

Concrete Durability

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Outline

- What is durable concrete?
- Why does concrete fail?
- What can we do about it?

What is durable concrete?

- The right
 - Materials
 - Proportions
 - Workmanship
- For the environment
- So that it lasts for the intended time

Concrete

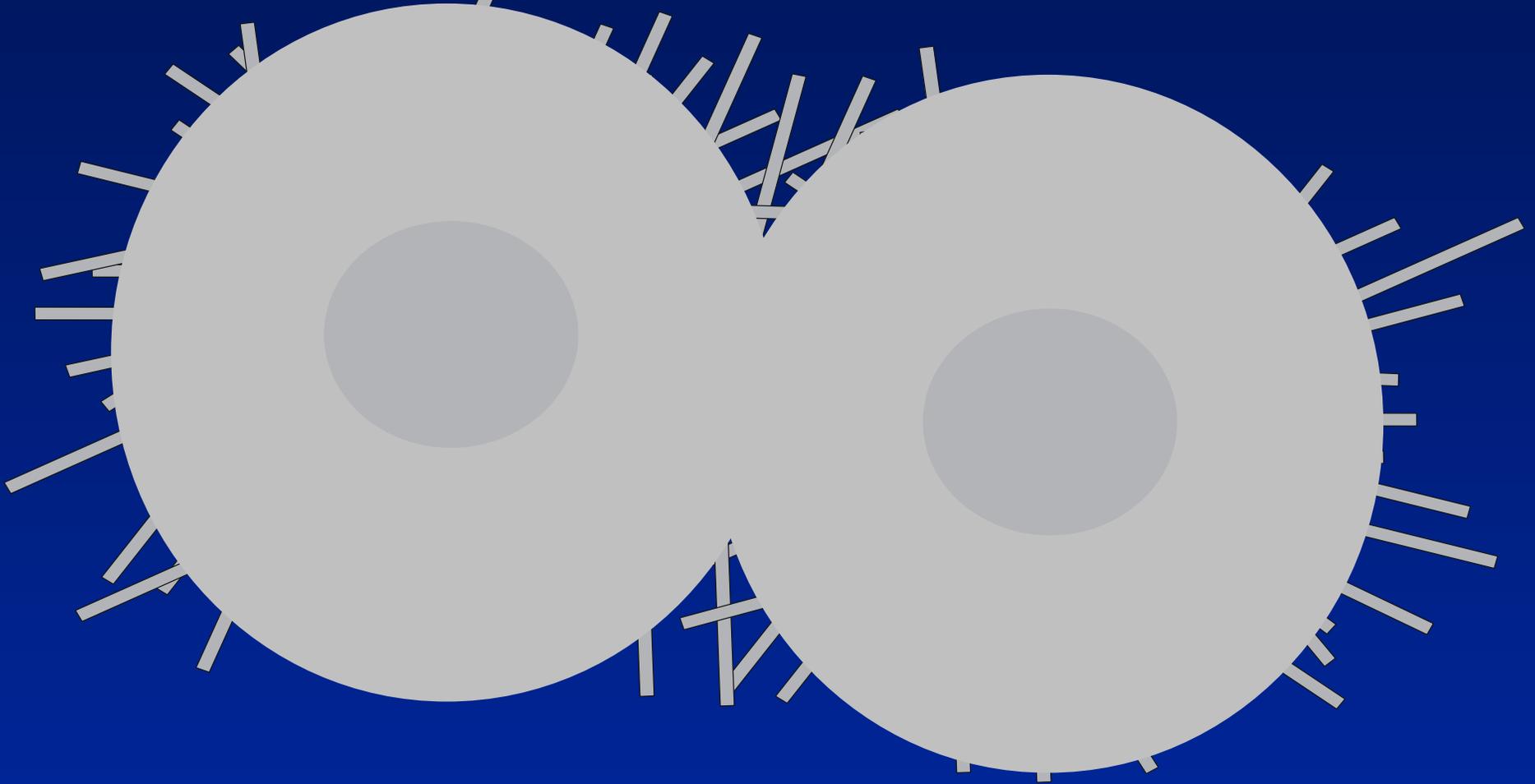


Portland Cement

- Traditional cements (Type I to Type V)
- Blended cements

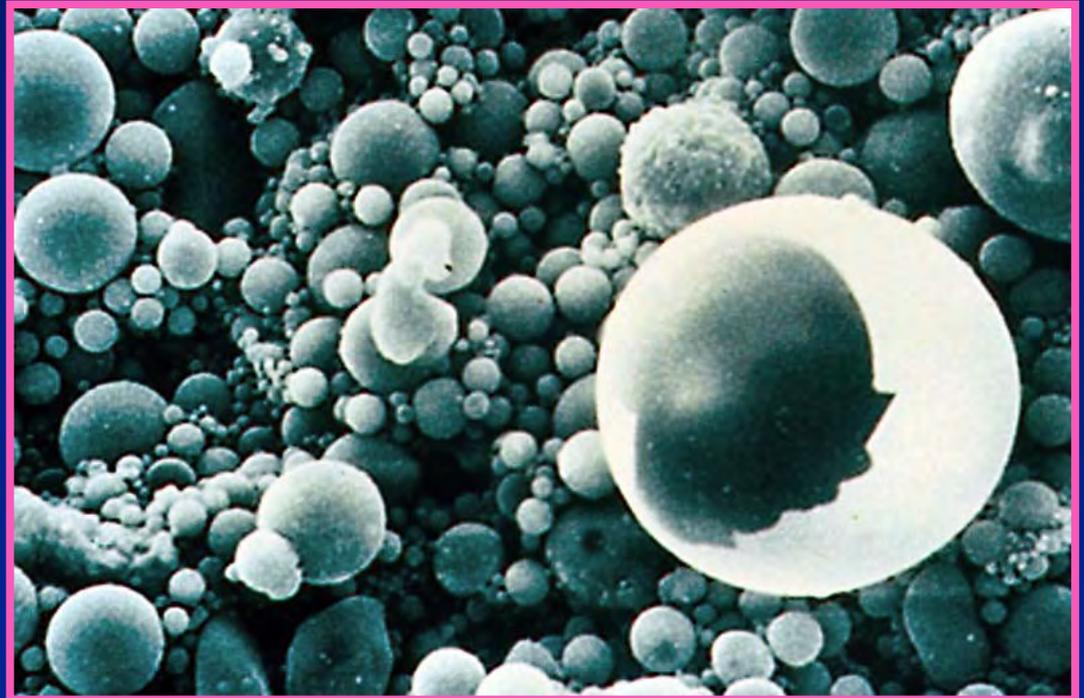


Microstructure of Hydrated Cement Paste



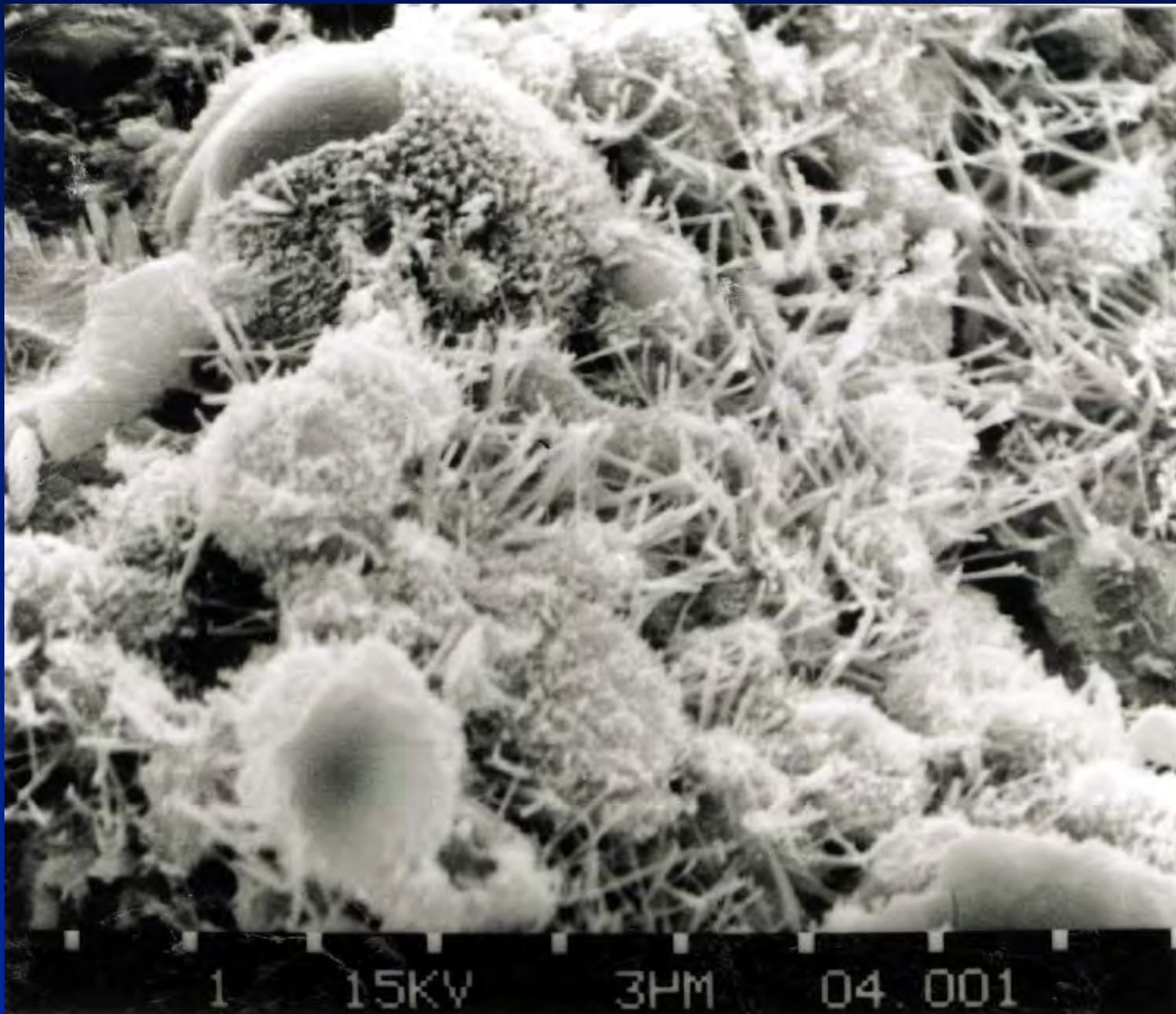
Pozzolans

- Slag (GGBFS)
- Fly ash
- Silica Fume
- Metakaolin



Cement Hydration

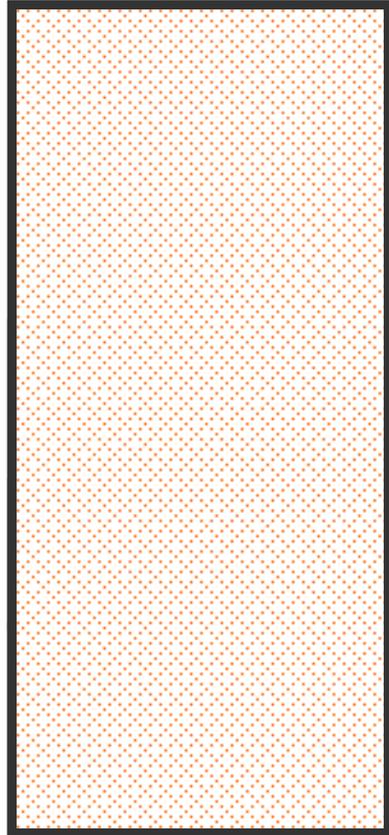




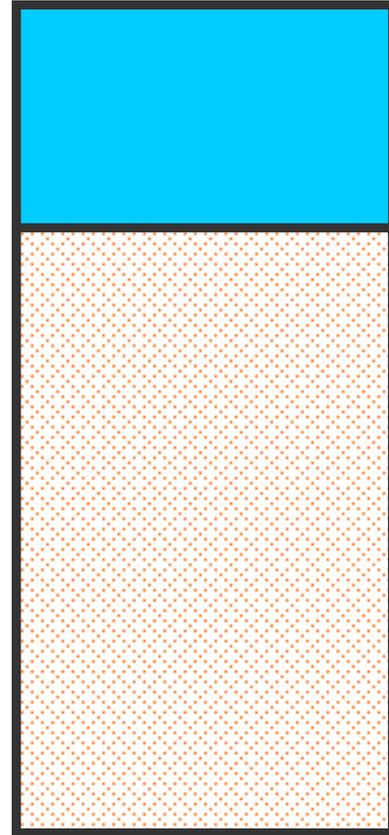


Water



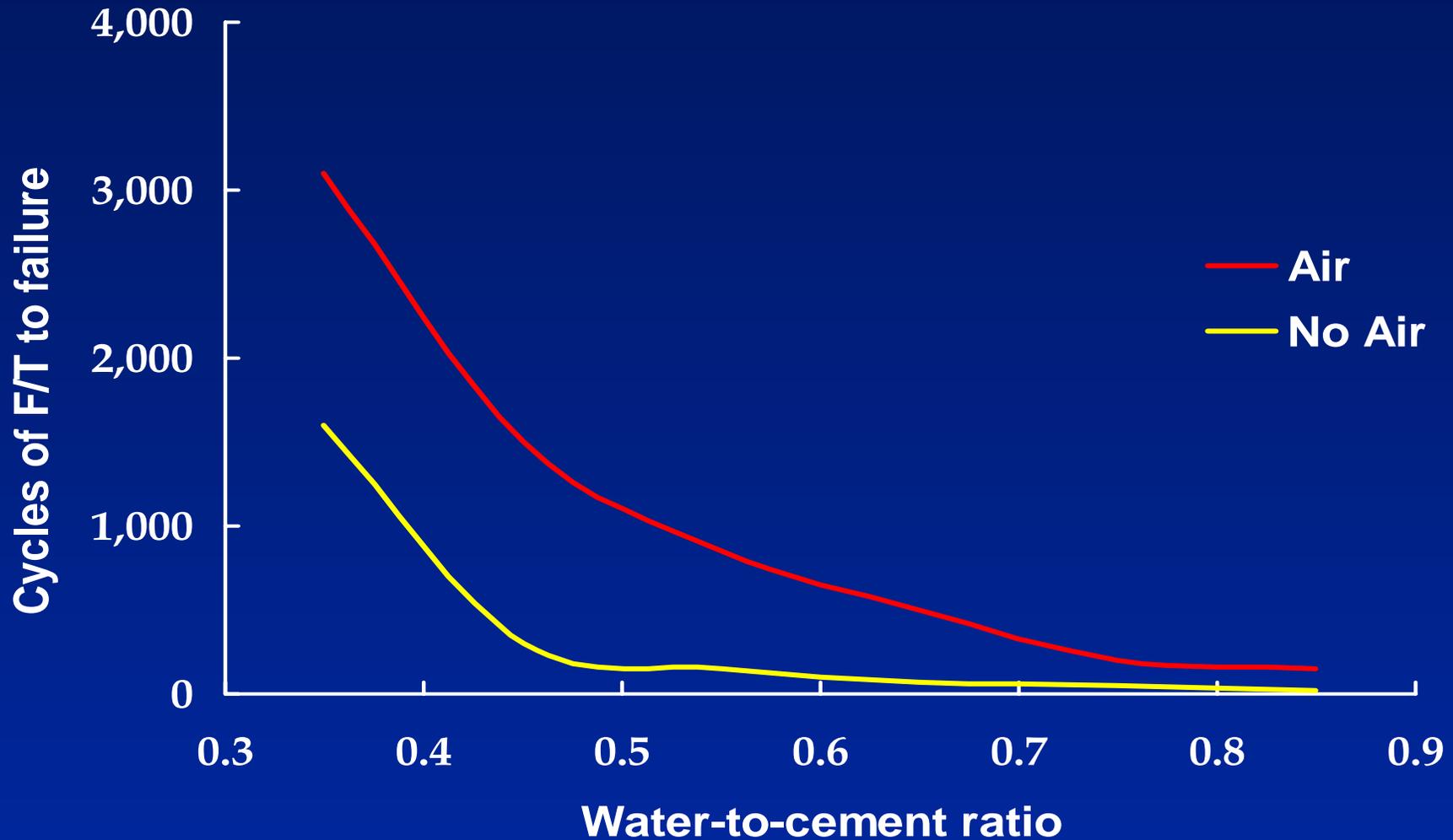


W/C = 0.45



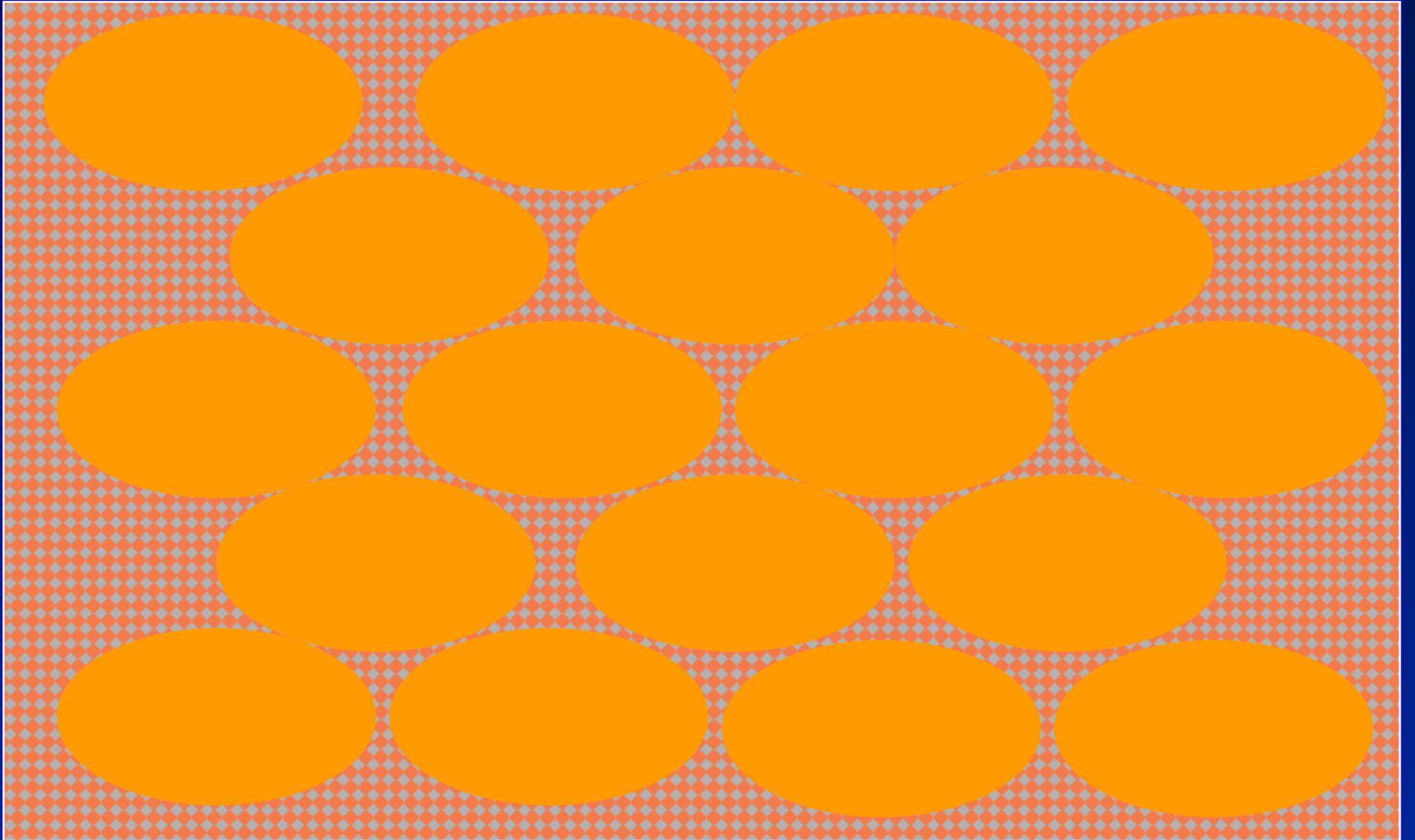
W/C = 0.75

Effect of w/c Ratio on F/T Resistance



Aggregates





Chemical Admixtures

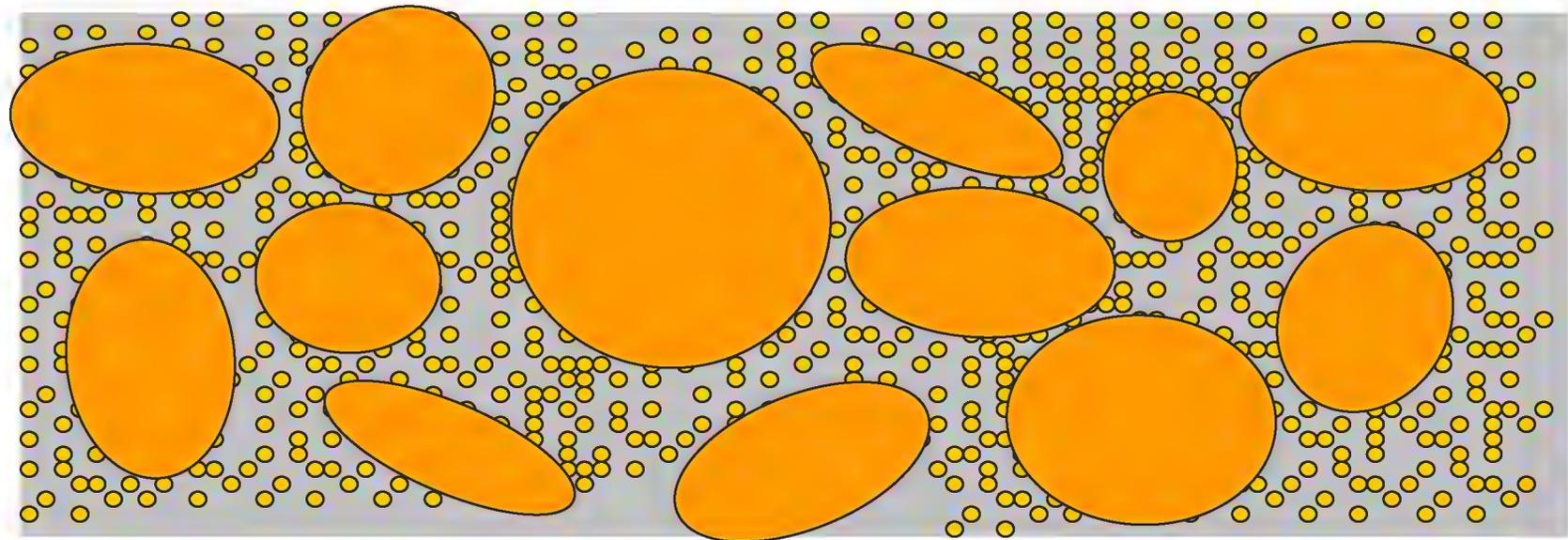


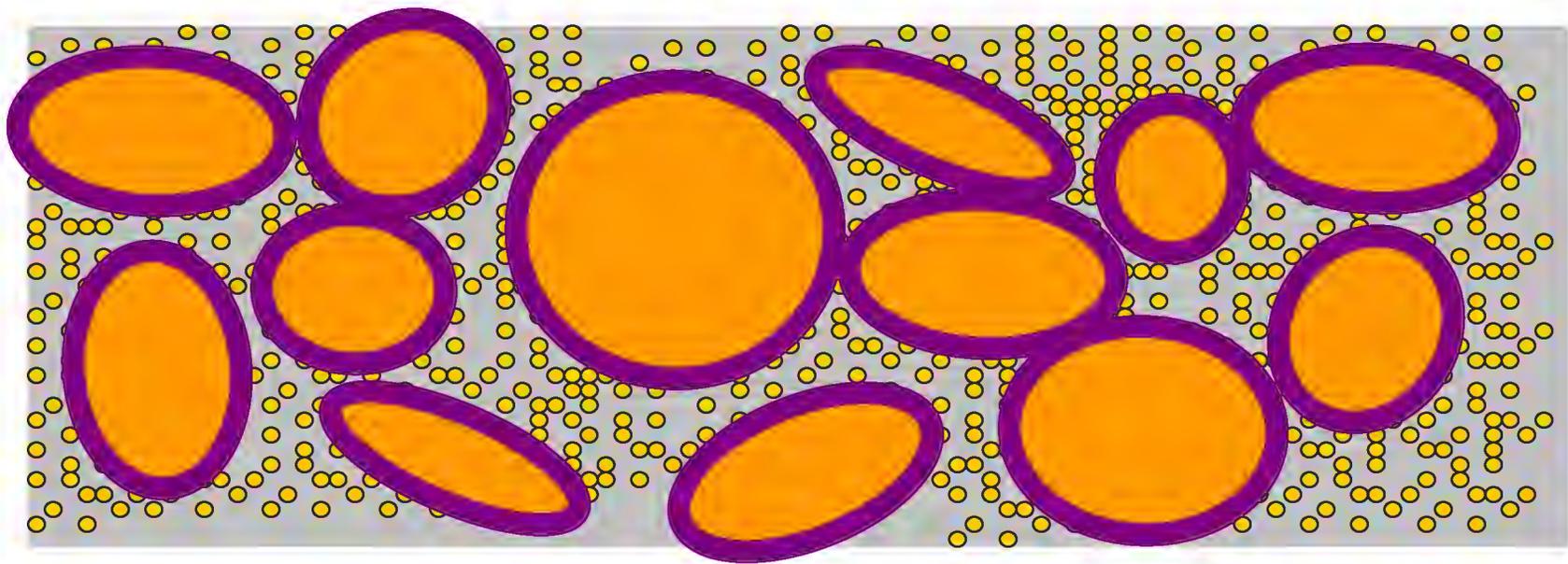
Why Does Concrete Fail?

- Alkali Silica Reaction
- Sulfate Attack
- Frost Related Damage
- Others...

Alkali Silica Reaction

- Water + alkali hydroxide + reactive silicate aggregate → alkali silicates
- Alkali silicates + water → gel + expansion





Sulfate Attack

- Sulfates
- Water
- C_3A

Sulfate Attack

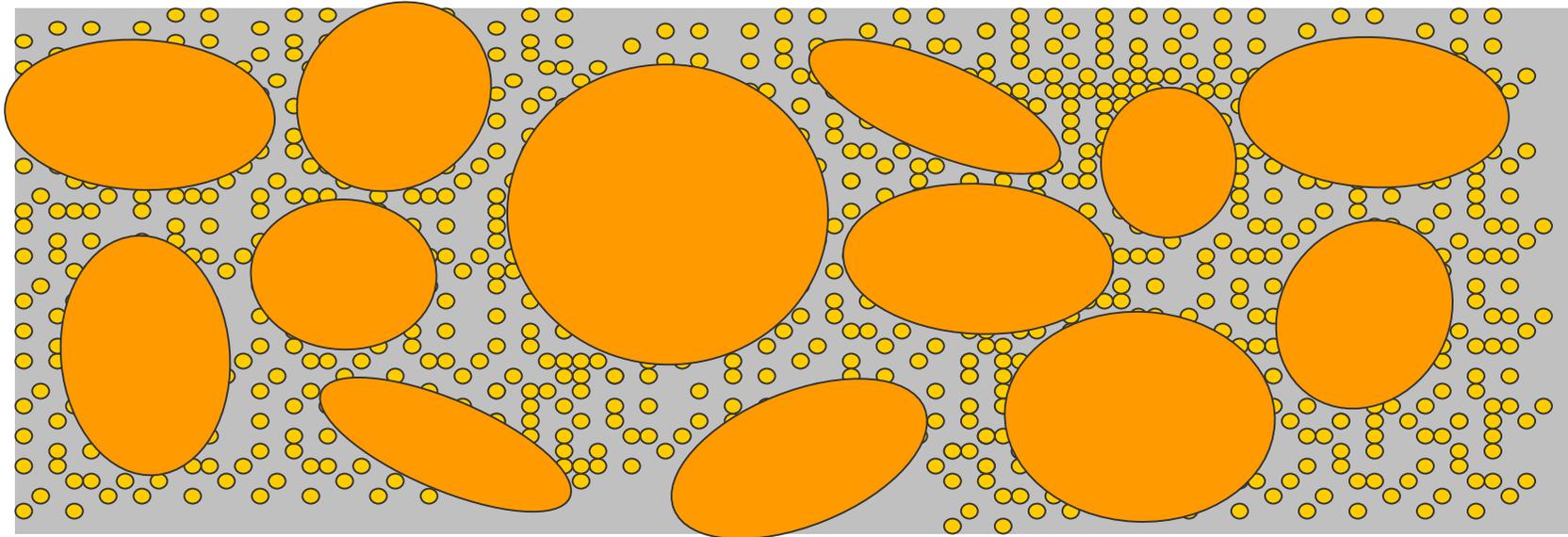
- $C_3A + C' + 12H \rightarrow C_4A'H_{12}$ (monosulfate)
- $C_4A'H_{12} + 2C' + 20H \rightarrow C_6A'_3H_{32}$ (ettringite)
- $Na_2SO_4 + Ca(OH)_2 + 2H_2O \rightarrow 2NaOH + CaSO_4 \cdot 2H_2O$ (gypsum)



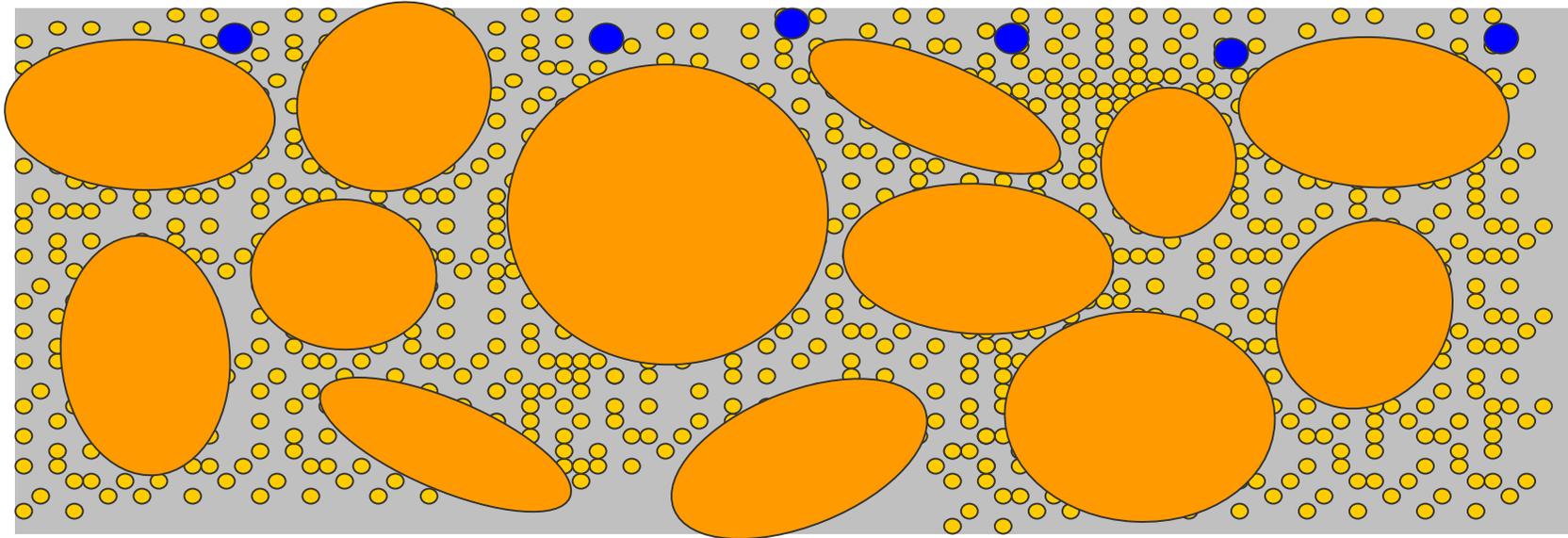
Freeze thaw / Salt scaling

- Cyclic freezing and expansion of water
- Osmotic pressure
- Salt crystallization
- D-Cracking

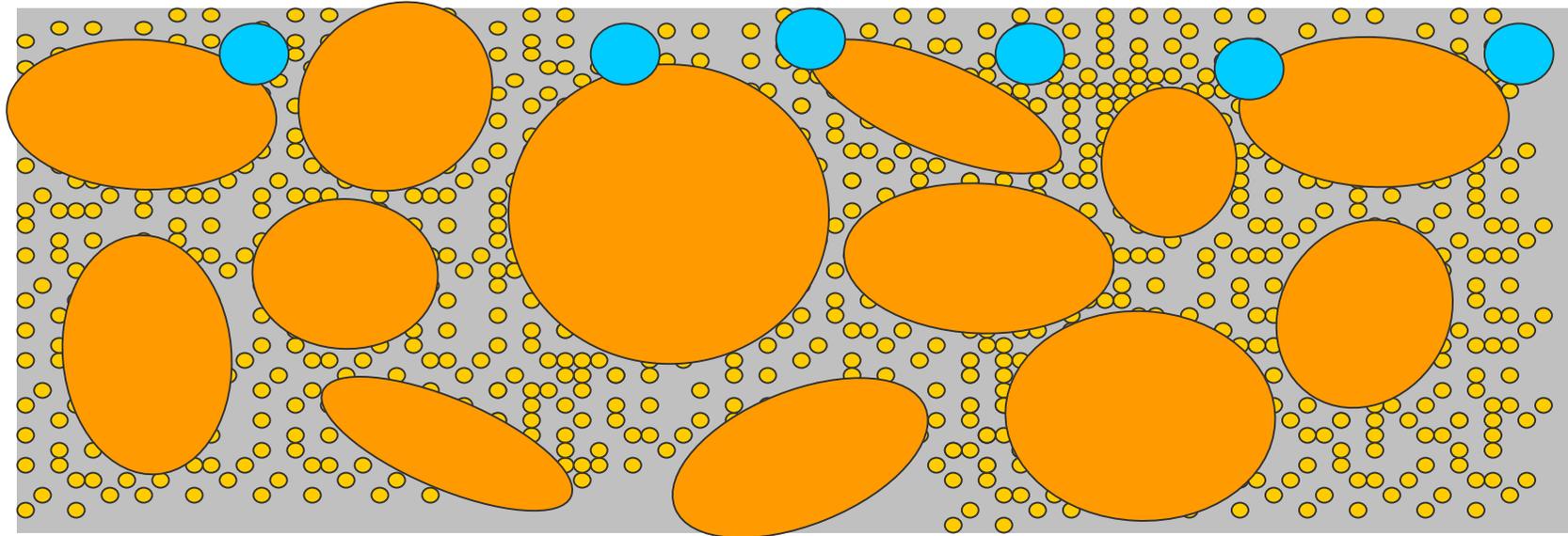
Freeze thaw



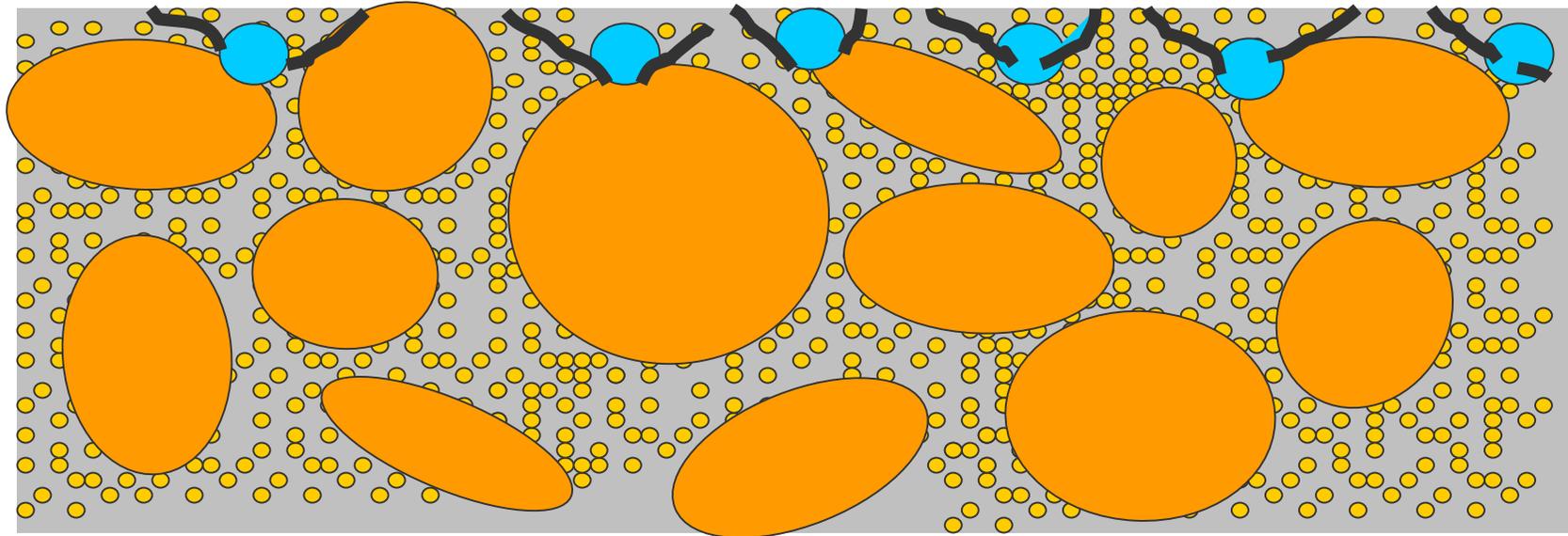
Freeze thaw



Freeze thaw



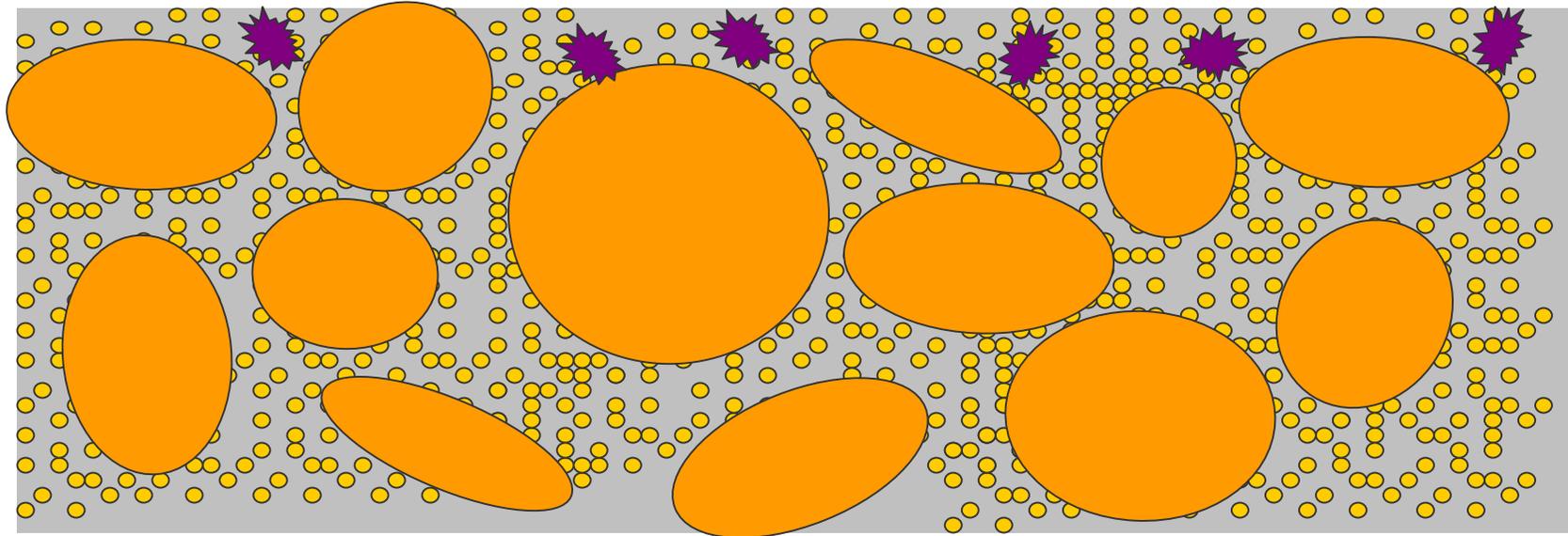
Freeze thaw



Freeze thaw



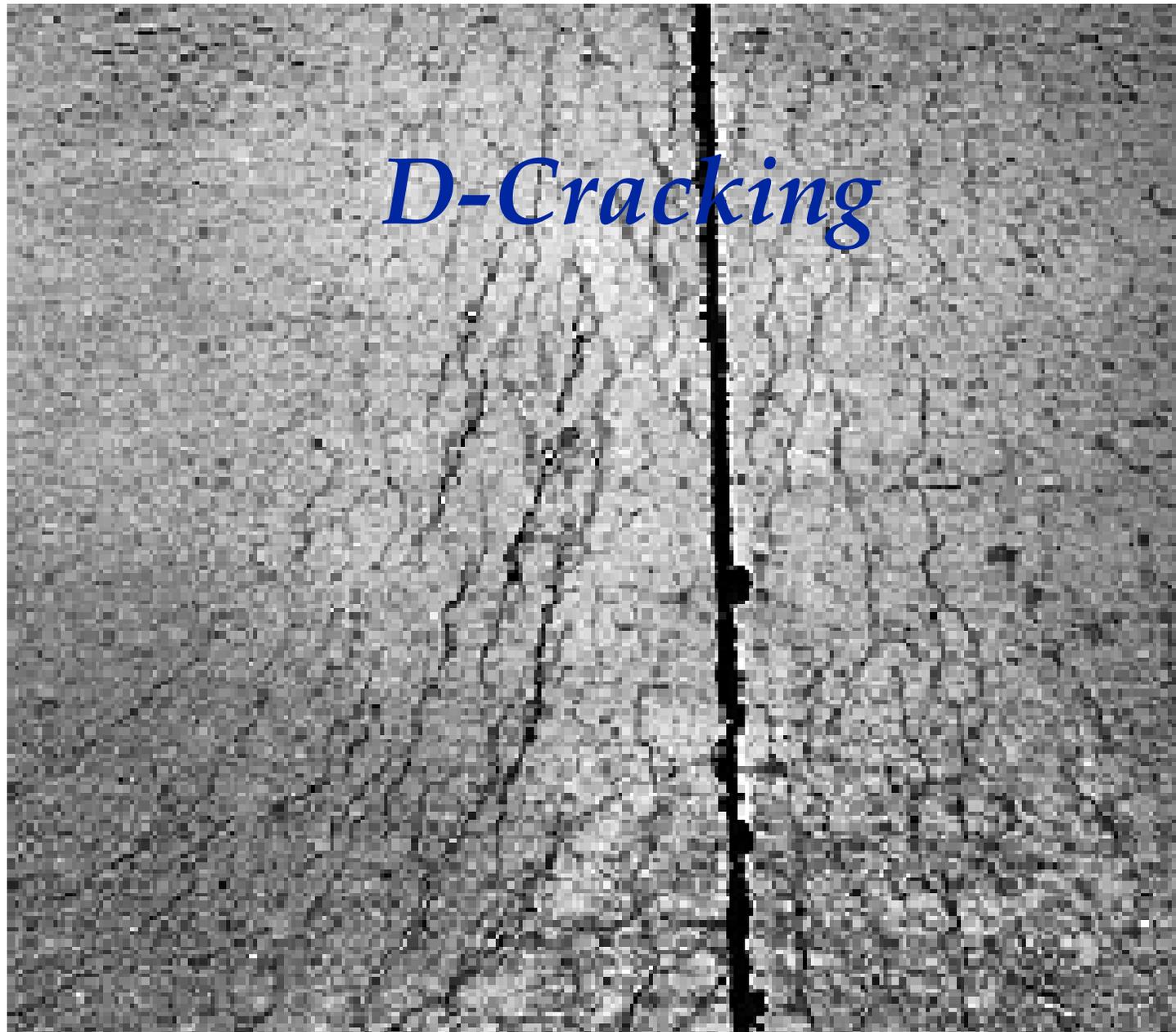
Salt Crystallization



Salt Crystallization



D-Cracking



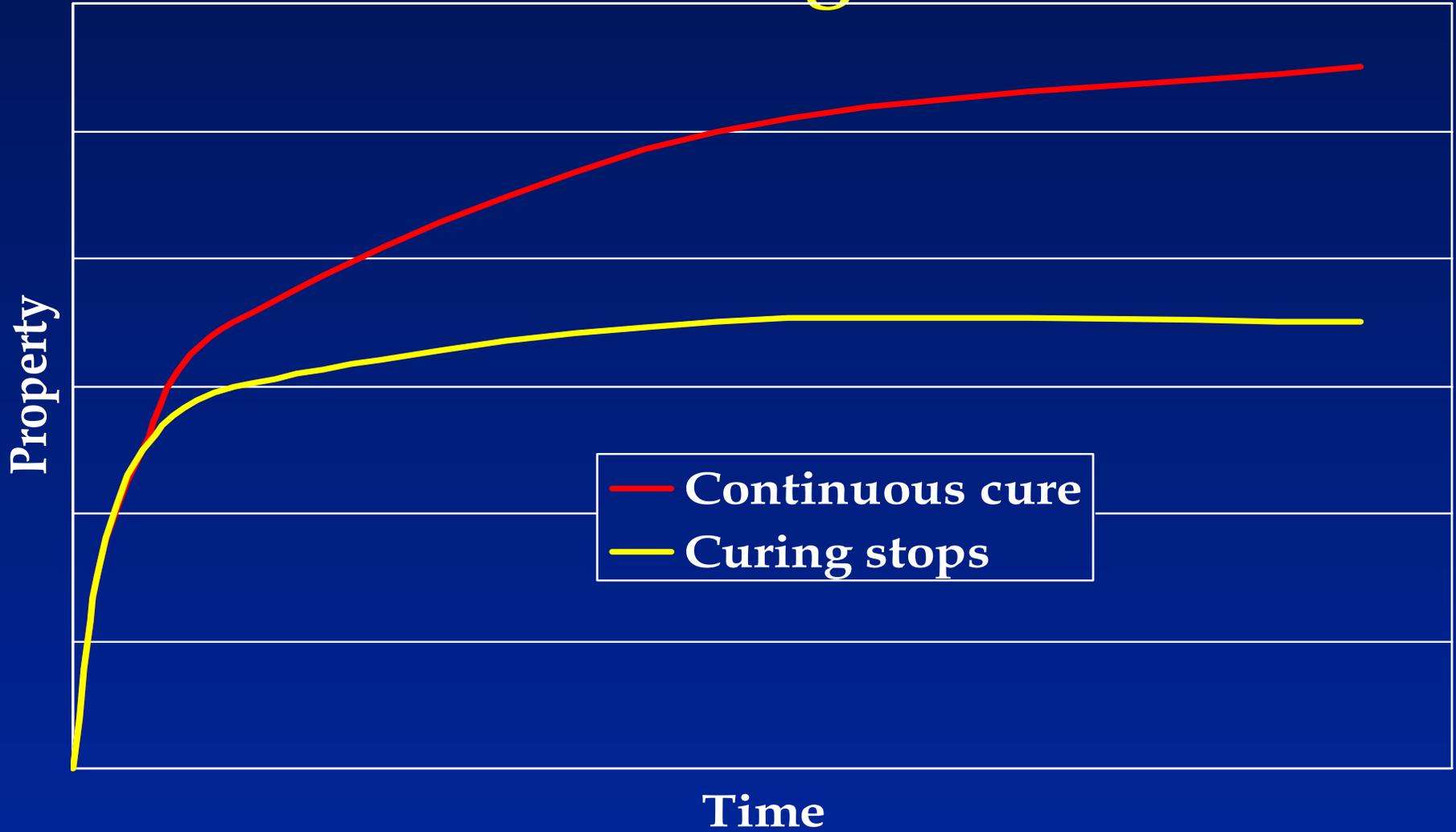
So How Do We Make Our Concrete Survive?

- Understand the environment
- Prevent water from getting in
- Choose the right materials
- Proportion them well
- Use good workmanship

Curing



Curing

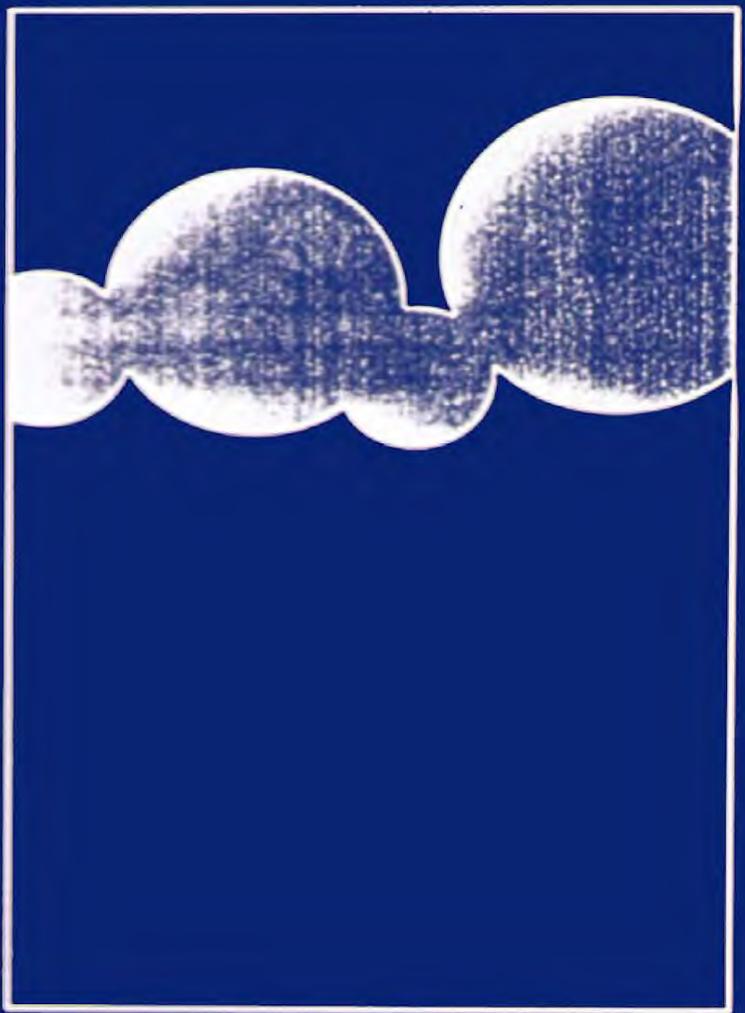
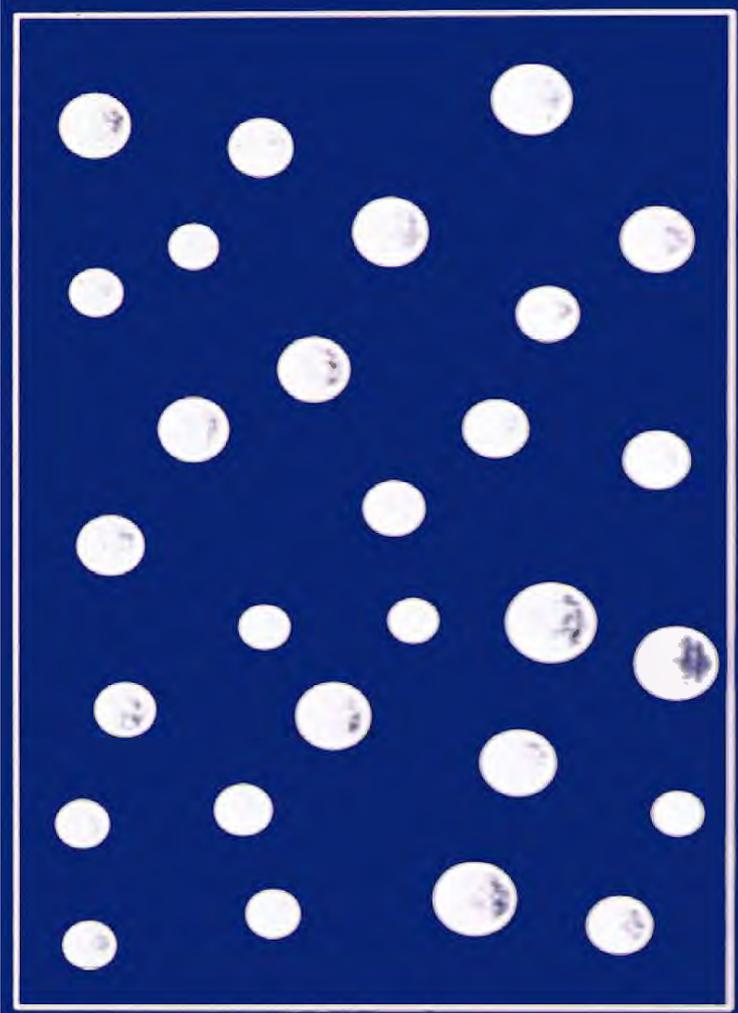


Permeability

- In concrete, low permeability is important for keeping things **out**:
 - oxygen: steel corrosion
 - water: frost damage, leaching, ASR, corrosion
 - other chemicals: sulfate attack, carbonation

Permeability

- Low water / cement ratio
- High degree of hydration
- Supplementary cementing materials
- Minimize voids
- Minimize cracking



Materials Selection

- Alkali-silica reaction
 - Reactive aggregate
 - Fly ash (CaO / SiO₂ ratio)
 - Alkali content of concrete
- Sulfate attack:
 - Cement C₃A content
 - Fly ash

Materials Selection

➤ Frost Damage

- D-Cracking – choose smaller size
- Appropriate air content
- Supplementary cementing materials

Proportioning

- Minimize paste content
- System grading
- Supplementary cementing materials dosage
- Water cementing materials ratio
- Air content

Mixing

- Batching sequence
- Time in the mixer
- Retempering
- Temperature

Placing

- Avoid segregation during transporting
- Ensure adequate compaction
- Protect from the elements
 - Wind
 - Rain
 - Temperature
- Time the joint cutting

Curing

- Start early
- Stay late
- Complete coverage
- Control temperature

Closing

- It is possible to make potentially durable concrete...



