

# 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


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- 
- 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

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- 
- 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.



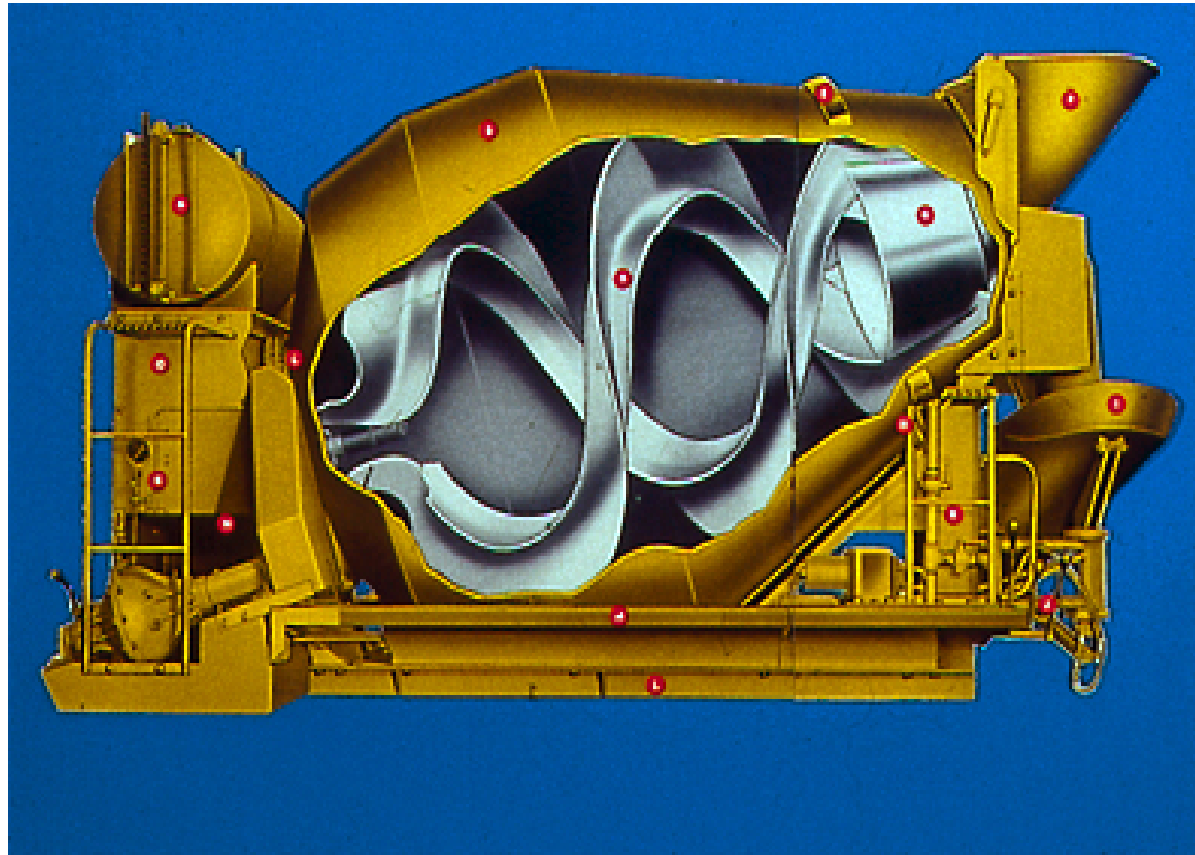


# Air-Entraining Agents

- 4 Categories:
  1. Wood Derived Products:  
Vinsol<sup>®</sup> 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

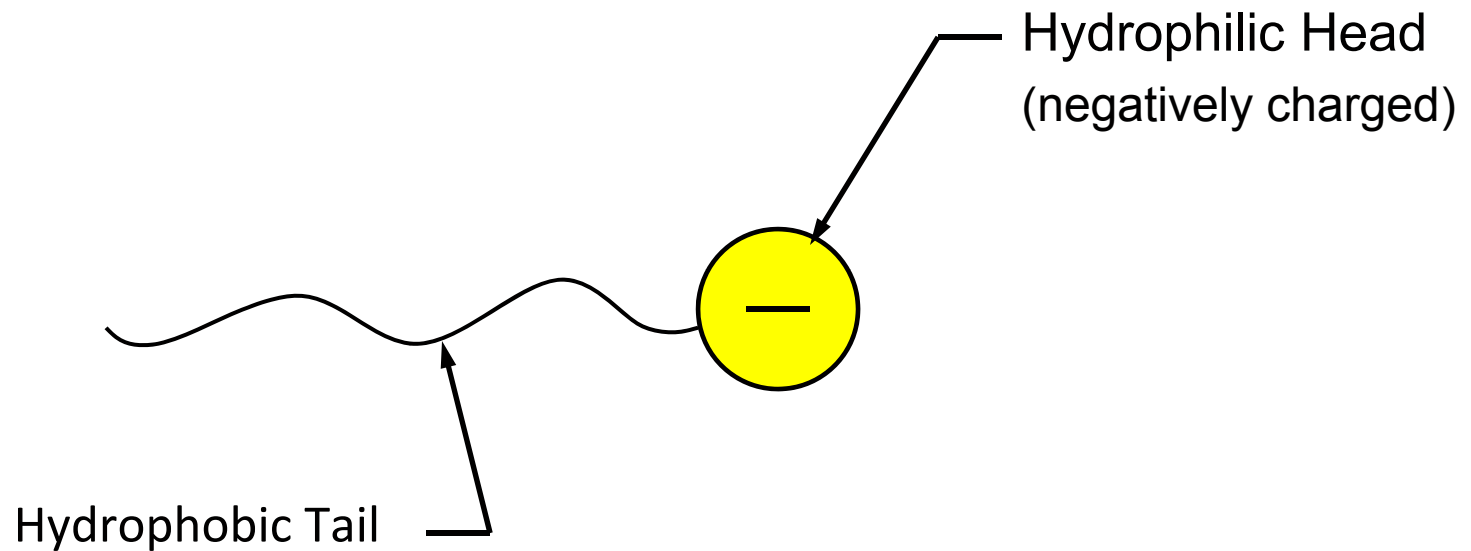
# Mechanism of Air-entrainment

- Air is Generated into Concrete During the Mixing Process

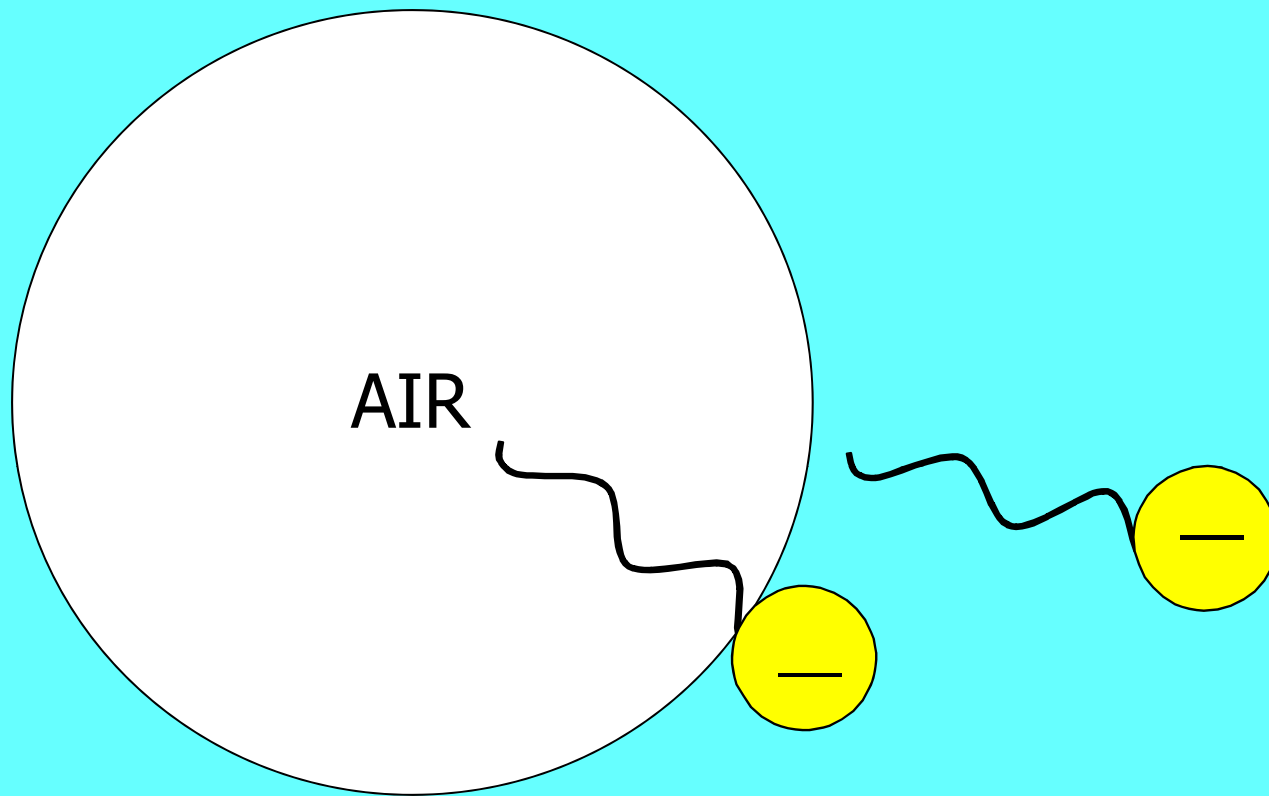


◆ Entrapped vs. Entrained Air...

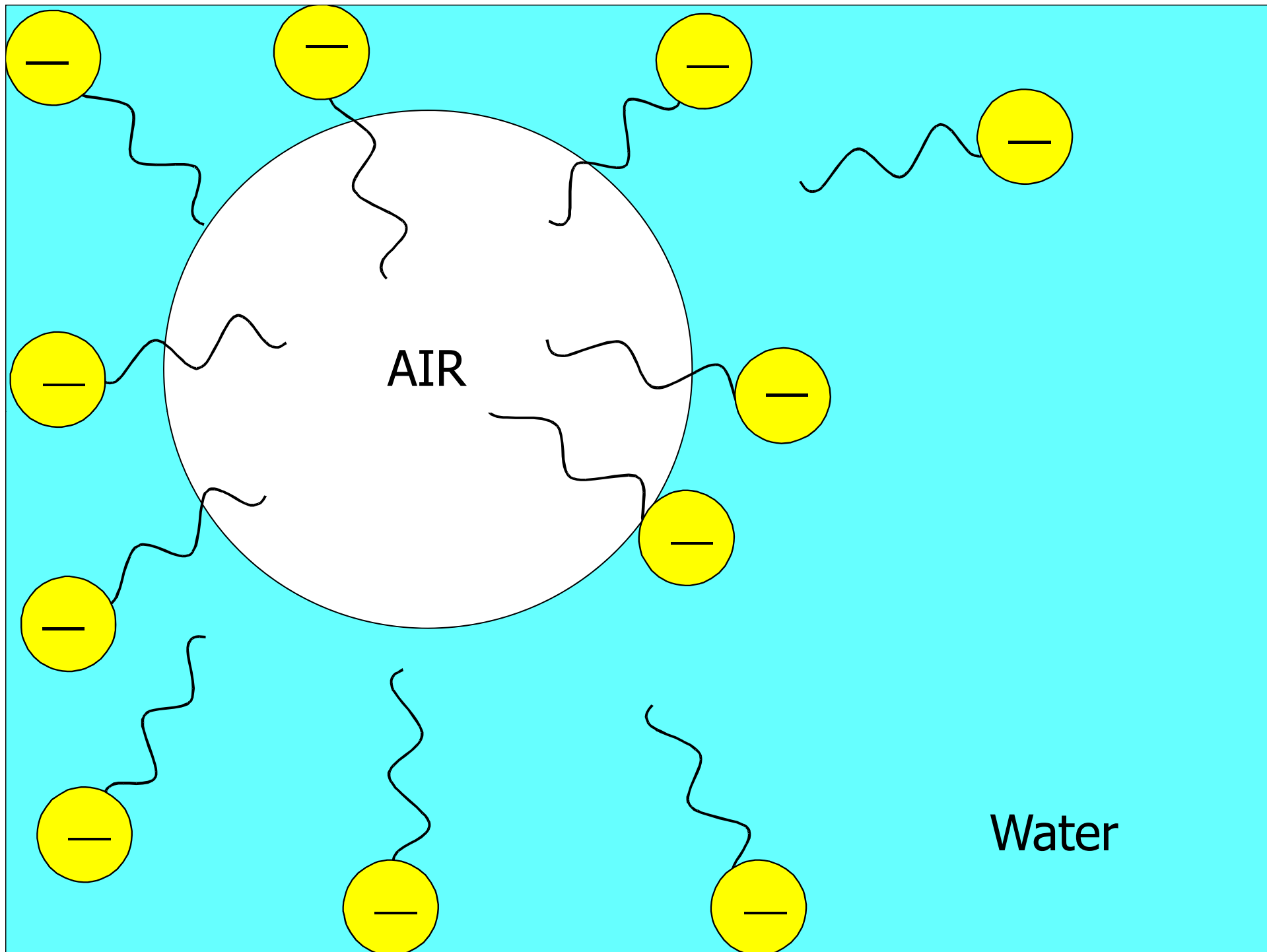
# Typical Anionic Surfactant



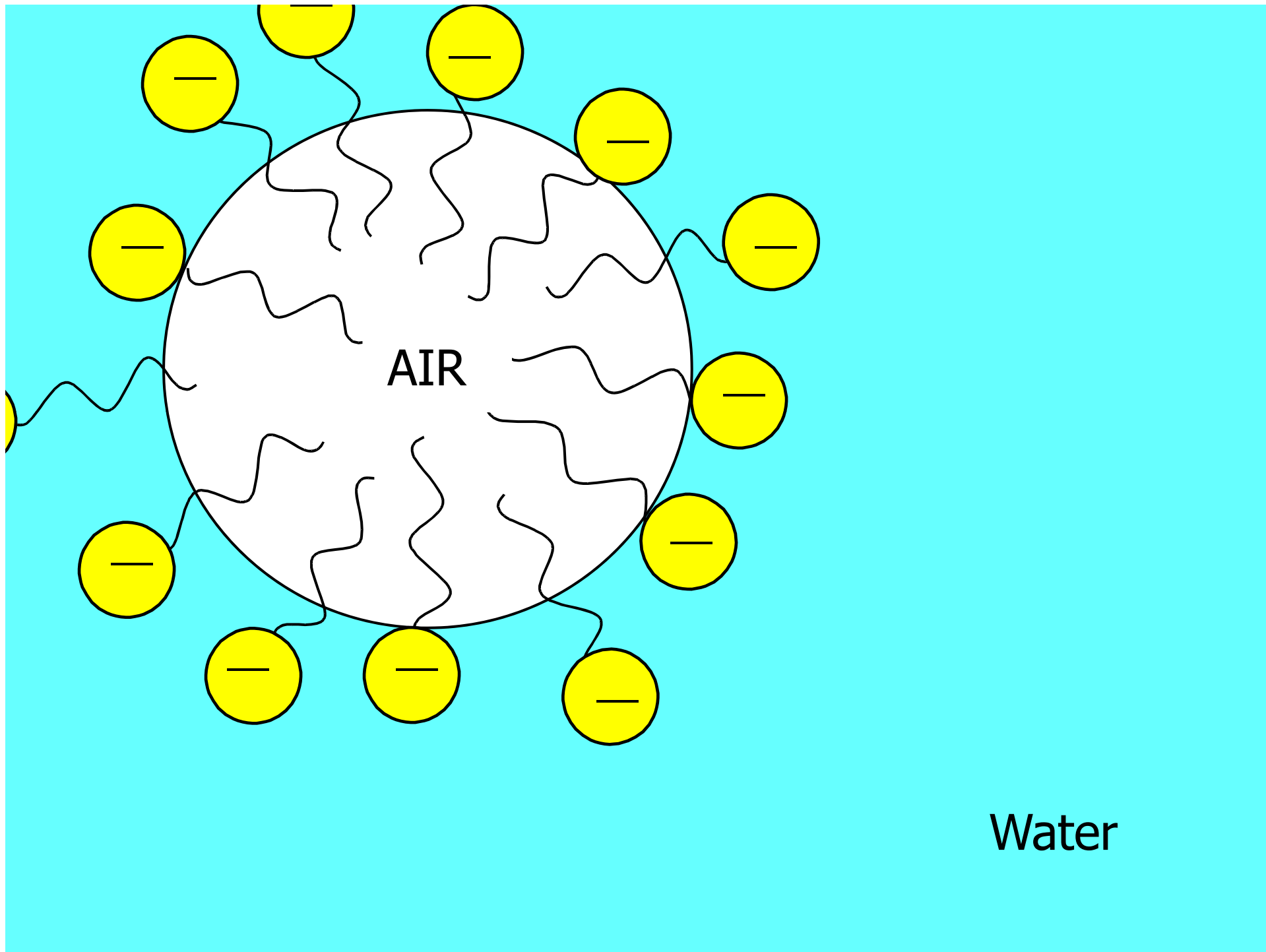
Air-Entraining Admixtures are typically surfactants that have a negatively charged head which is hydrophilic, and a hydrophobic tail.

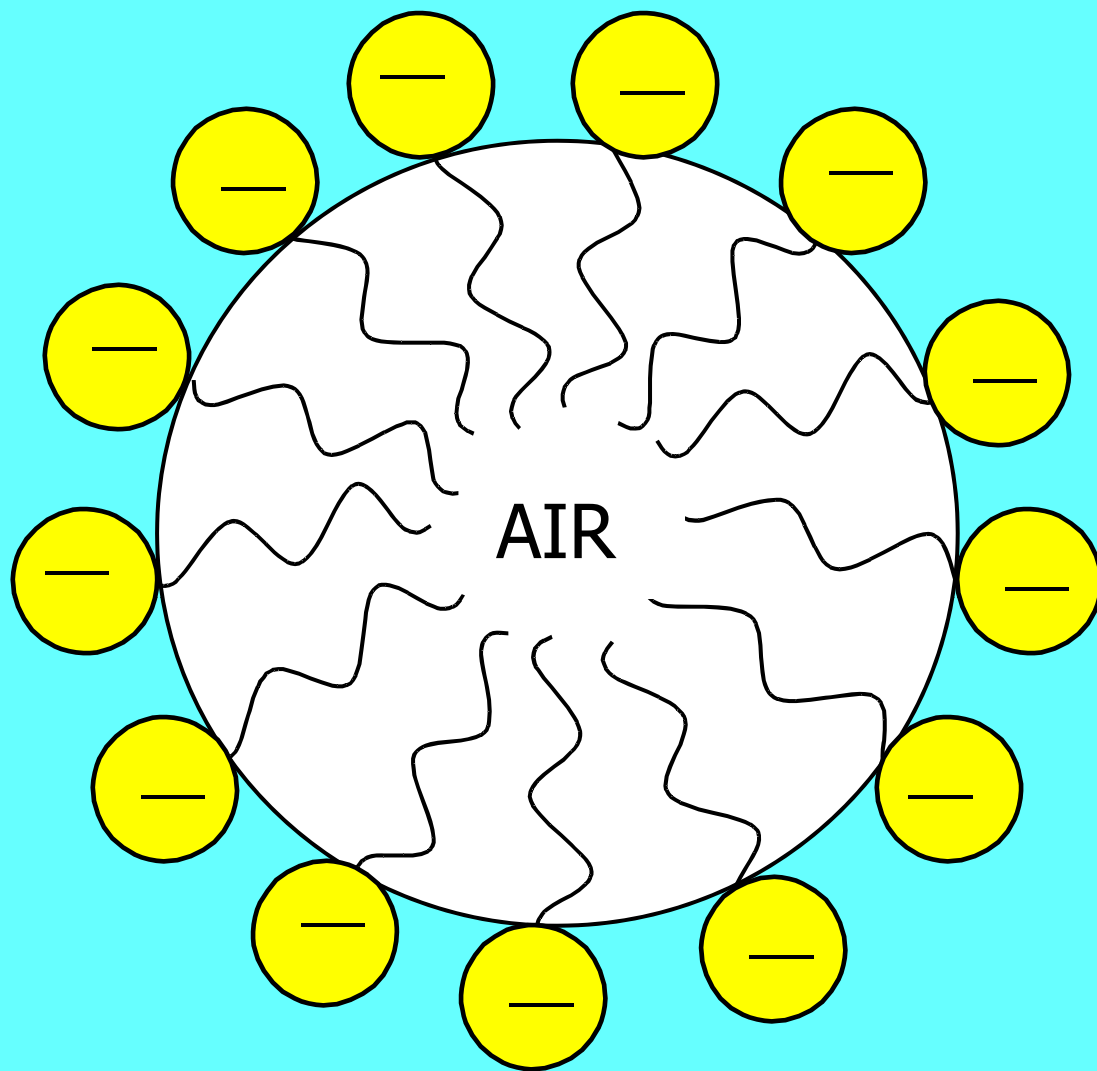


Water

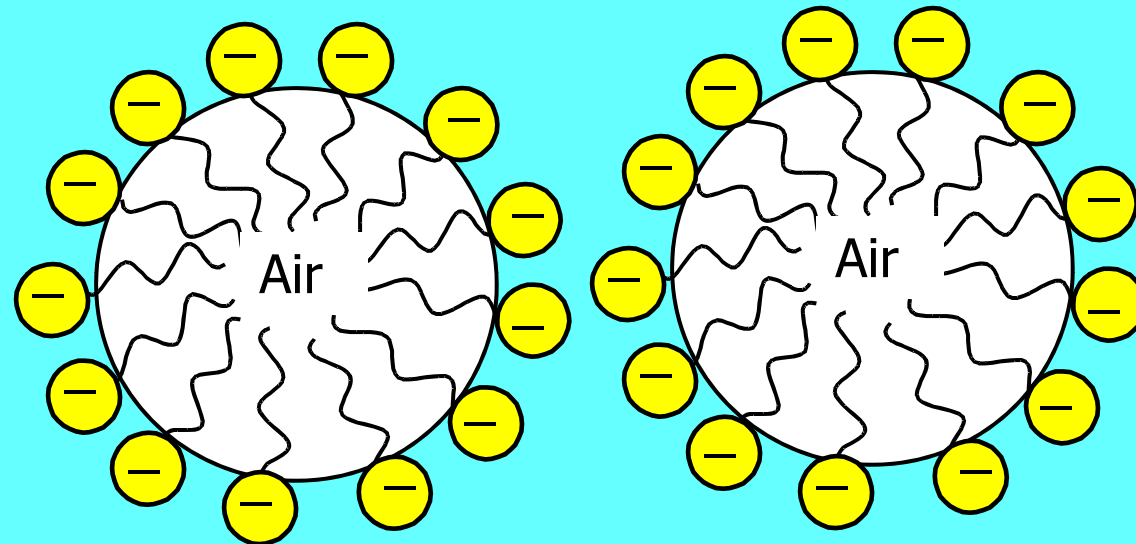




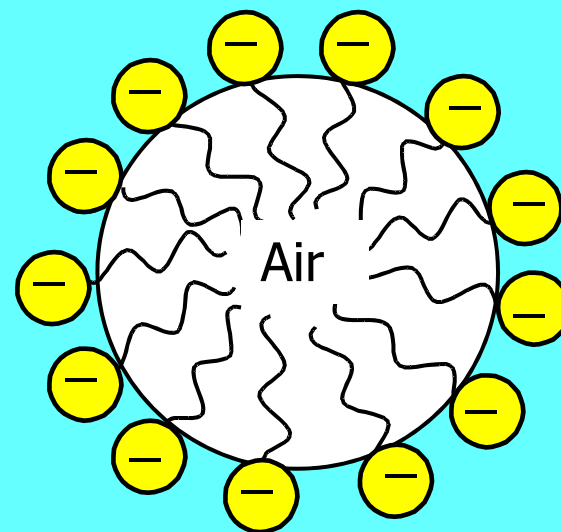
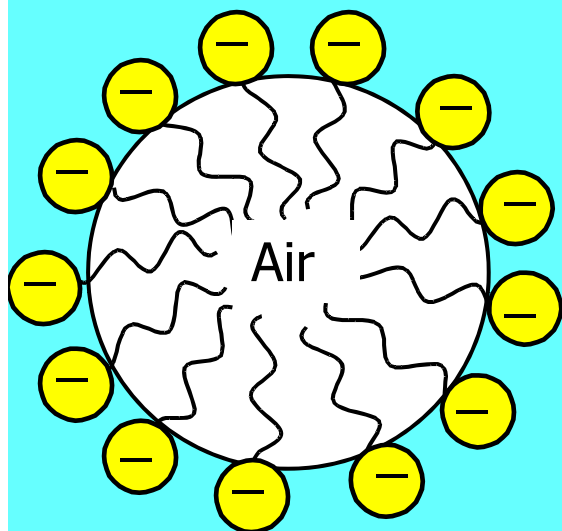




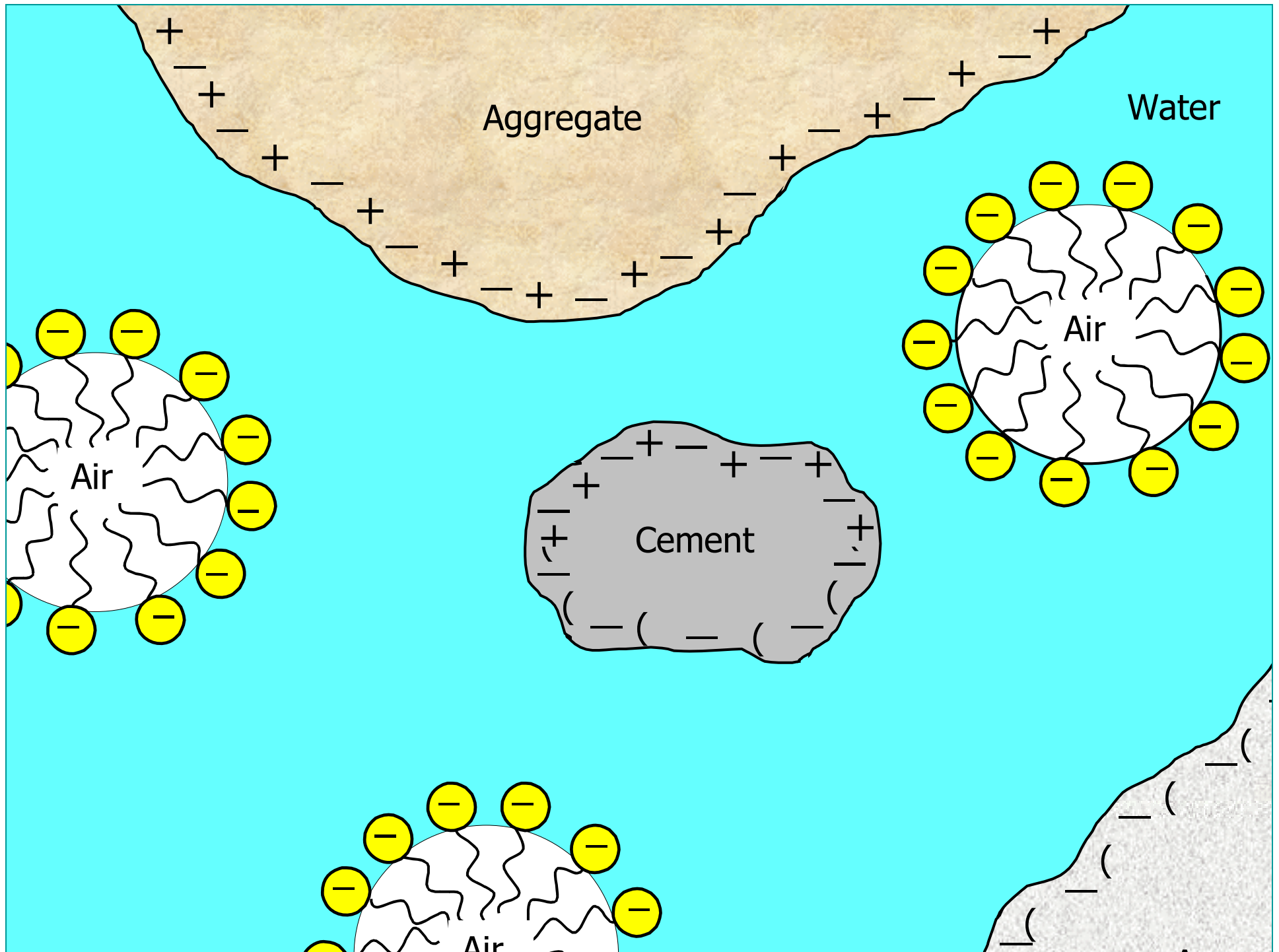
Water

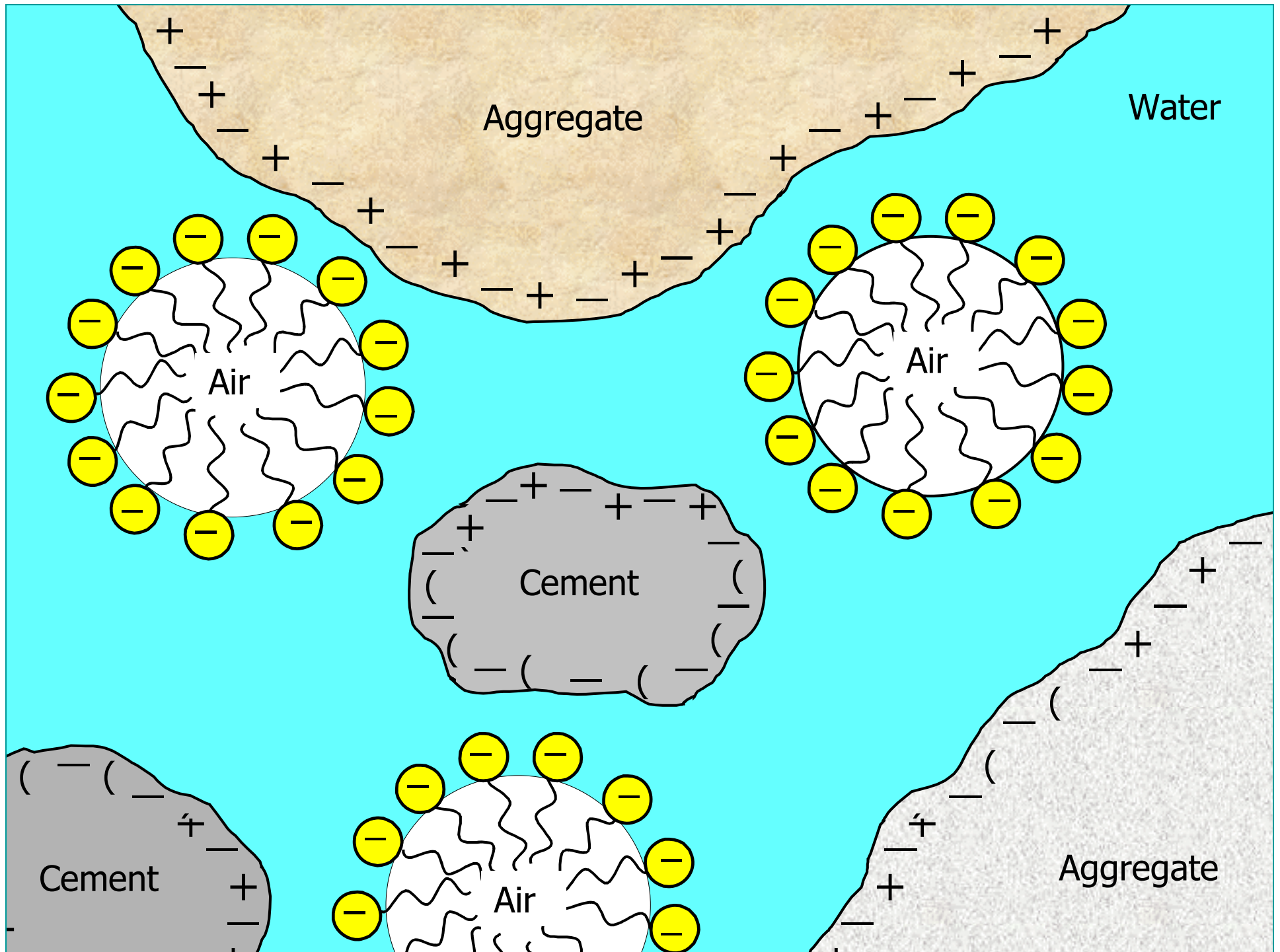


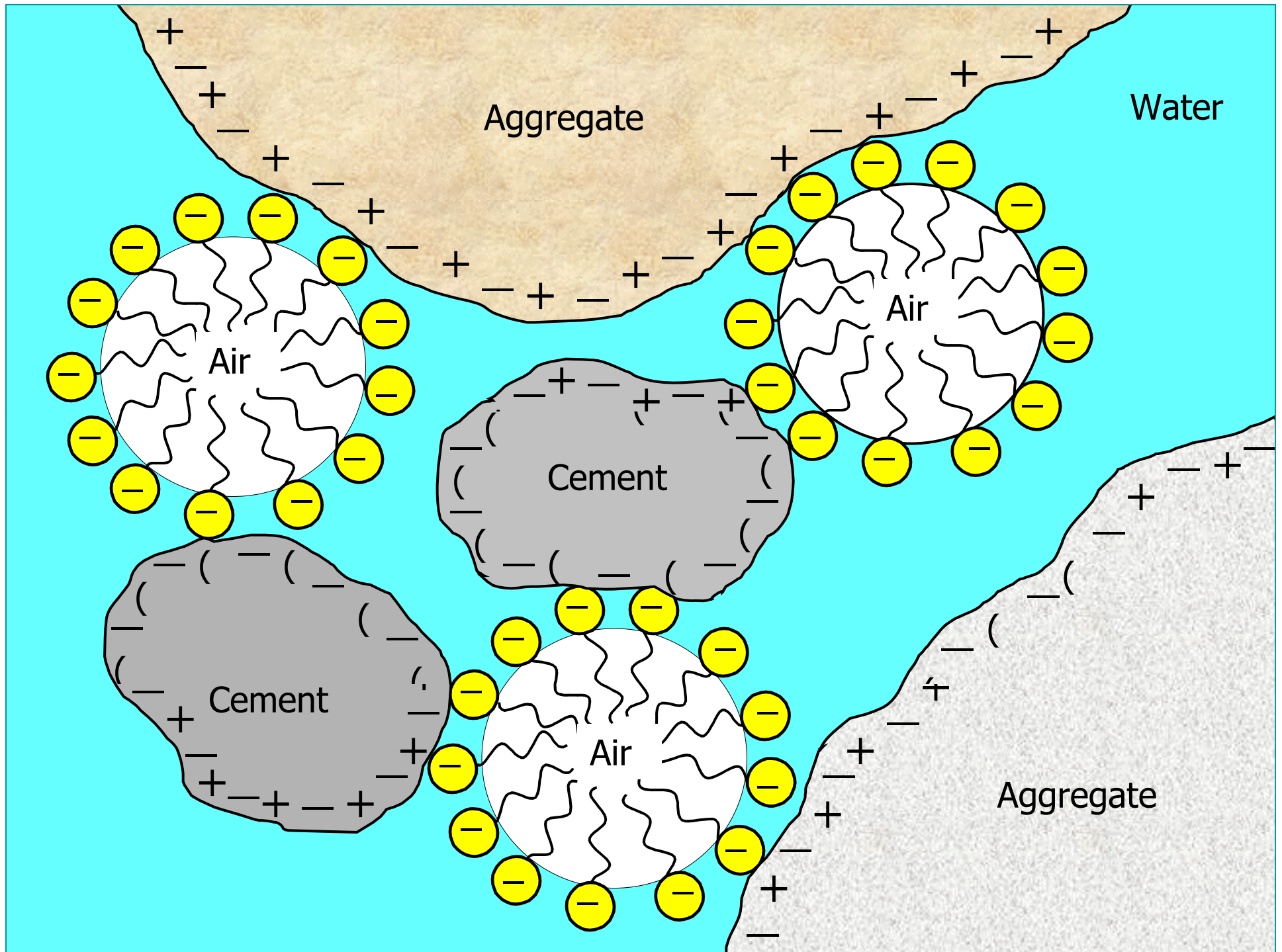
Water



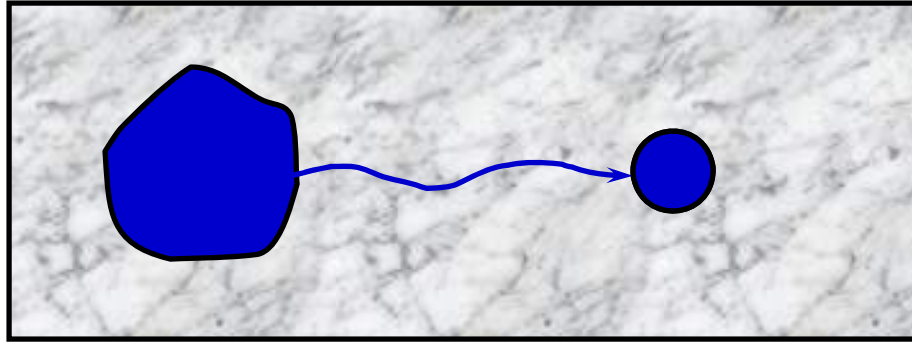
Water











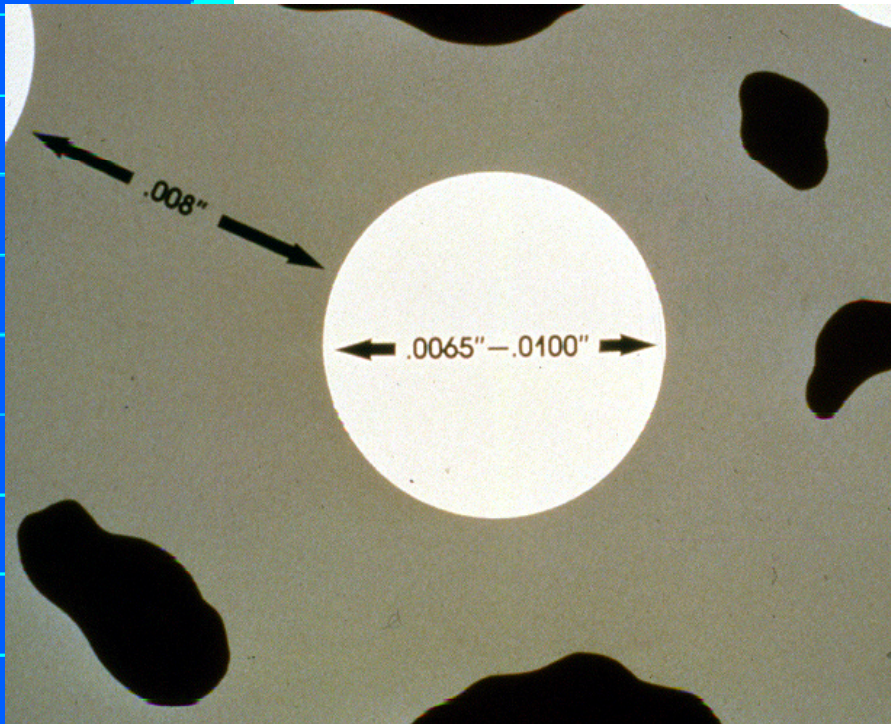
The amount of hydraulic pressure generated as a result of the water in the void (or capillary) being expelled depends on:

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

# For Durability

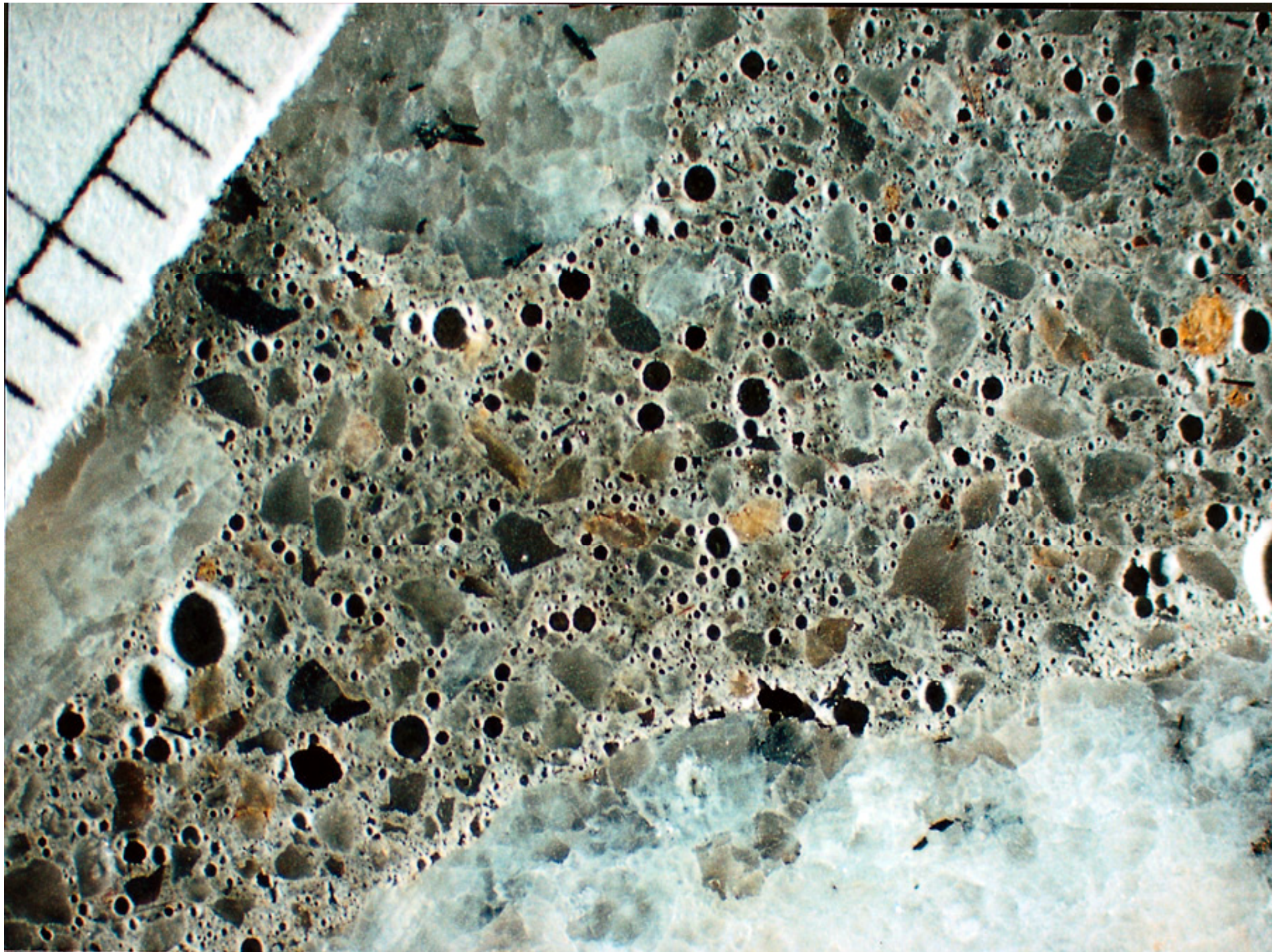
## ASTM C457

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



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



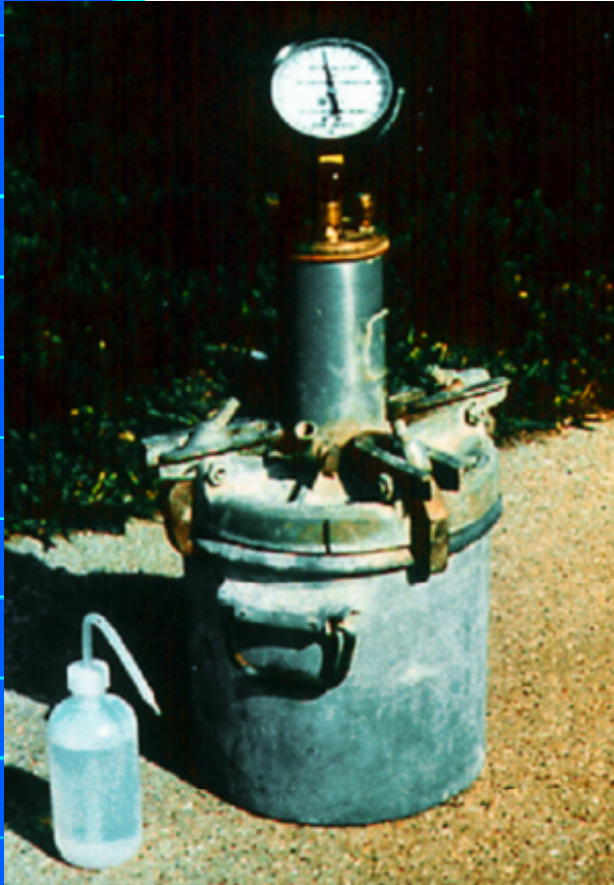






# Why Do We Focus on Volume of Air Content? (%Air)

# 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



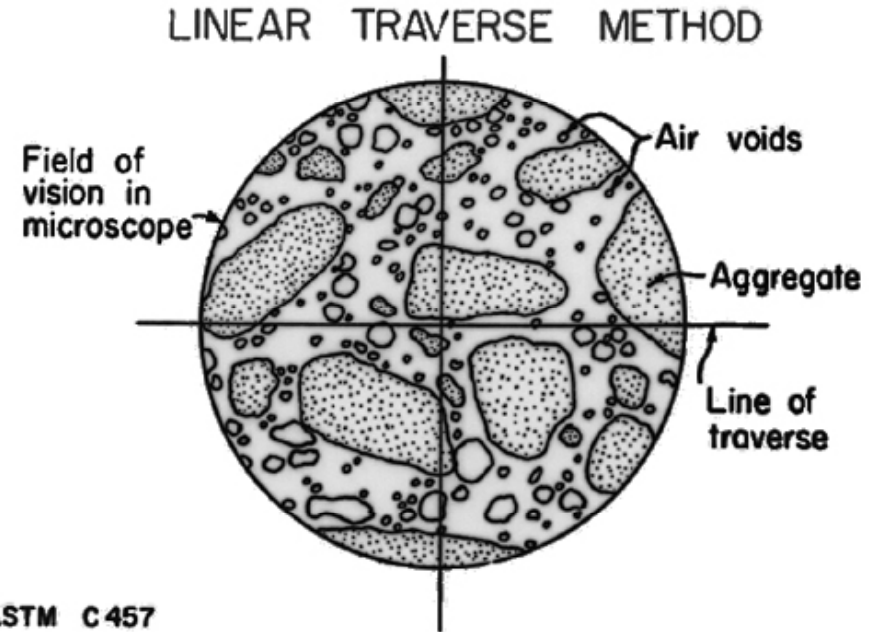
Chace Air Indicator – AASHTO T 199  
(uses mortar sample from concrete)



Gravimetric Method – ASTM C138  
(requires accurate knowledge of relative density and absolute volumes of concrete ingredients)



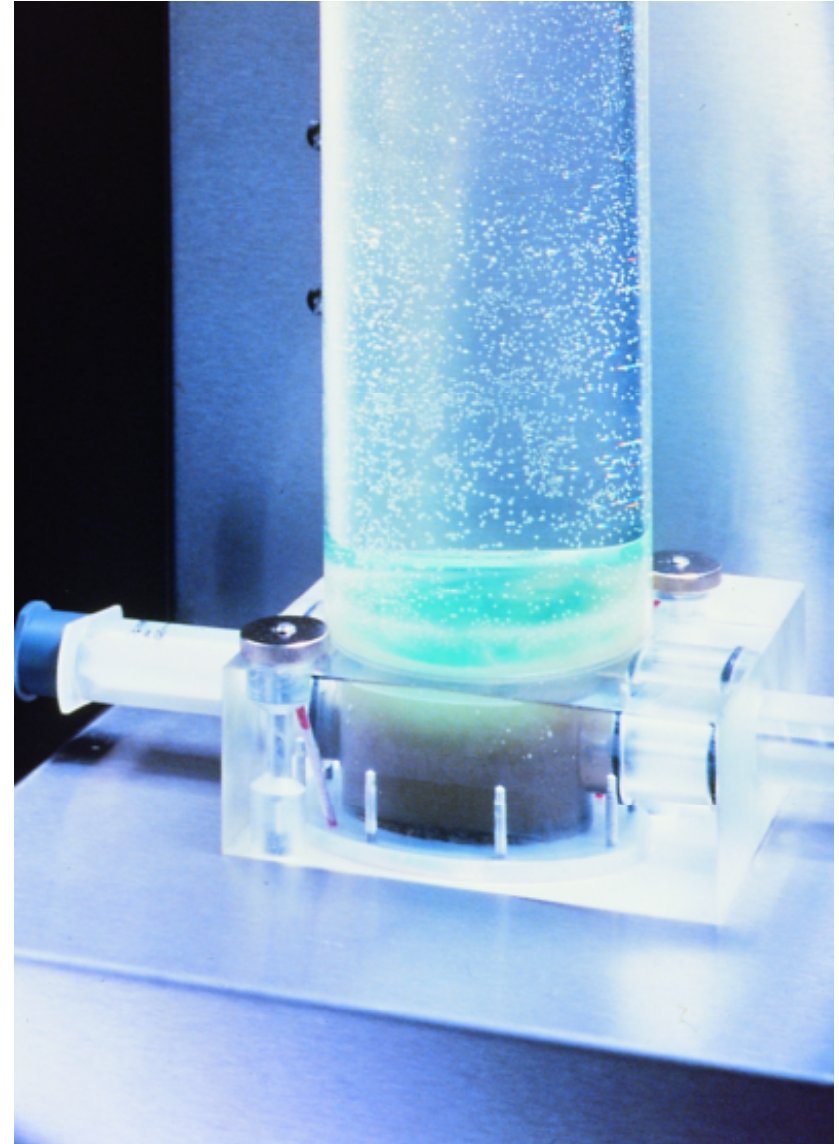
# Measuring Air in Hardened Concrete



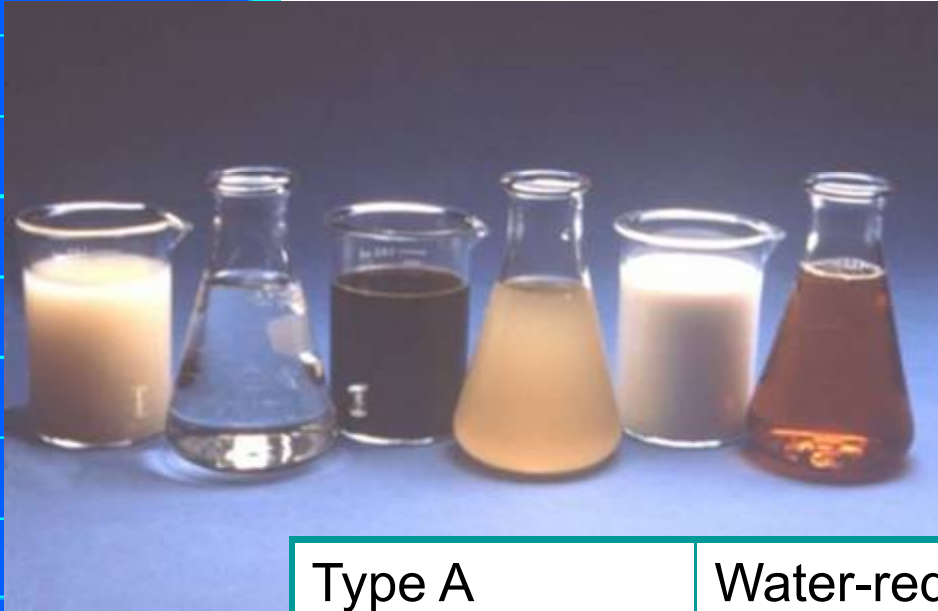
ASTM C457



# Fresh Concrete Air Void Analyzer



# Chemical Admixtures



ASTM C494 (AASHTO M 194)

## Classification

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 |

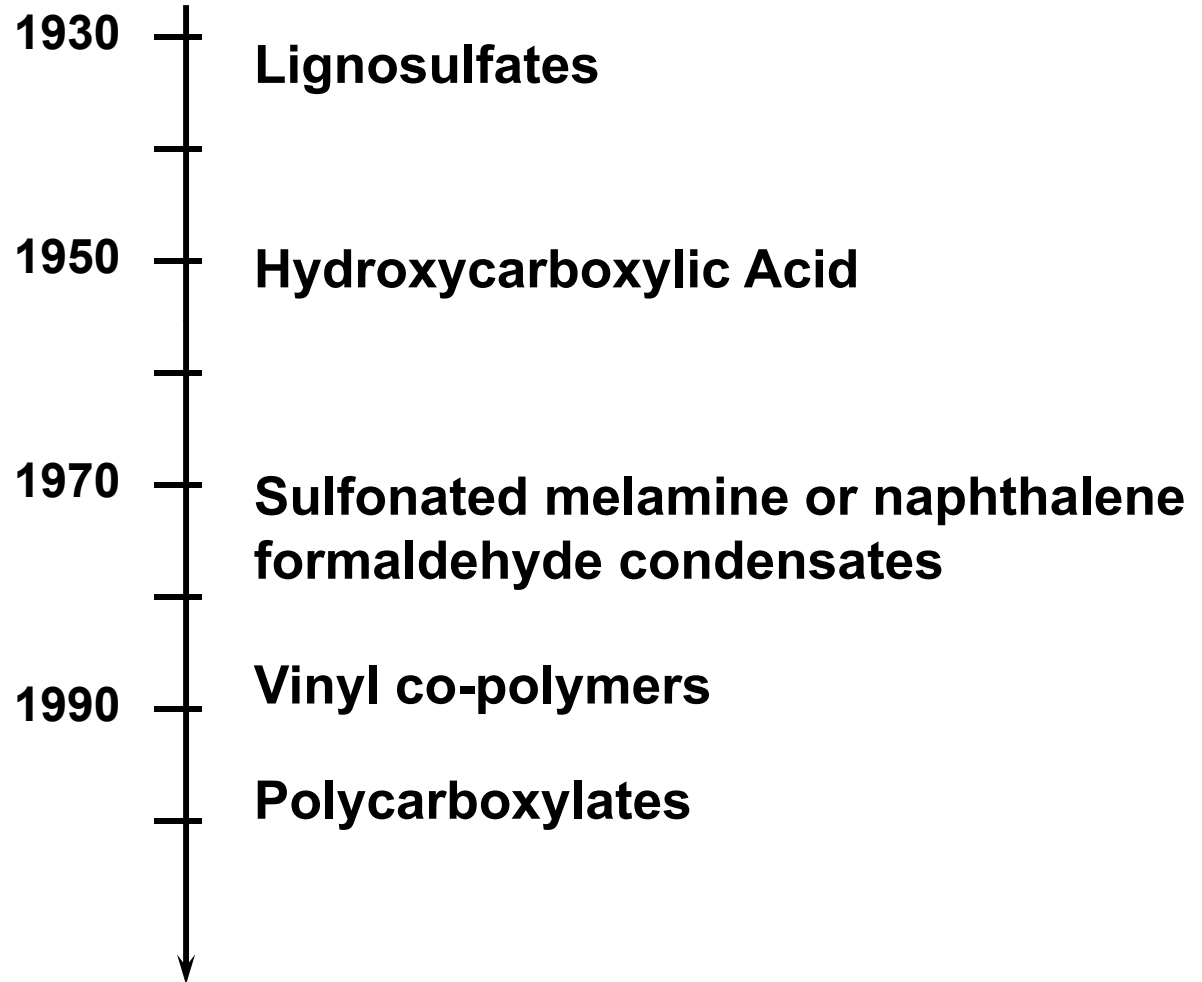
# Water Reducers

- 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

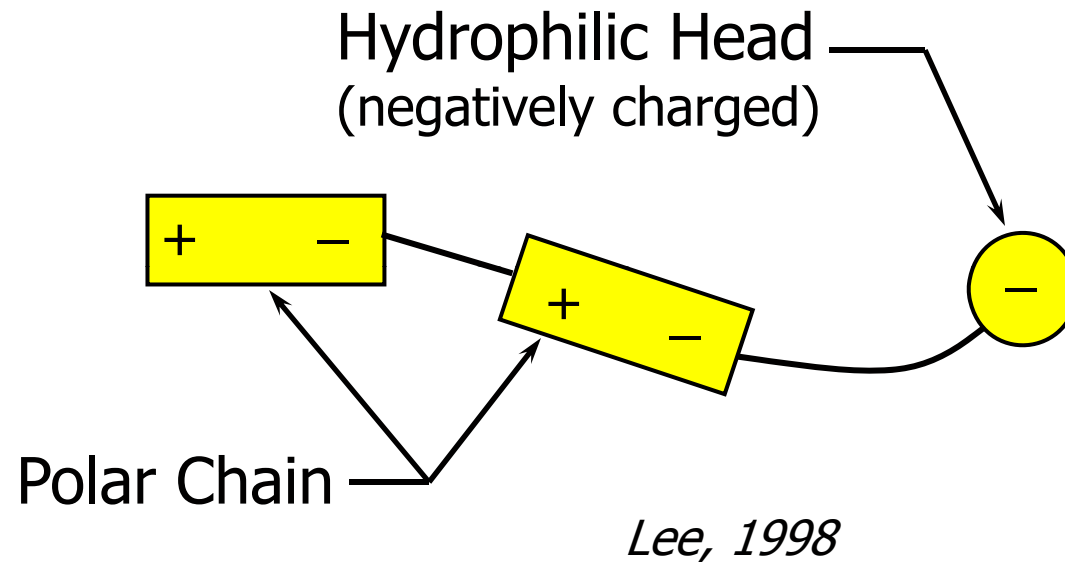


High-range water-reducing  
admixtures (HRWR) or  
Superplasticizers

12 - 30

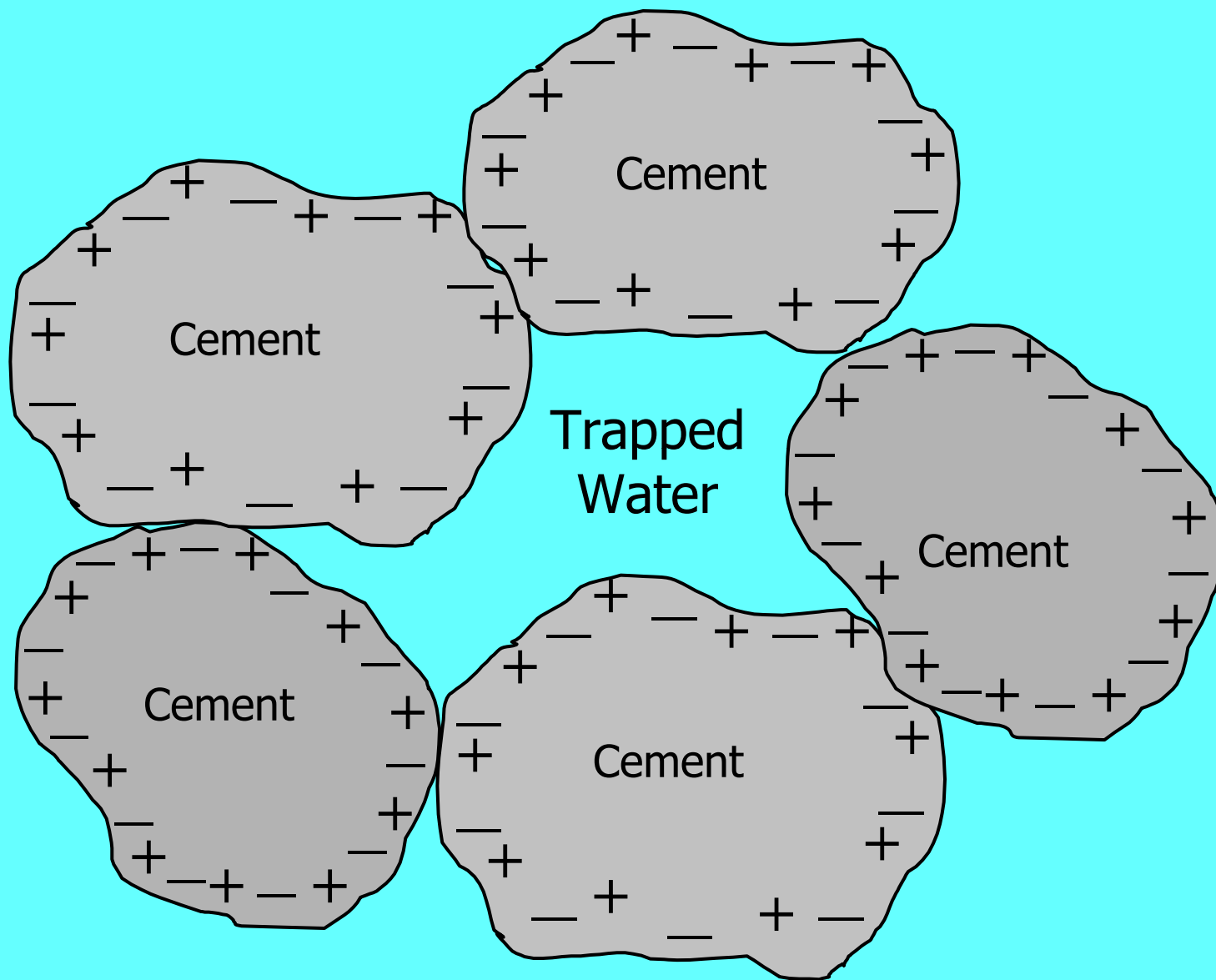


# Typical Water Reducer

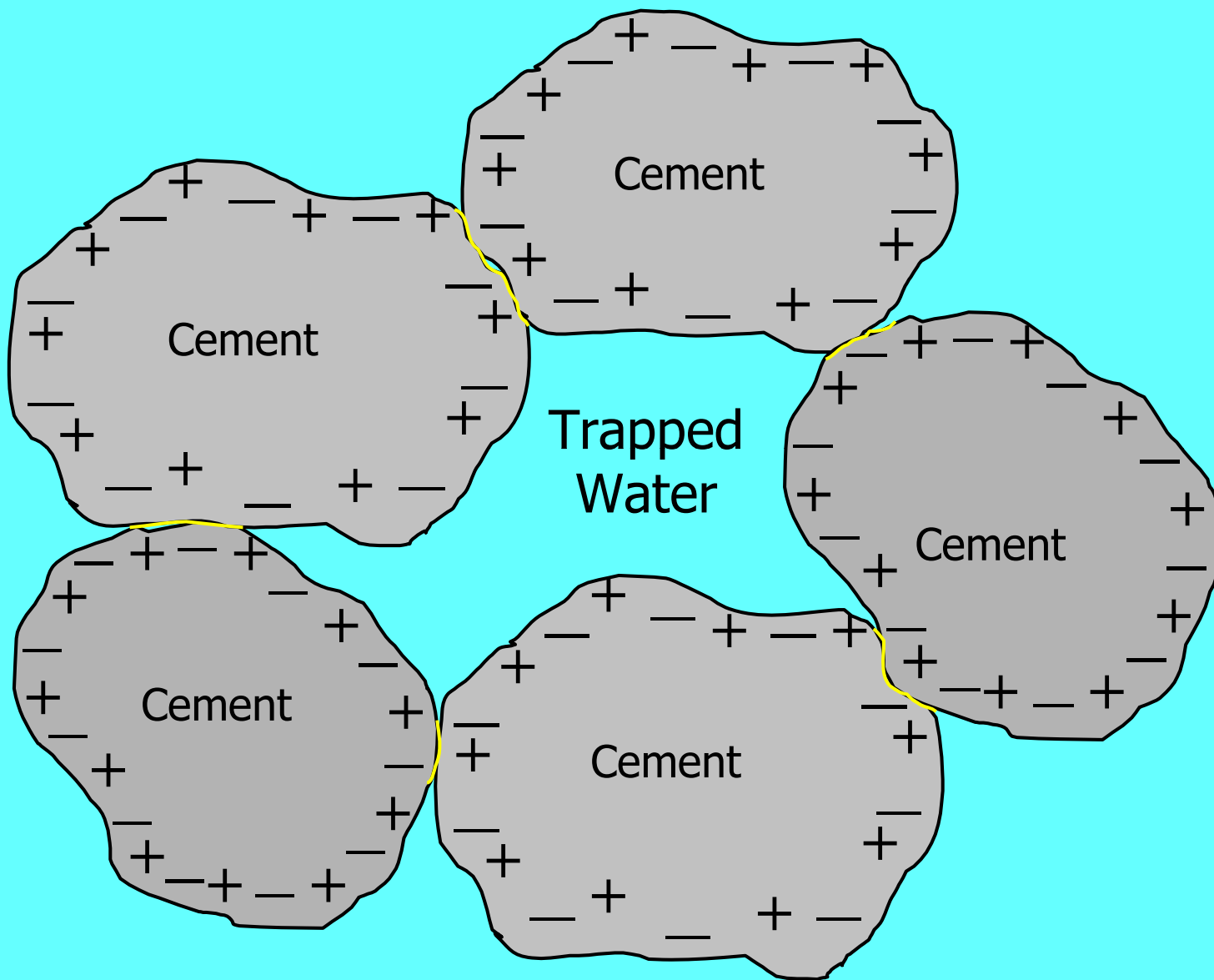


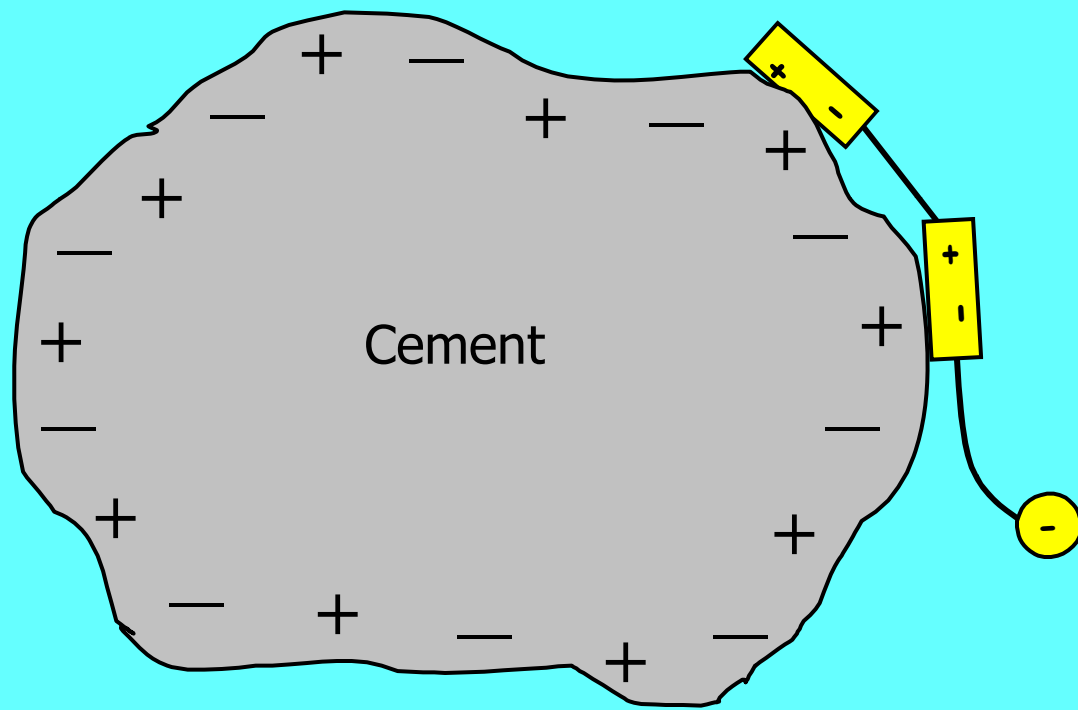
Water Reducers are typically hydrophilic surfactants which consist of a polar chain and a negatively charged head.



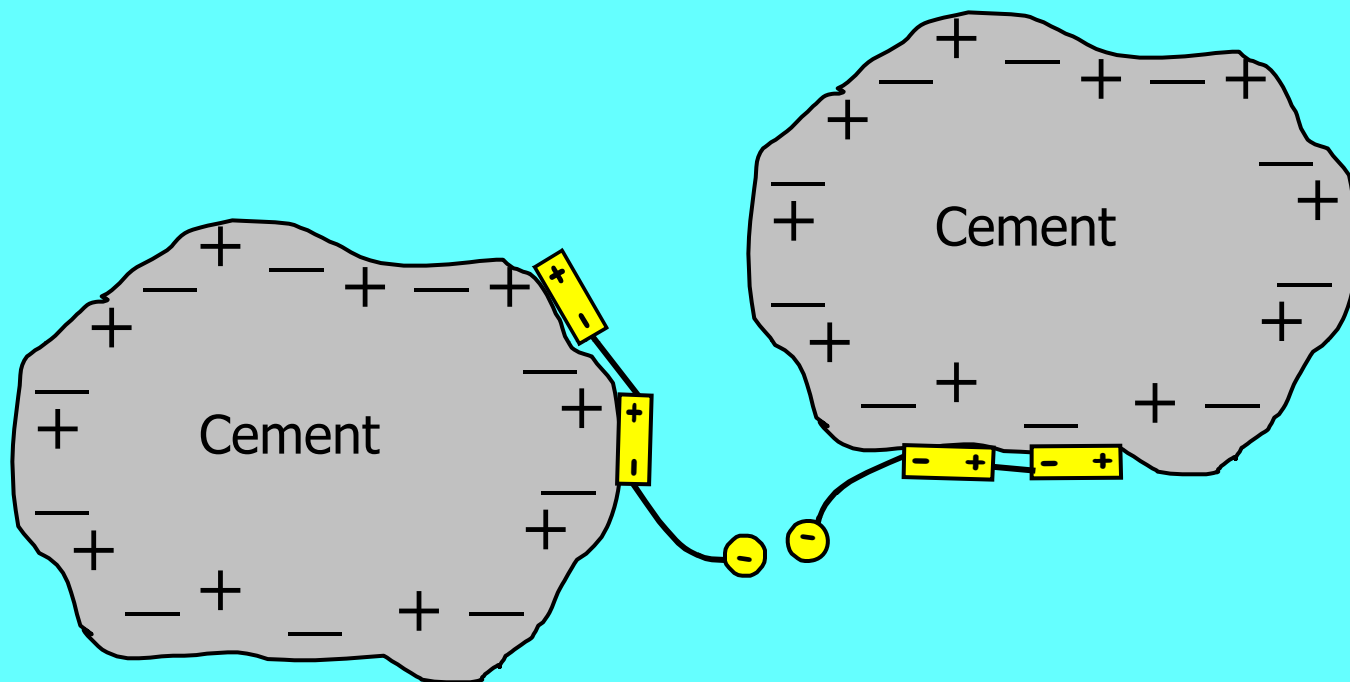


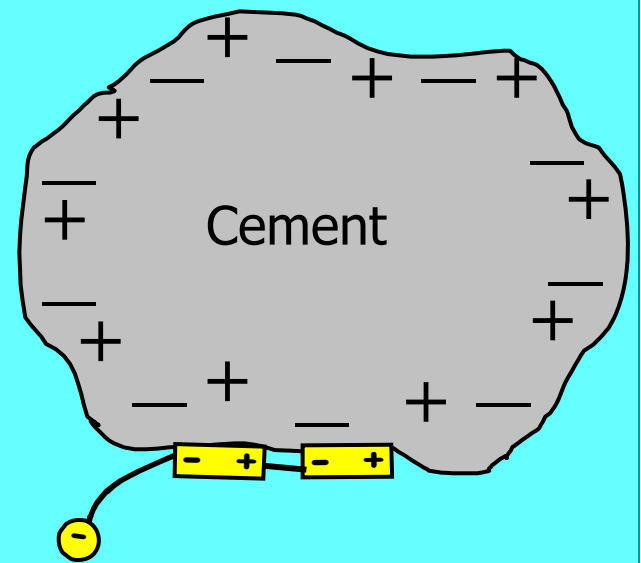
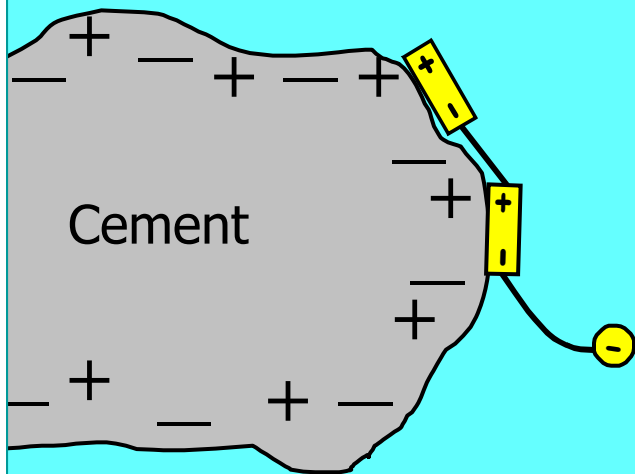


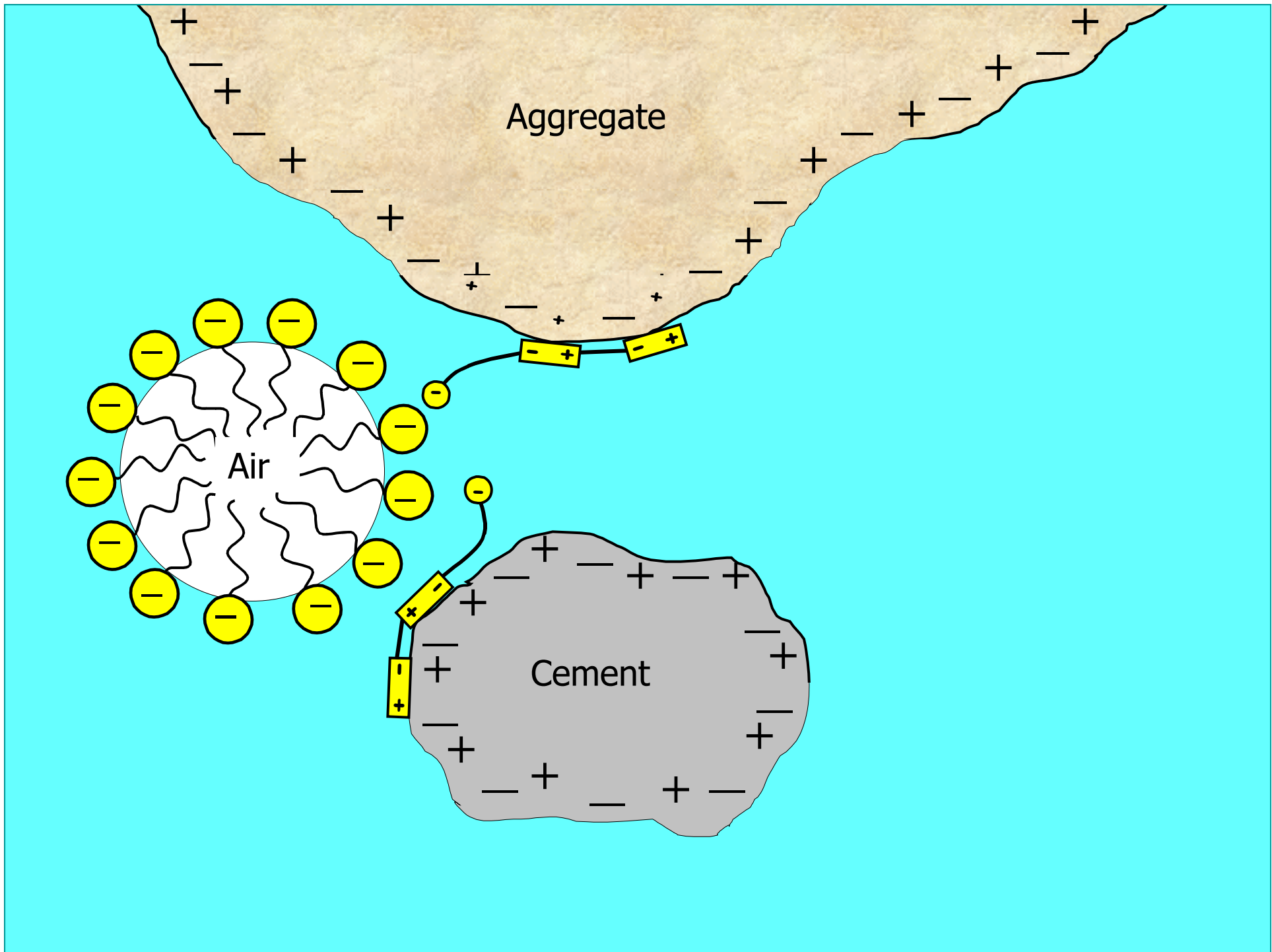


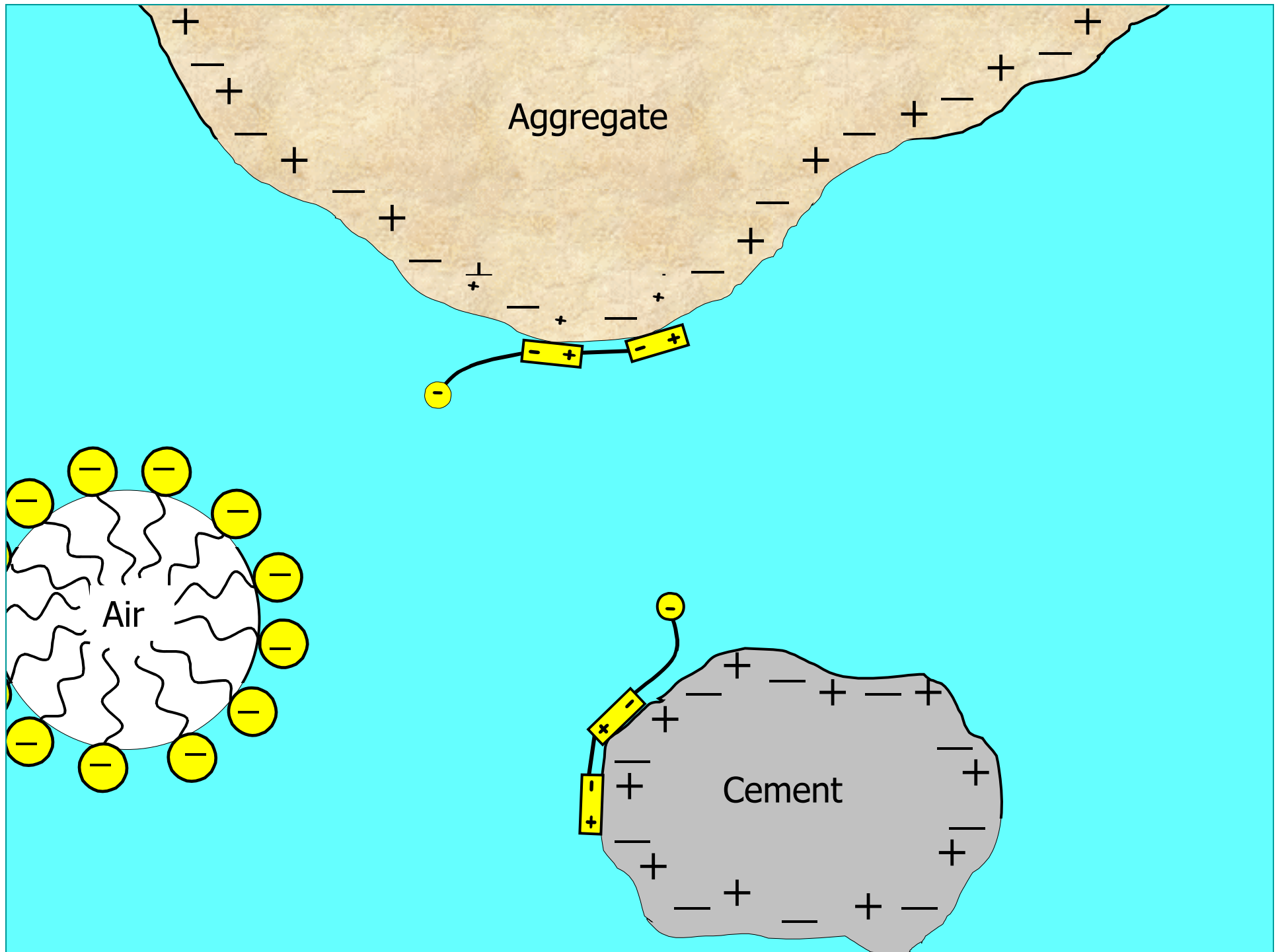


*Lee, 1998*

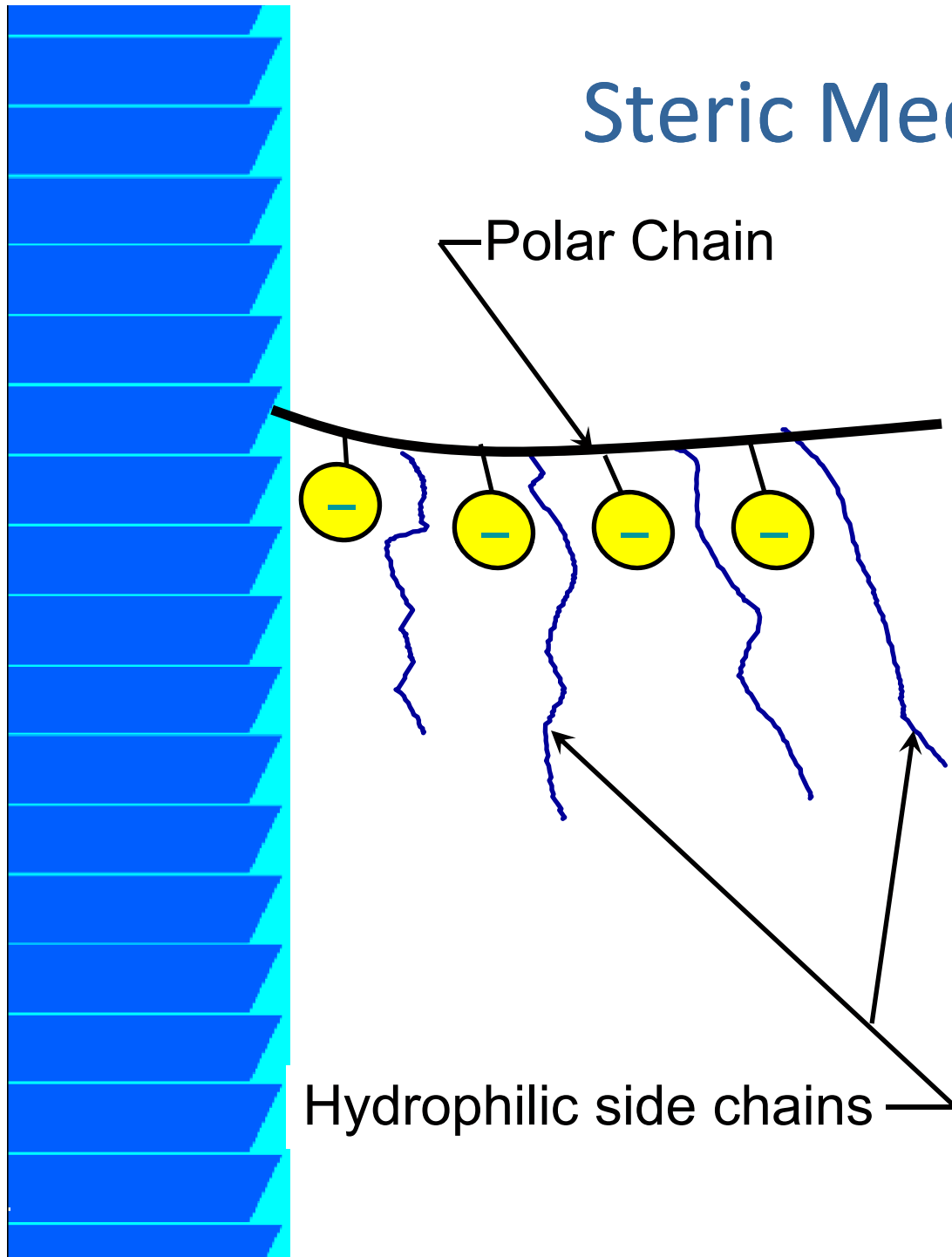






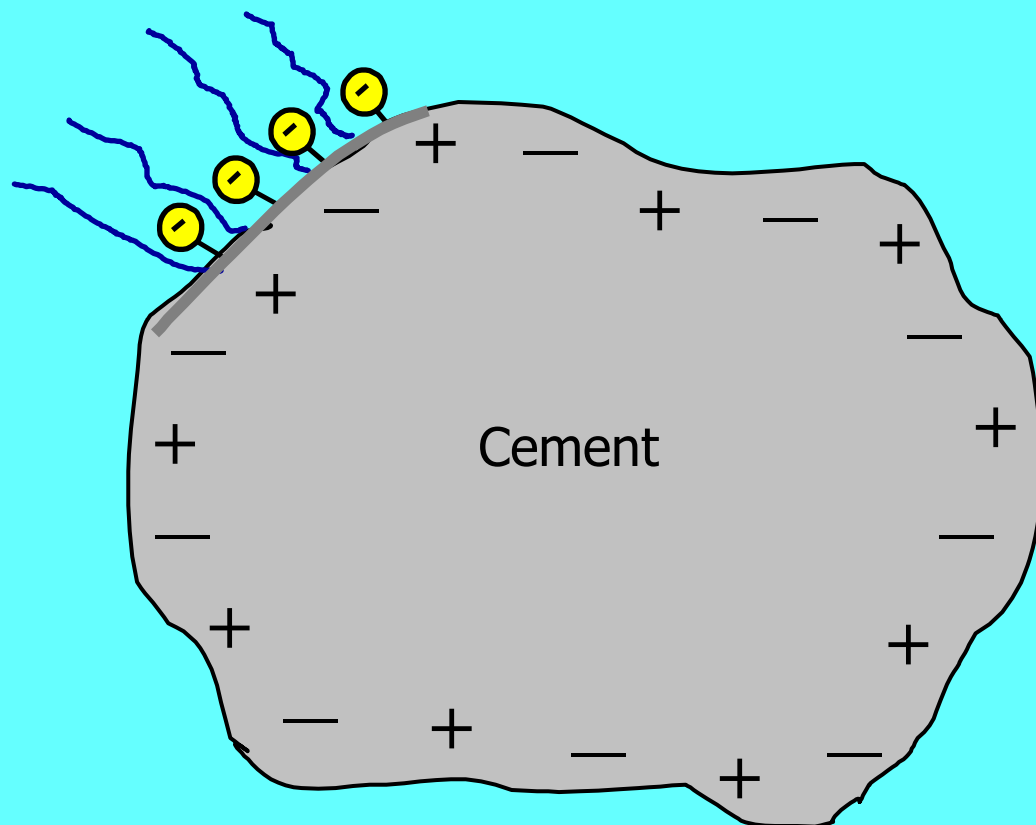


# Steric Mechanism

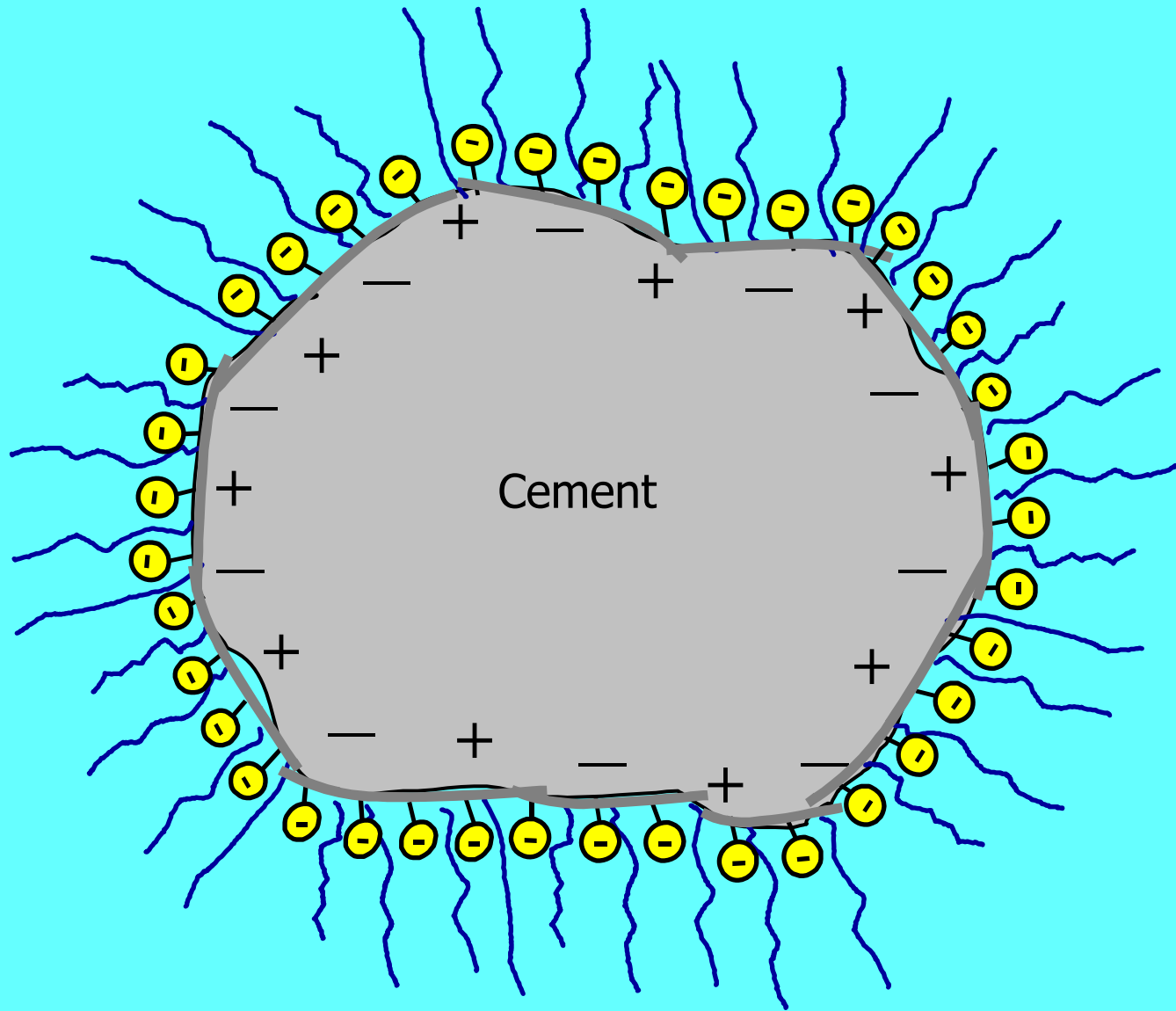


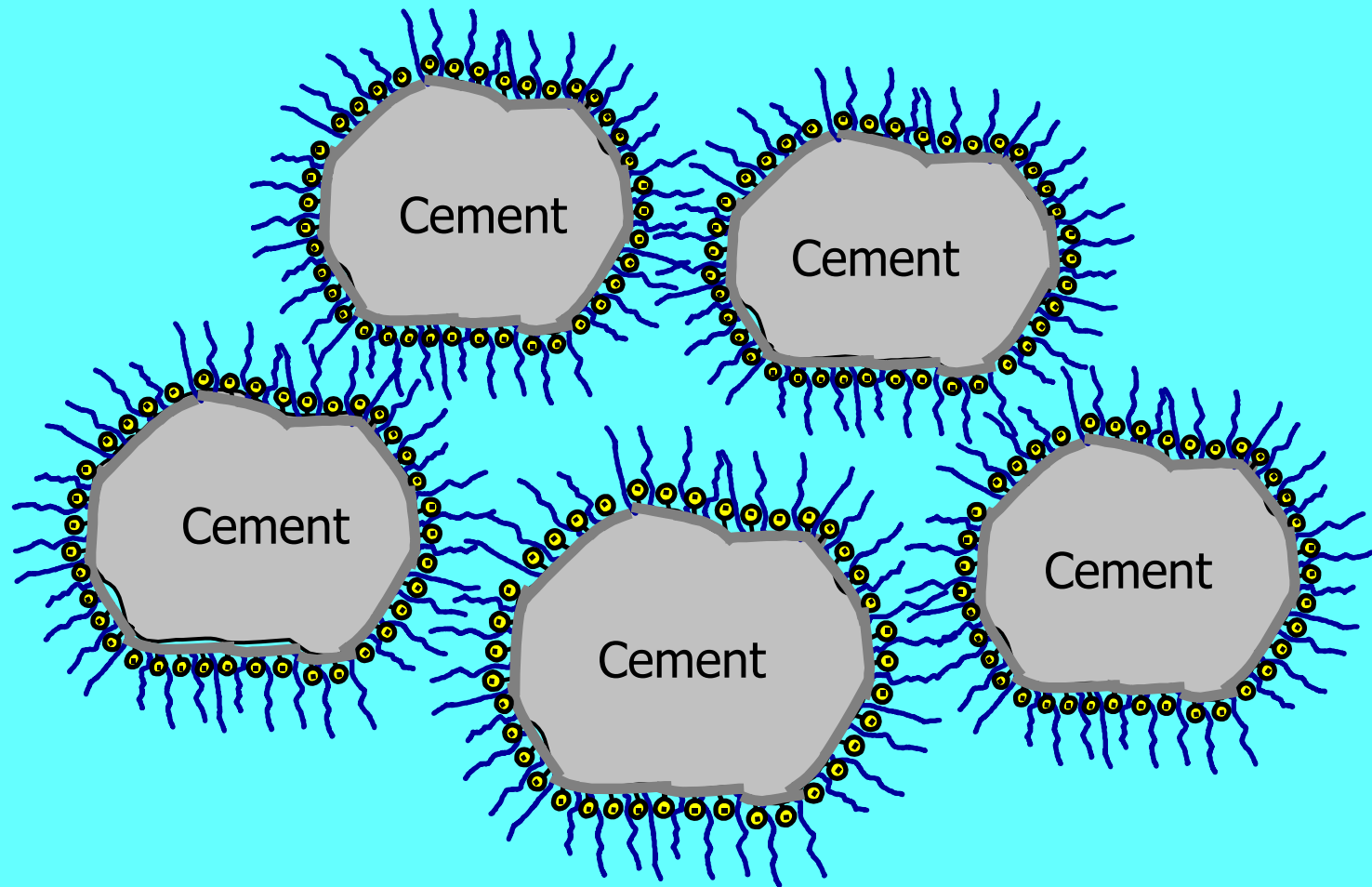
Unlike traditional superplasticizers, molecules of polycarboxylate consist of ether with a very flexible polar chain carrying negative functional groups and long hydrophilic side chains

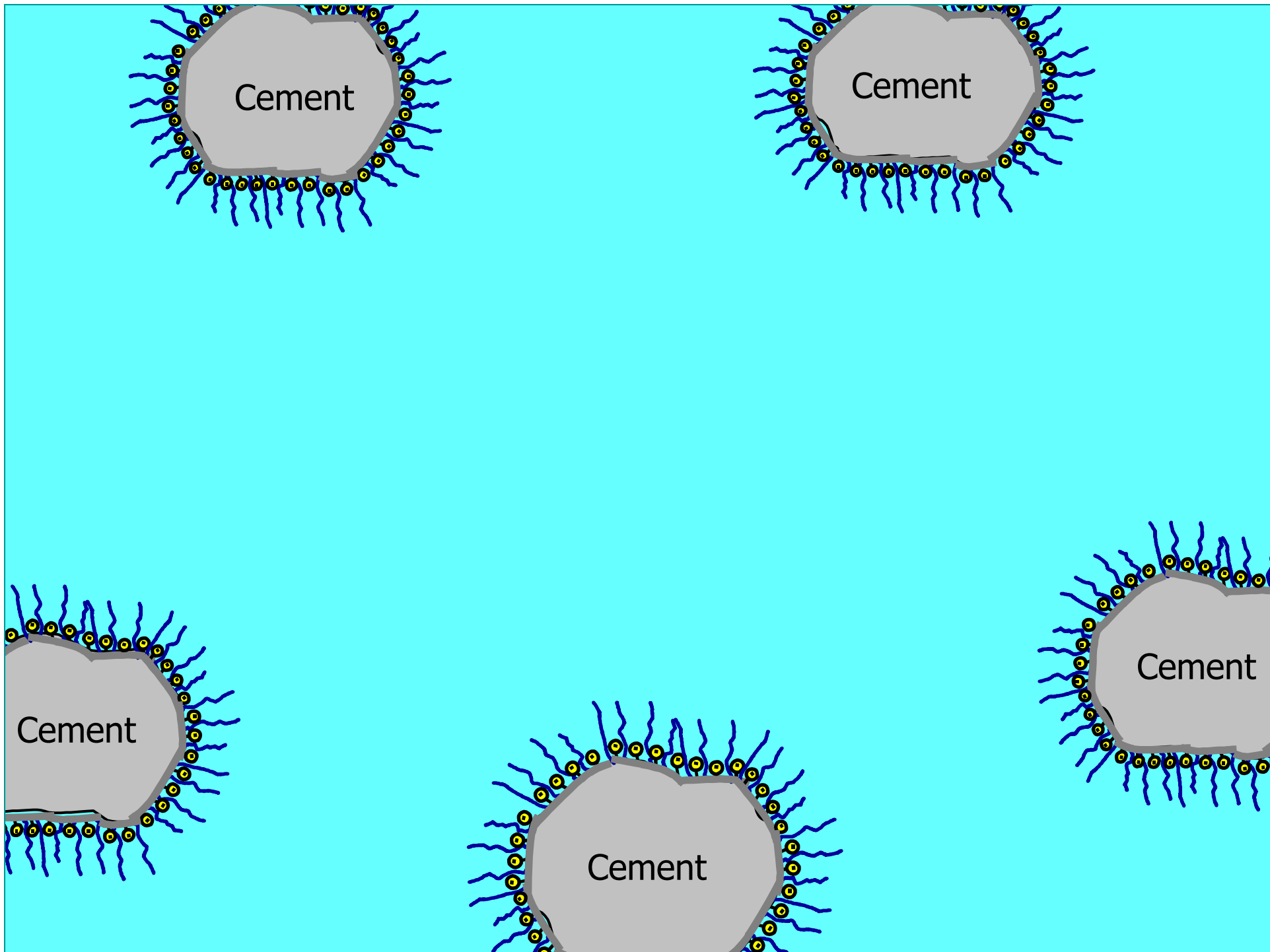
*BASF*

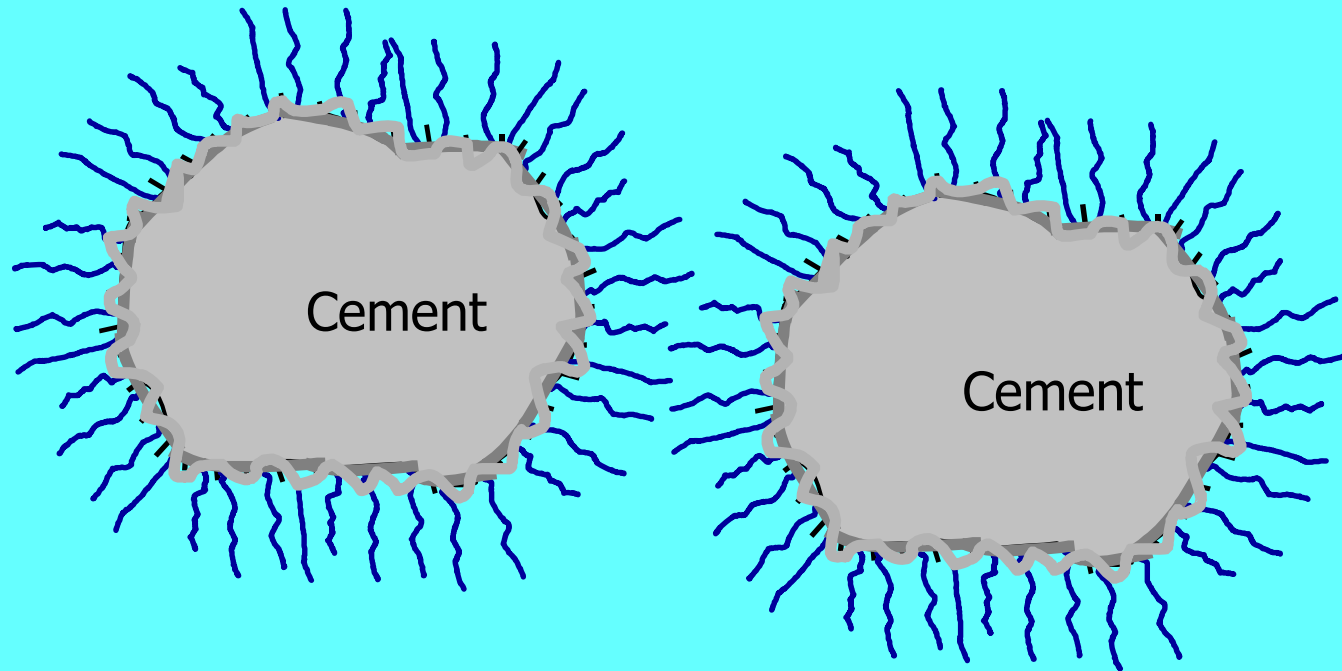












# Effect of Plasticizers on Properties of Fresh Concrete



- 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%  $\text{CaCl}_2$  (minimum)
- Pellet or granular (ASTM D98 Type 2) - 94%  $\text{CaCl}_2$  (minimum)

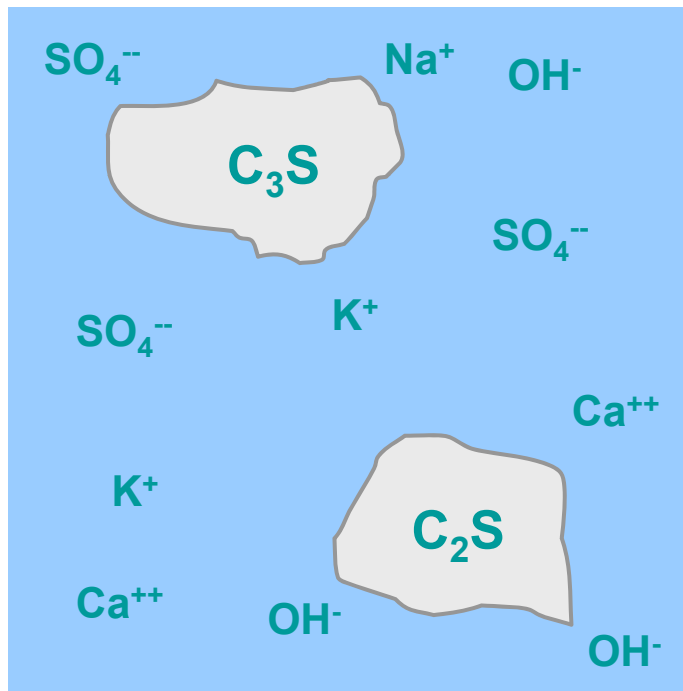
## **Non-chloride accelerators:**

- 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

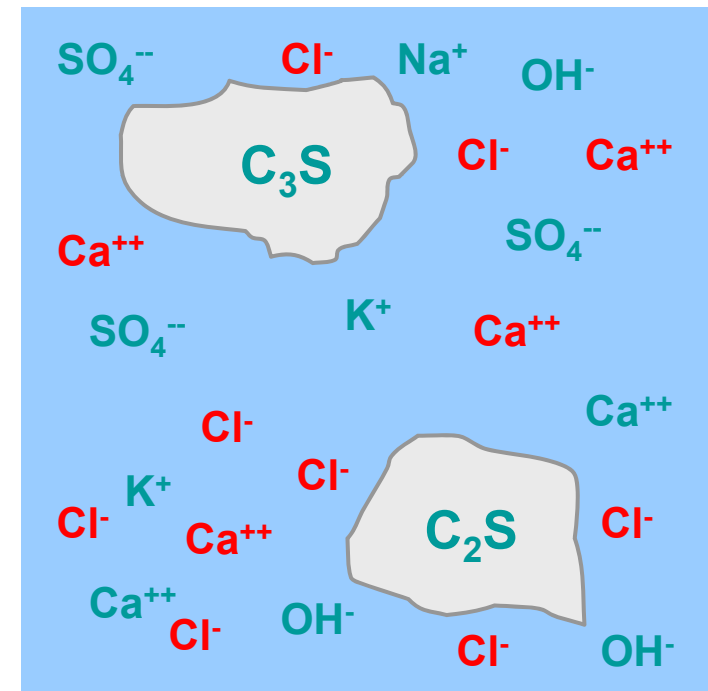
**Should meet requirements for Type C or Type E in ASTM C494**

# Accelerators – Mechanisms

No Admixture

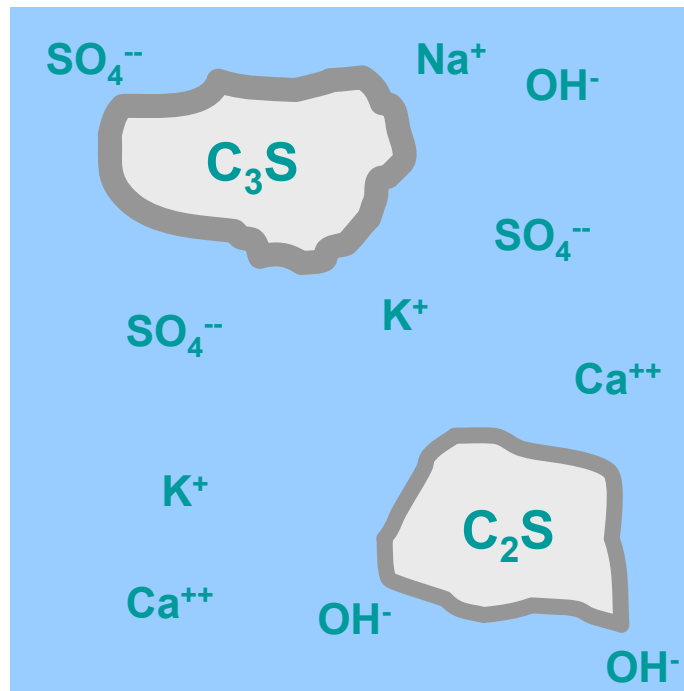


CaCl<sub>2</sub> Accelerator

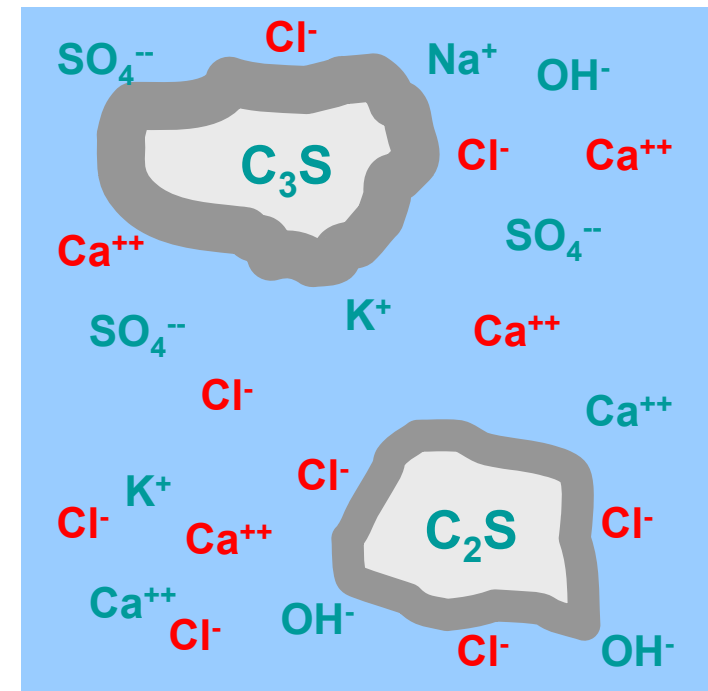


# Accelerators – Mechanisms

No Admixture



CaCl<sub>2</sub> Accelerator



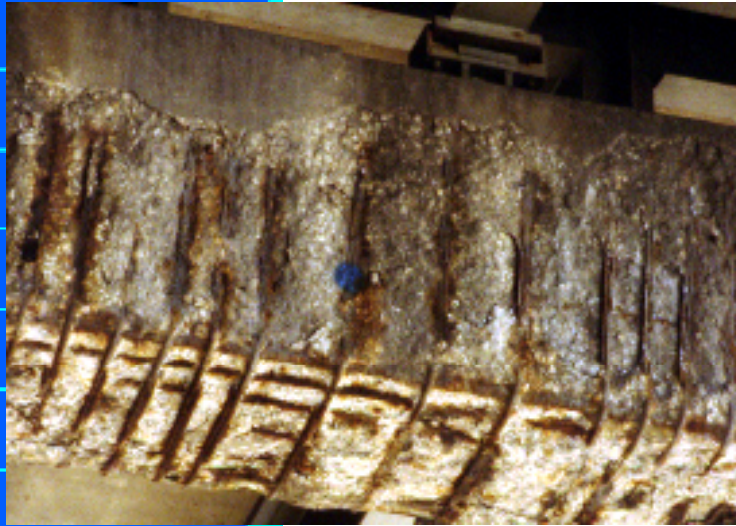


# Effects on Concrete Properties

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.



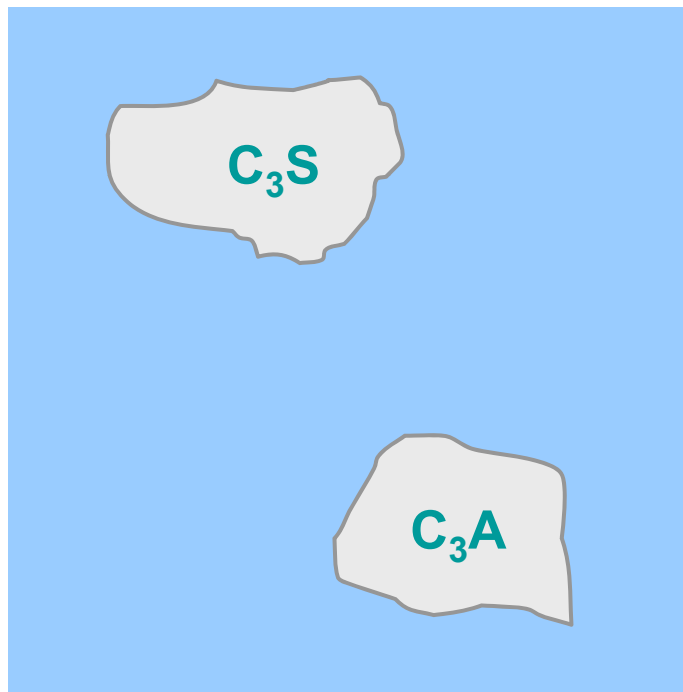


# Types of Retarders

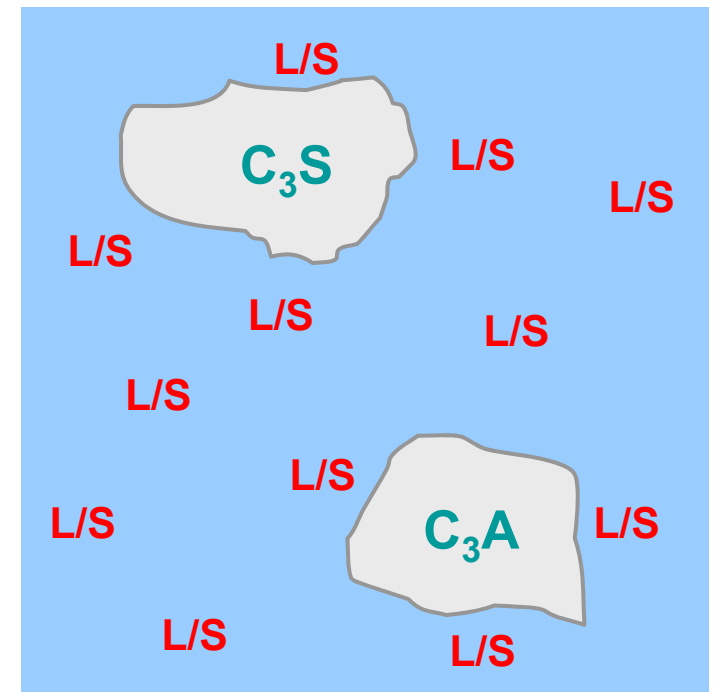
- Lignosulfates
- Hydroxycarboxylic acid
- Sugars
- Tartaric Acid and Salts

# Retarders – Mechanisms

No Admixture

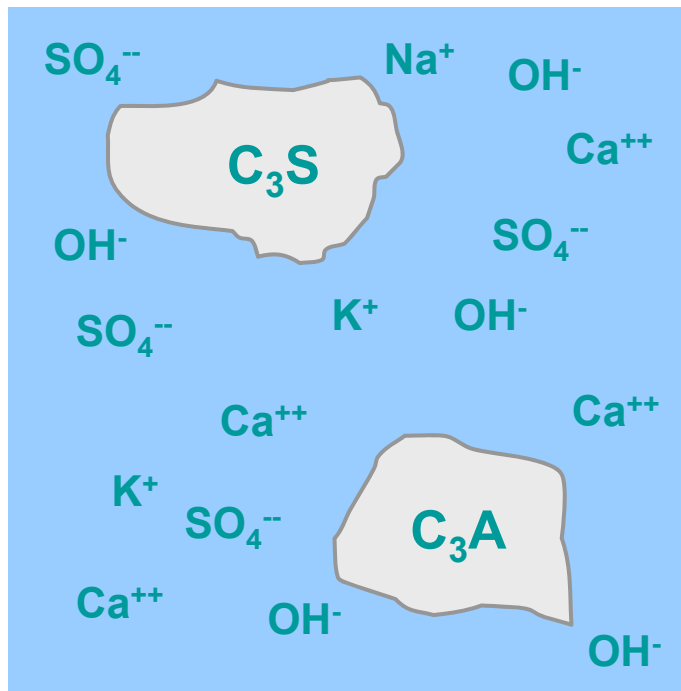


Retarder (e.g. Lignosulfate)

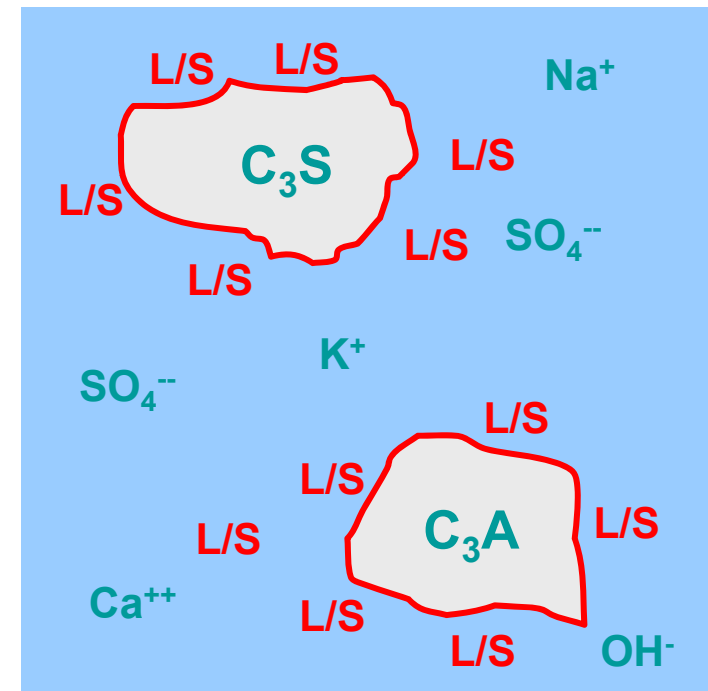


# Retarders – Mechanisms

No Admixture



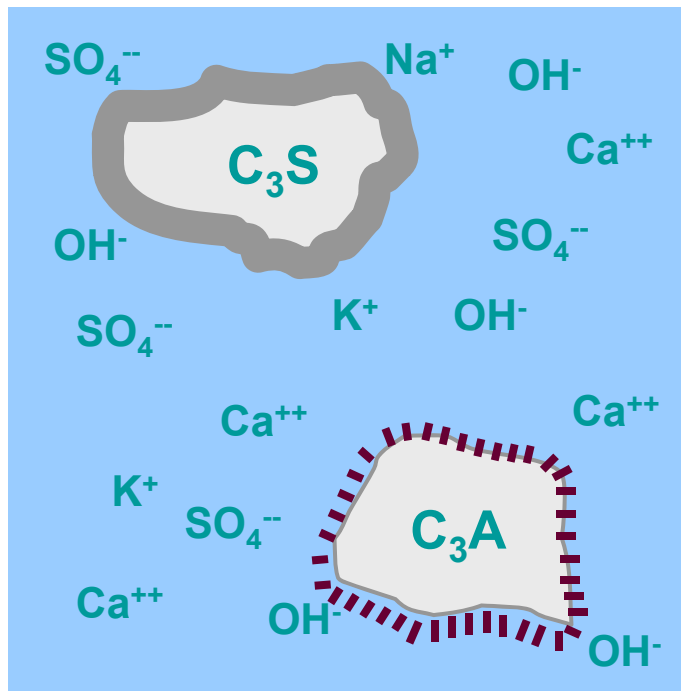
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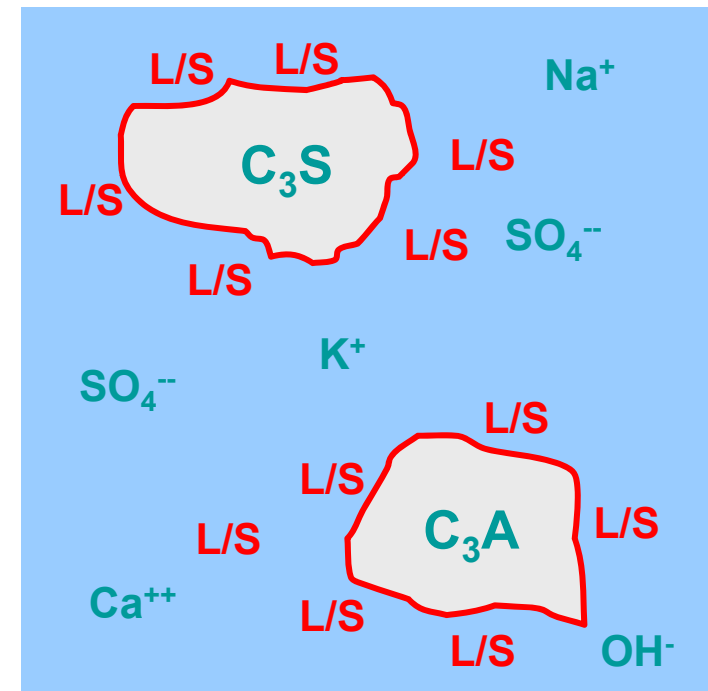


# Retarders – Mechanisms

No Admixture

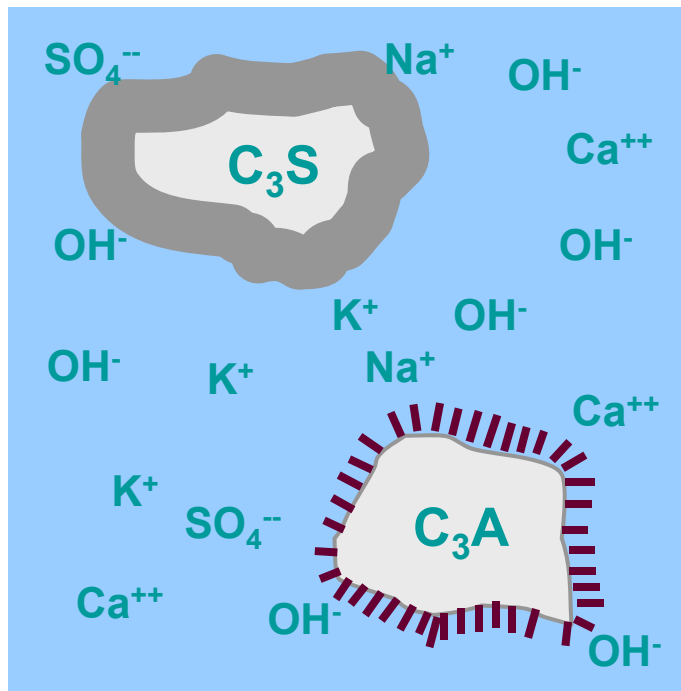


Retarder (e.g. Lignosulfate)

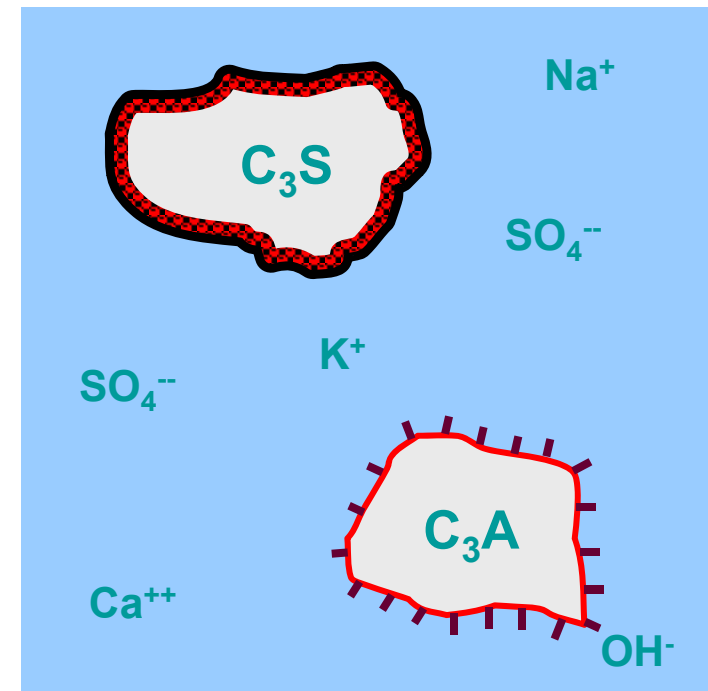


# Retarders – Mechanisms

No Admixture



Retarder (e.g. Lignosulfate)





# 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**

