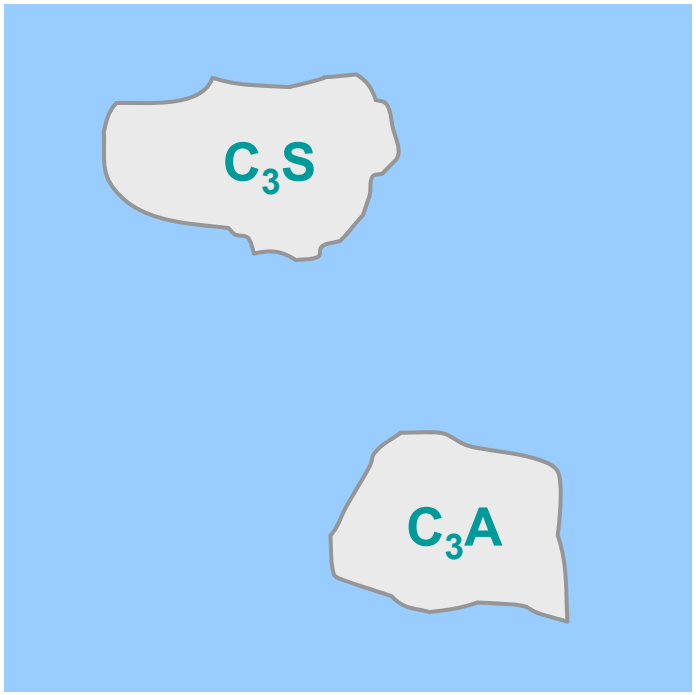
- **Retarding, and Water-reducing and retarding admixtures are used to offset acceleration and unwanted effects of high temperature and keep concrete workable during placement and consolidation.**

Types of Retarders

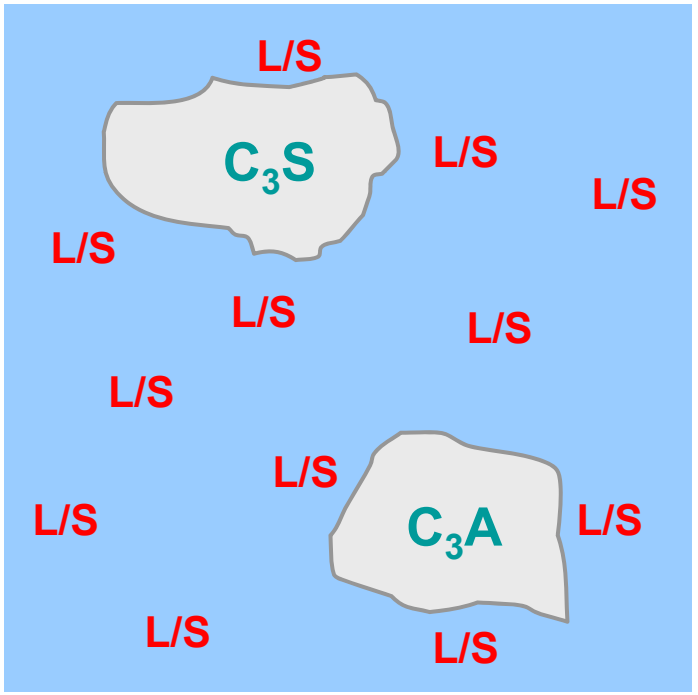
- Lignosulfates
- Hydroxycarboxylic acid
- Sugars
- Tartaric Acid and Salts

Retarders – Mechanisms

No Admixture

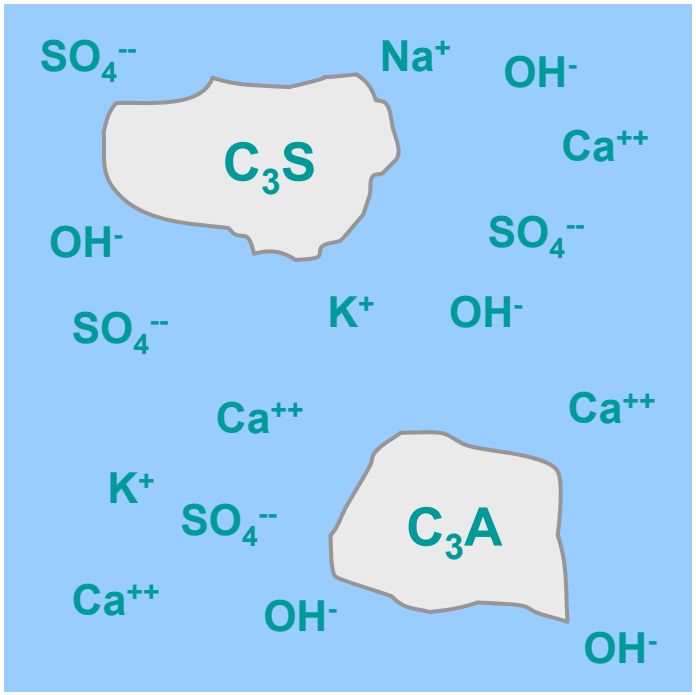


Retarder (e.g. Lignosulfate)

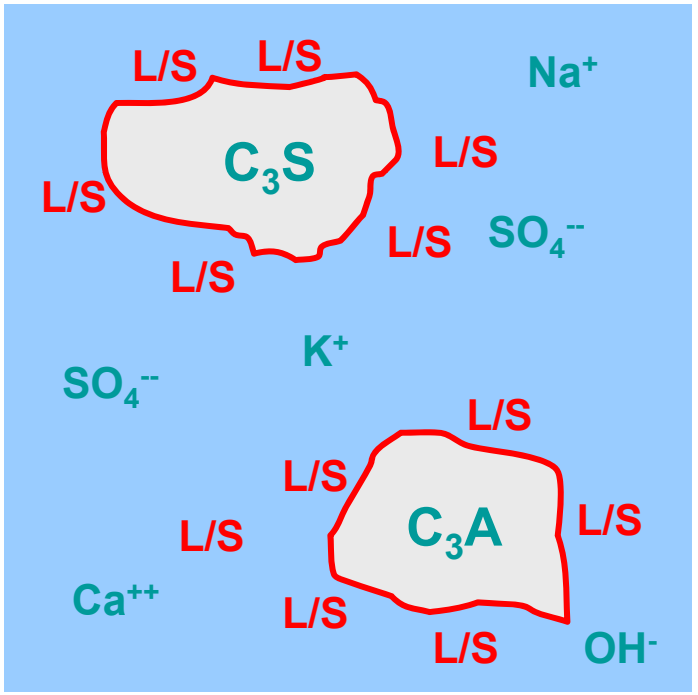


Retarders – Mechanisms

No Admixture

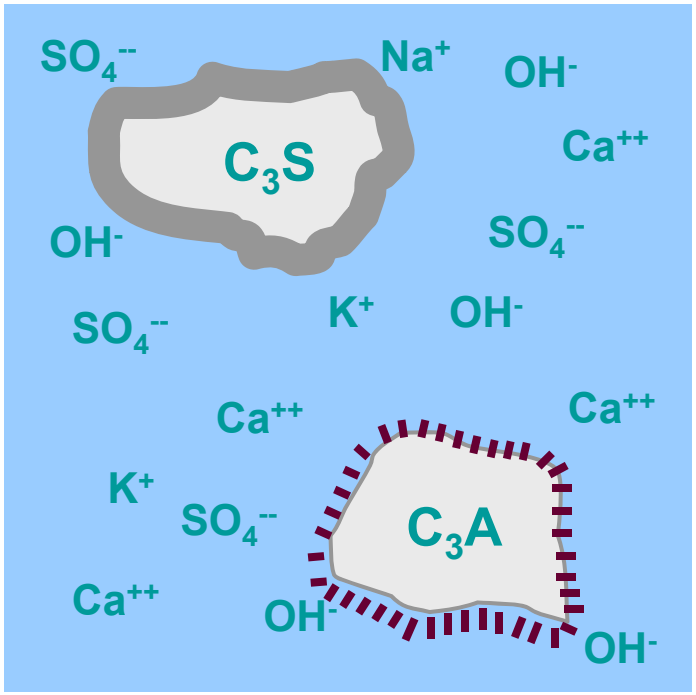


Retarder (e.g. Lignosulfate)



Retarders – Mechanisms

No Admixture



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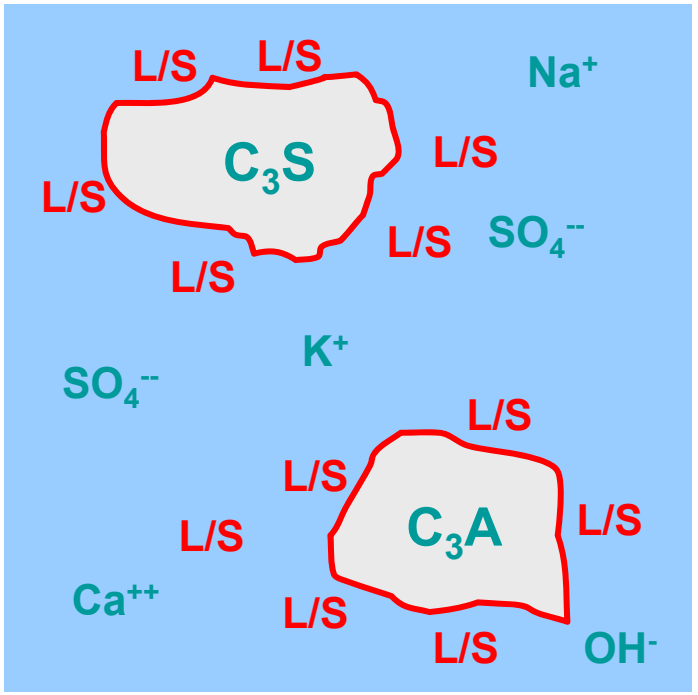

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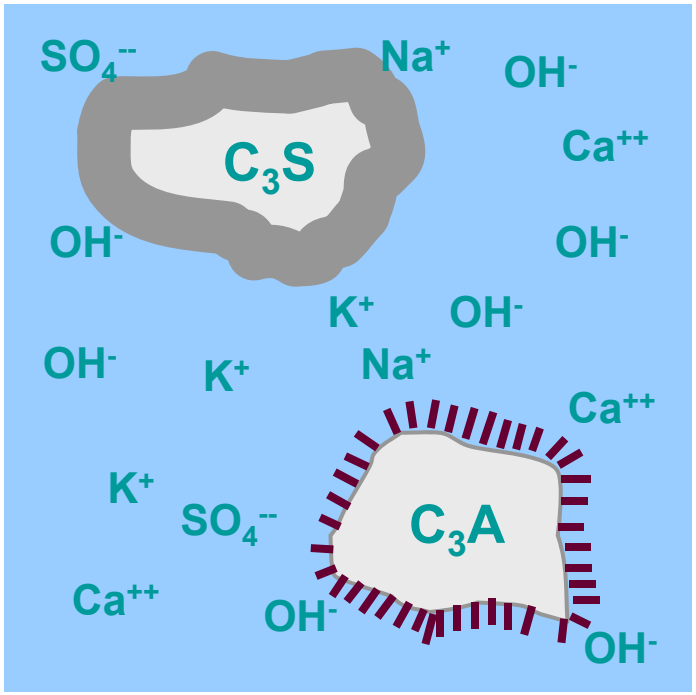

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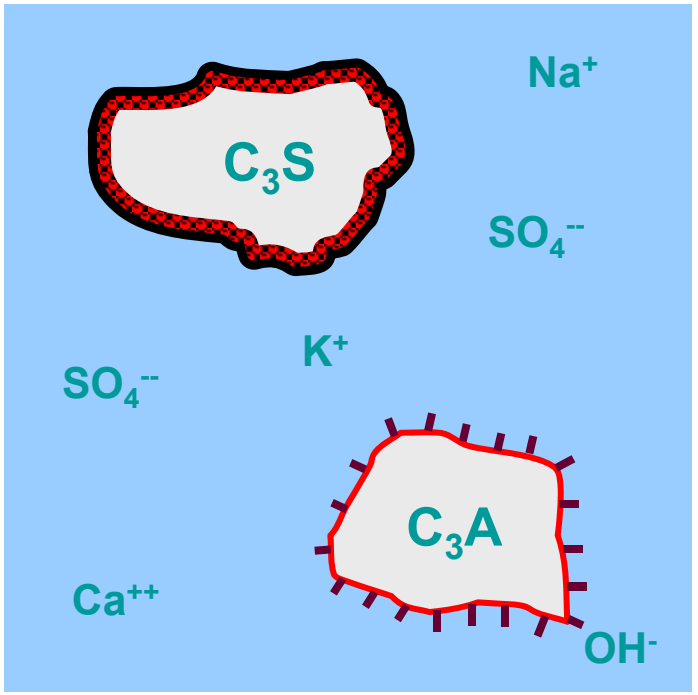


Effects on Concrete Properties

Effect of retarders on other concrete properties:

- Increased slump
- Increased bleeding
- Increased air
- Reduced internal temperature
- Reduced early-age strength
- Increased long-term strength

Overdosing with retarders may inhibit hydration completely

Hydration-Control Admixtures

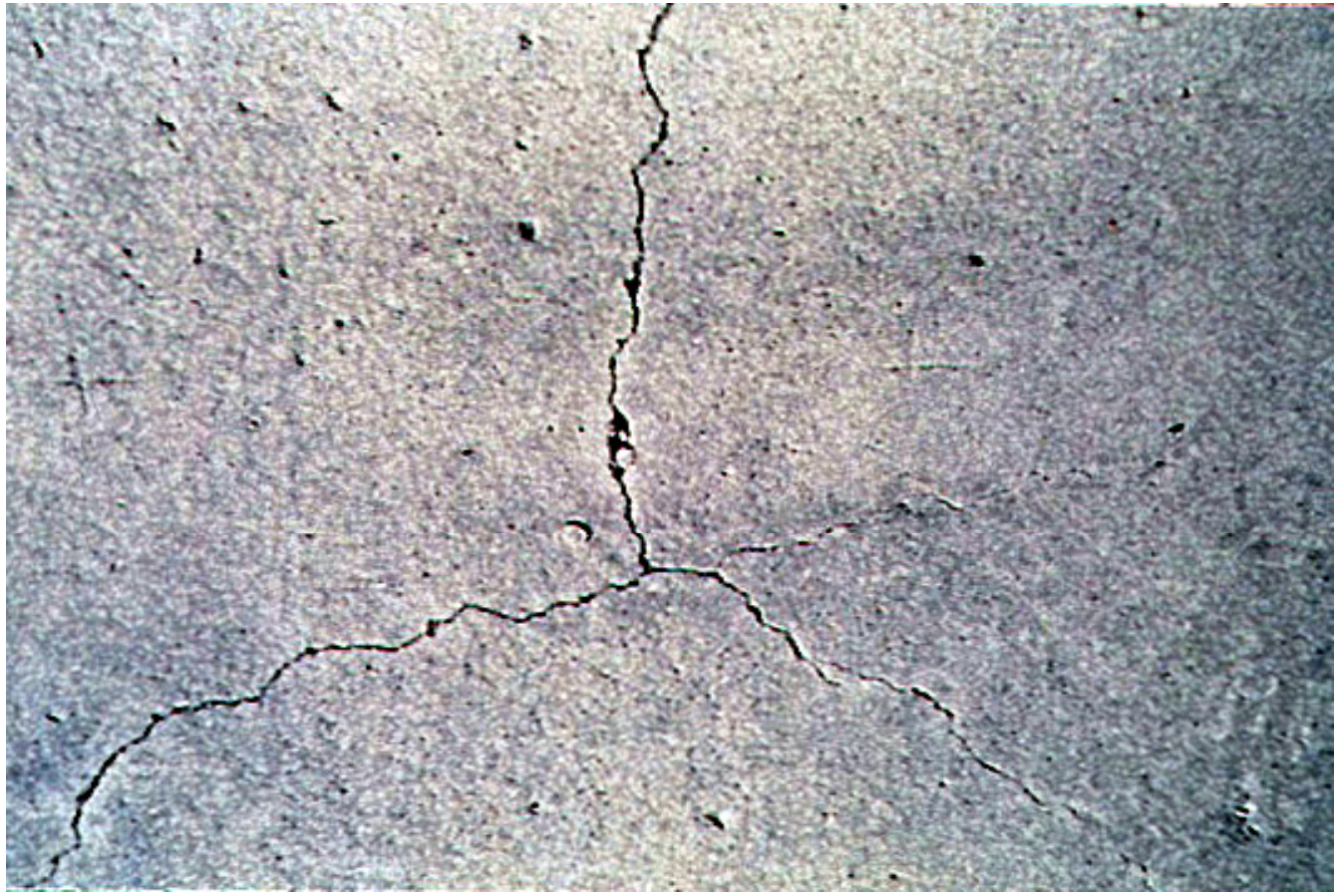
- **Hydration-Control Admixtures suspend the hydration of cement for stabilization during long hauls or for preventing setting so concrete can be reused.**

Corrosion Inhibitors

- **Corrosion Inhibitors are used to mitigate corrosion of reinforcing steel in concrete.**

Shrinkage Reducing Admixtures

- **Shrinkage Reducing Admixtures are used to minimize drying shrinkage cracking in concrete.**



ASR Inhibitors

- **ASR Inhibitors (primarily Lithium) are used to mitigate alkali-silica reactivity in concrete.**

Specialty Admixtures

- Coloring Admixtures
- Workability Agents
- Bonding Admixtures
- Dampproofing Admixtures
- Permeability-Reducing
- Grouting
- Gas-forming
- Anti-Washout
- Foaming
- Pumping Aids

The Effectiveness of an Admixture

- **Depends on:**

The Type & Brand

Amount of Cement

Water Content

Temperature

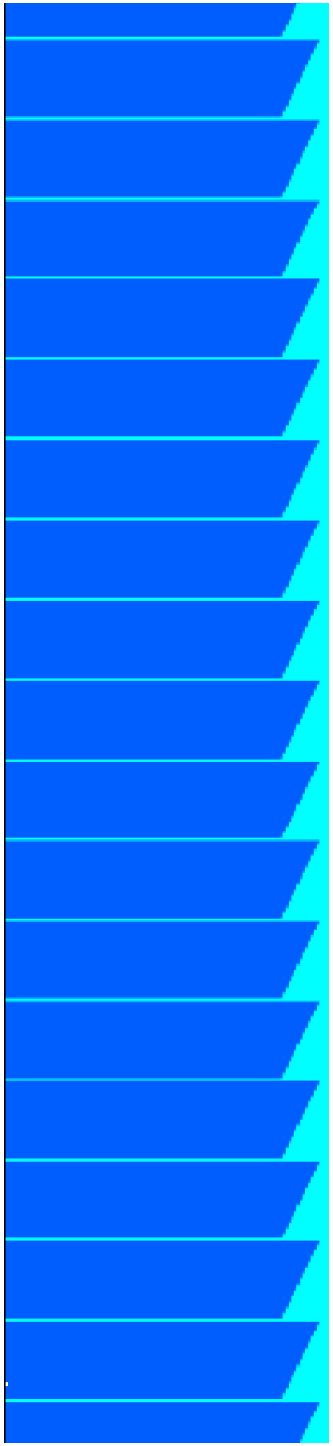
Aggregate Shape

Proportions

Mixing Time

Consistency of the Mix

Sequencing



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