Freezing and Thawing of Concrete

ACI-201R-16, Chapter 4

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Conditions for Frost Damage

- Sufficient Internal Moisture
  - Generally > 75-80% saturation
- Freezing Conditions
  - Cold enough to freeze water in pores (colder than 28-30°F)
  - Repeated freezing and thawing increases damage

Types of Frost Damage

- Surface Scaling
  - Associated with de-icing salt use
  - Most common frost damage type
- Internal Damage
  - Usually requires many freeze-thaw cycles
- D-cracking
  - Non-durable aggregates

Preventing Surface Scaling

- Maximum w/cm of 0.45
  - Reduced freezable water and reduced permeability
- 4,500 psi before repeated freeze-thaw
  - Adequate curing to reduce freezable water
  - Adequate curing to reduce carbonation
  - Adequate strength to resist frost expansion
- Entrained air
  - 18% by volume of paste (Table 4.2.3.2.4)

Surface Scaling

Preventing Surface Scaling so what has changed?

- Now 4,500 psi (was 3,500)
- Clarification of:

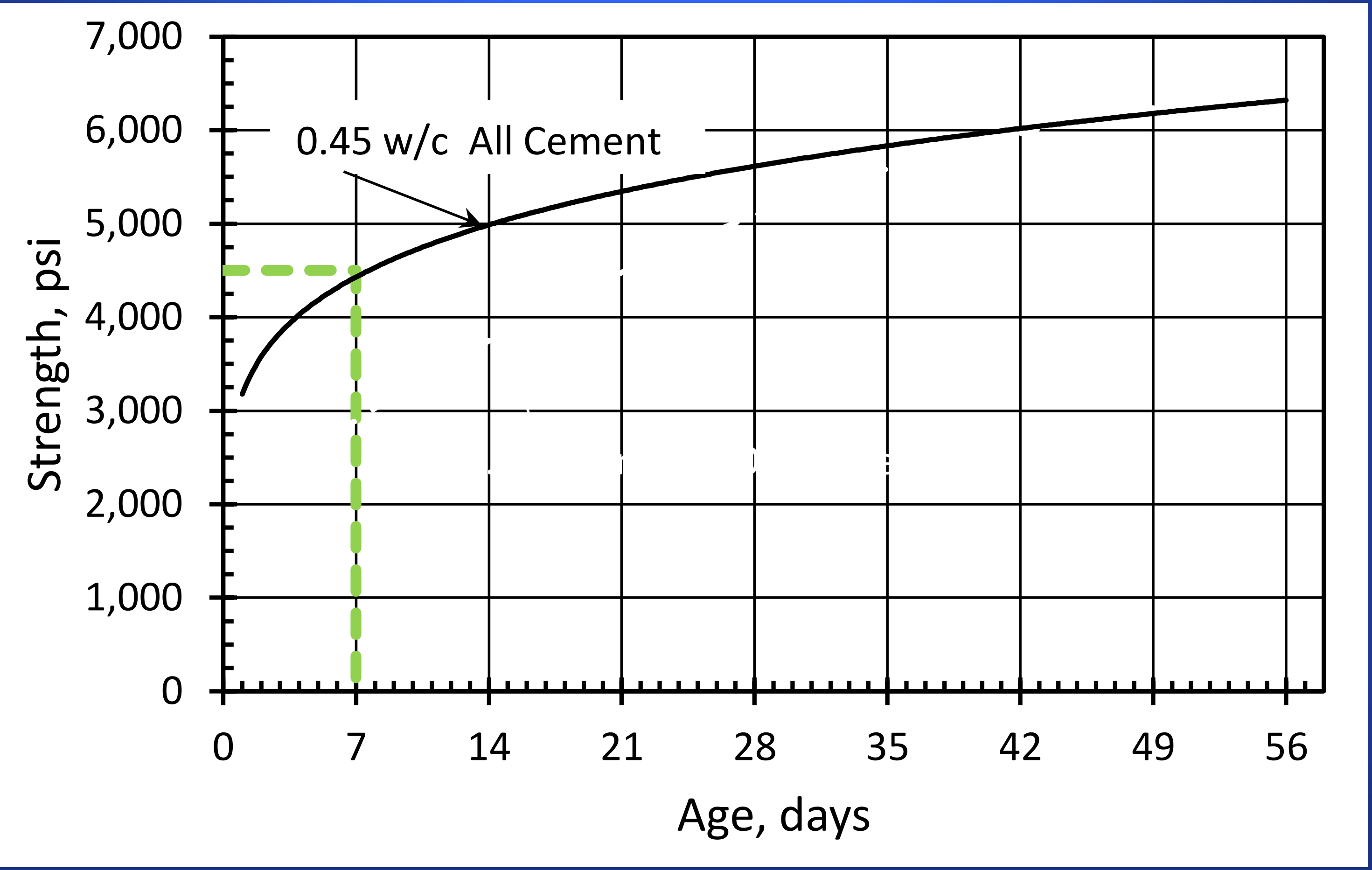
4,500 psi before repeated freeze-thaw

versus

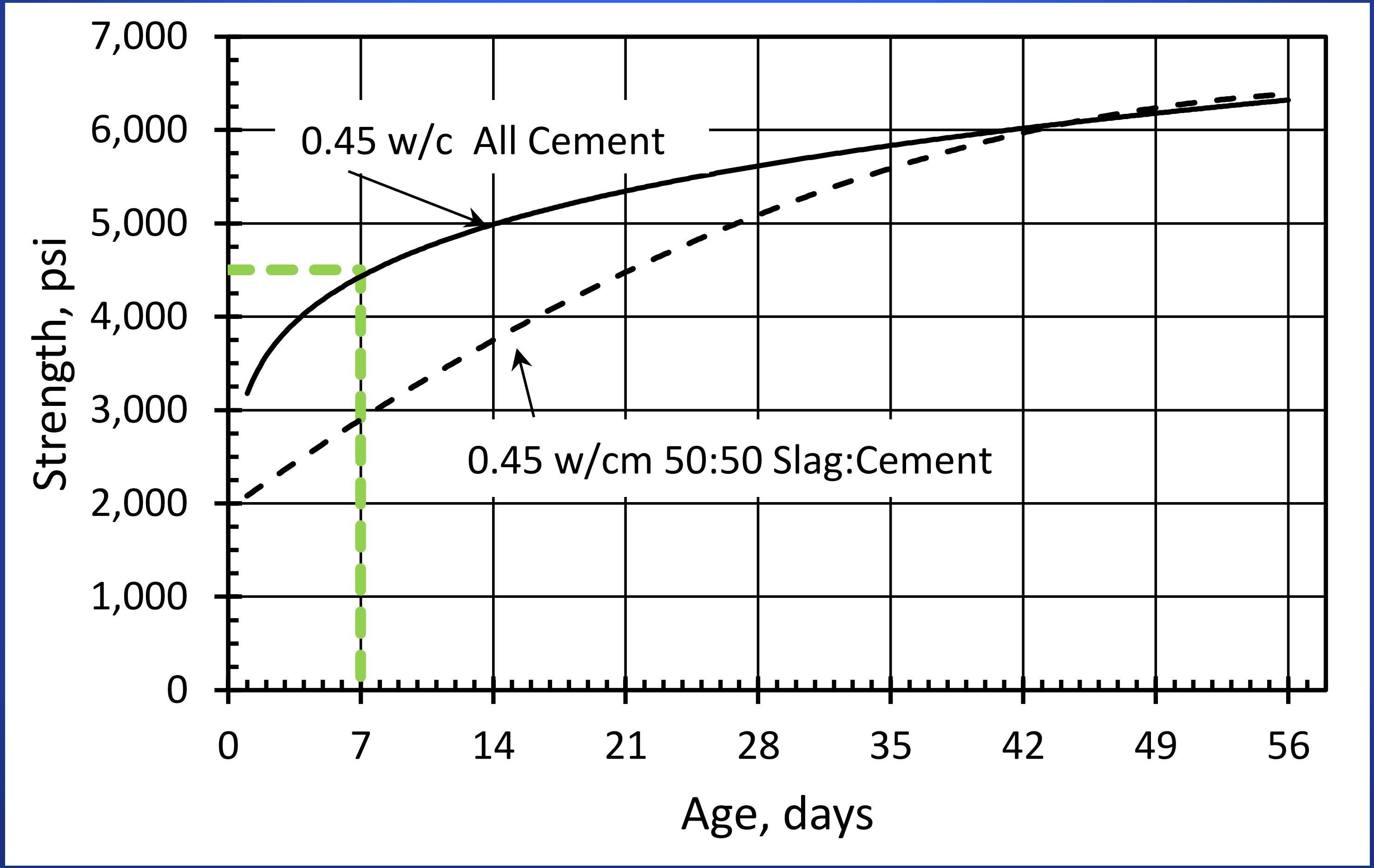
$f_c' = 4{,}500$ psi (ACI 318)

(average strength at time of freeze-thaw versus design strength)

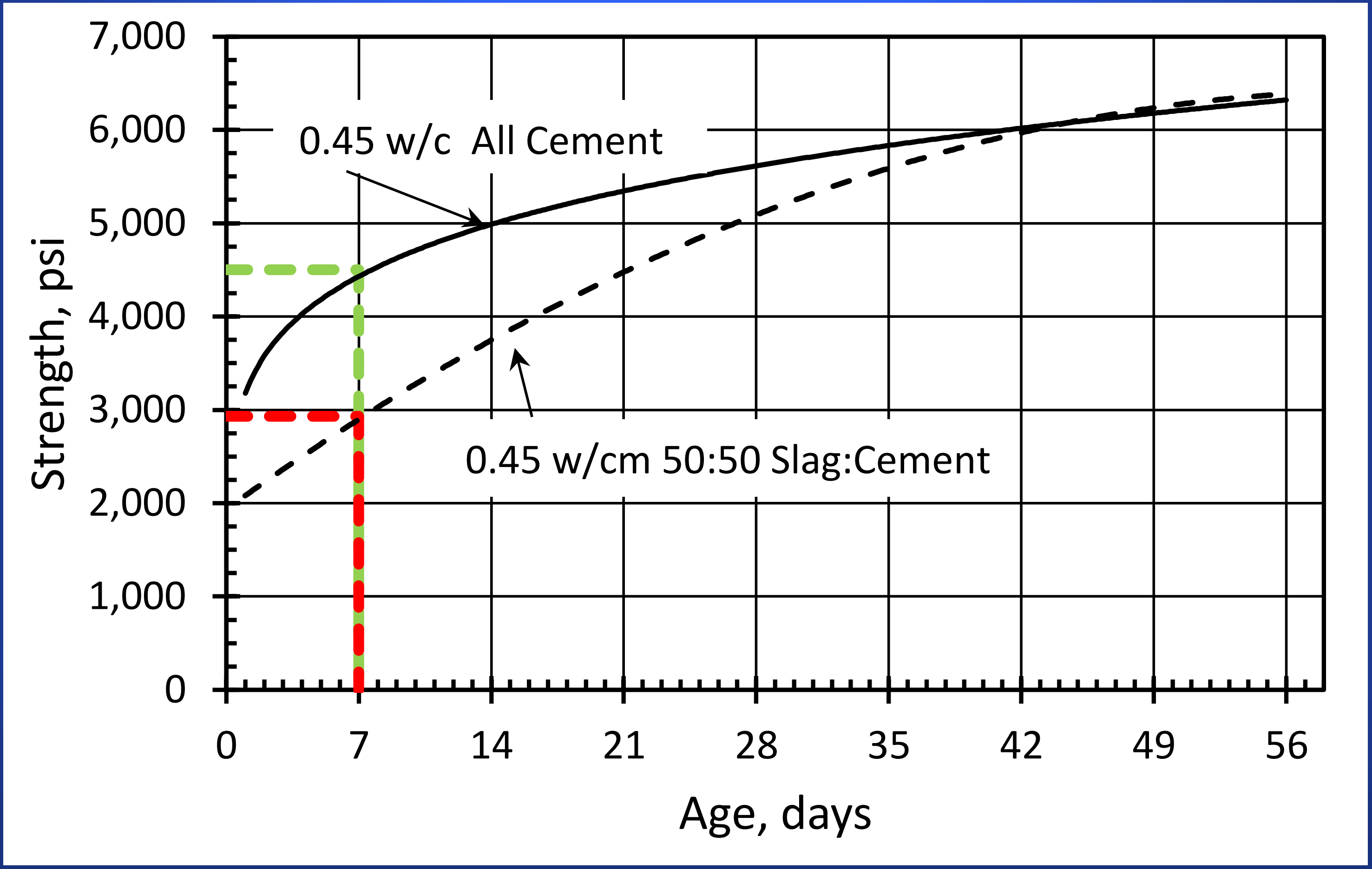
Curing for 4,500 psi



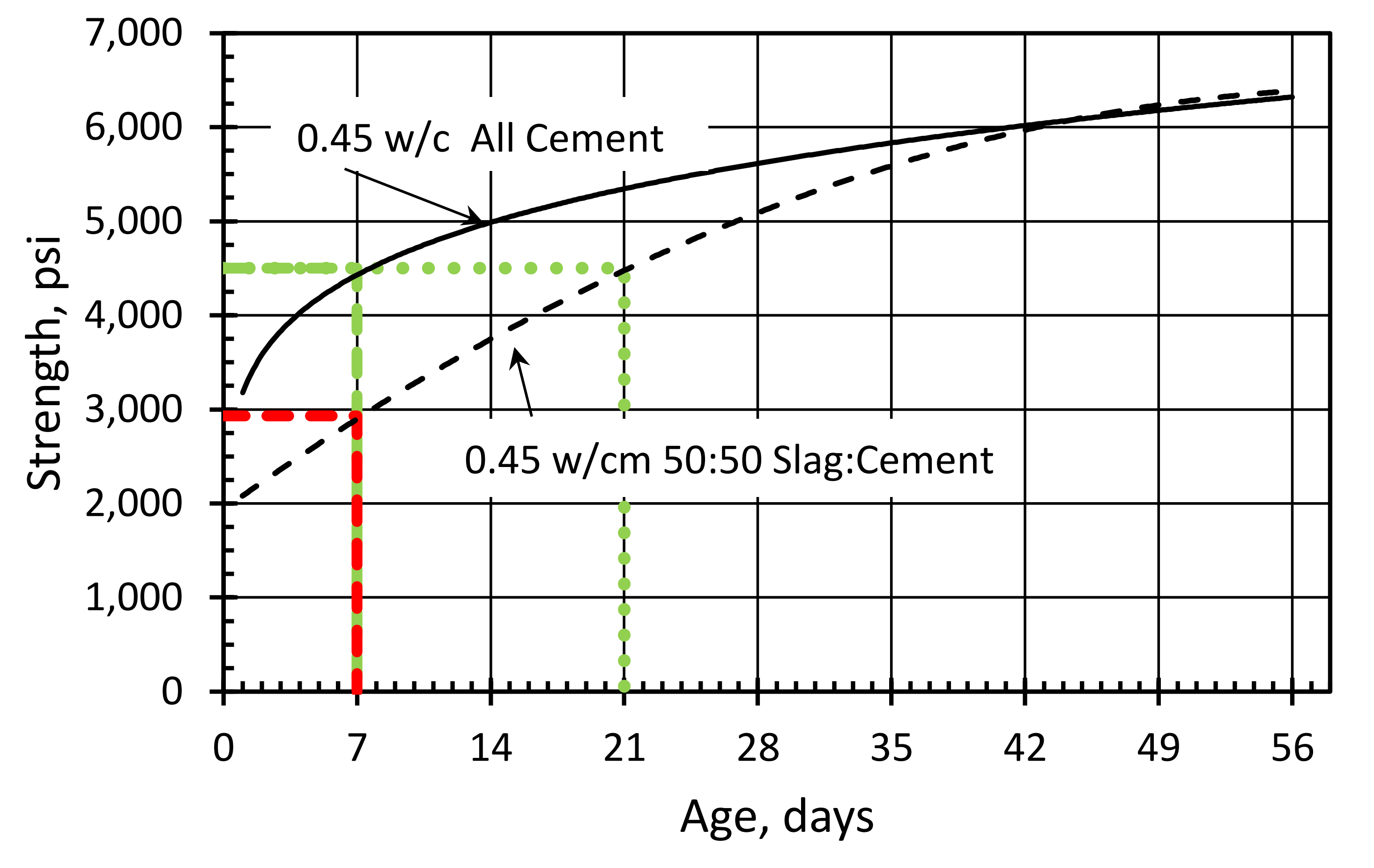
Curing for 4,500 psi



Curing for 4,500 psi



Curing for 4,500 psi



Curing for 4,500 psi

- "Old" Experience of 7-day Curing
  - Adequate for all-cement
  - Not adequate for high cement replacement
- Curing Requirement Should Reflect Actual Mixture Requirements

Preventing Surface Scaling so what else has changed?

- Added Exposure Class F3b
  - No restriction on supplementary cementitious materials for machine-finished surfaces
  - Based on field observations of mixtures with high flyash contents
  - ACI 318 Exposure Class F3 still limits supplementary materials

Clarification of Air Content Table (Table 4.2.3.2.4)

Maximum aggregate size, in.	Air content, percent	
	Exposure F1	Exposure F2 and F3
3/8	7	7.5
1/2	7	7
3/4	6.5	7
1	6.5	6.5

Clarification of Air Content Table (Table 4.2.3.2.4)

- Air content is 18% of paste
  - Concrete with rounded aggregate often has lower paste content
  - Air contents calculate to about 1 percentage lower
- Rounded to nearest 0.5%
- Tolerance ±1-1/2 percent


Internal Damage

Preventing Internal Damage

- Maximum w/cm of 0.45 (0.50 for mild)
  - Reduced freezable water and reduced permeability
- 3,500 psi before repeated freeze-thaw
  - Adequate curing to reduce freezable water
  - Adequate strength to resist frost expansion
- Entrained air
  - 18% by volume of paste (Table 4.2.3.2.4)

    Slightly less for mild exposure

D-cracking

Preventing D-cracking

- Use durable coarse aggregate
  - D-cracking can happen on corners of vertical surfaces if moisture exposure is adequate
  - State DOT’s are best source of information on durability of coarse aggregate

Future Changes

- Examination of Field Exposure Sites
  - Most freeze-thaw data is based on accelerated lab tests
  - Field data will be used to possibly modify future recommendations
    (as was done for supplementary cementitious materials limitation)
- Other Changes to be Determined

Comments?

Questions?