

PCA

Concrete Technology and Codes

Cold Weathering Concrete



Portland Cement Association

What are the Ideal Conditions for Concrete?



- Air Temperature
- Concrete Temperature
- Wind Speed
- Humidity



ACI 306 Definition

“Cold weather is defined as a period when, for more than 3 consecutive days, the following conditions exist:

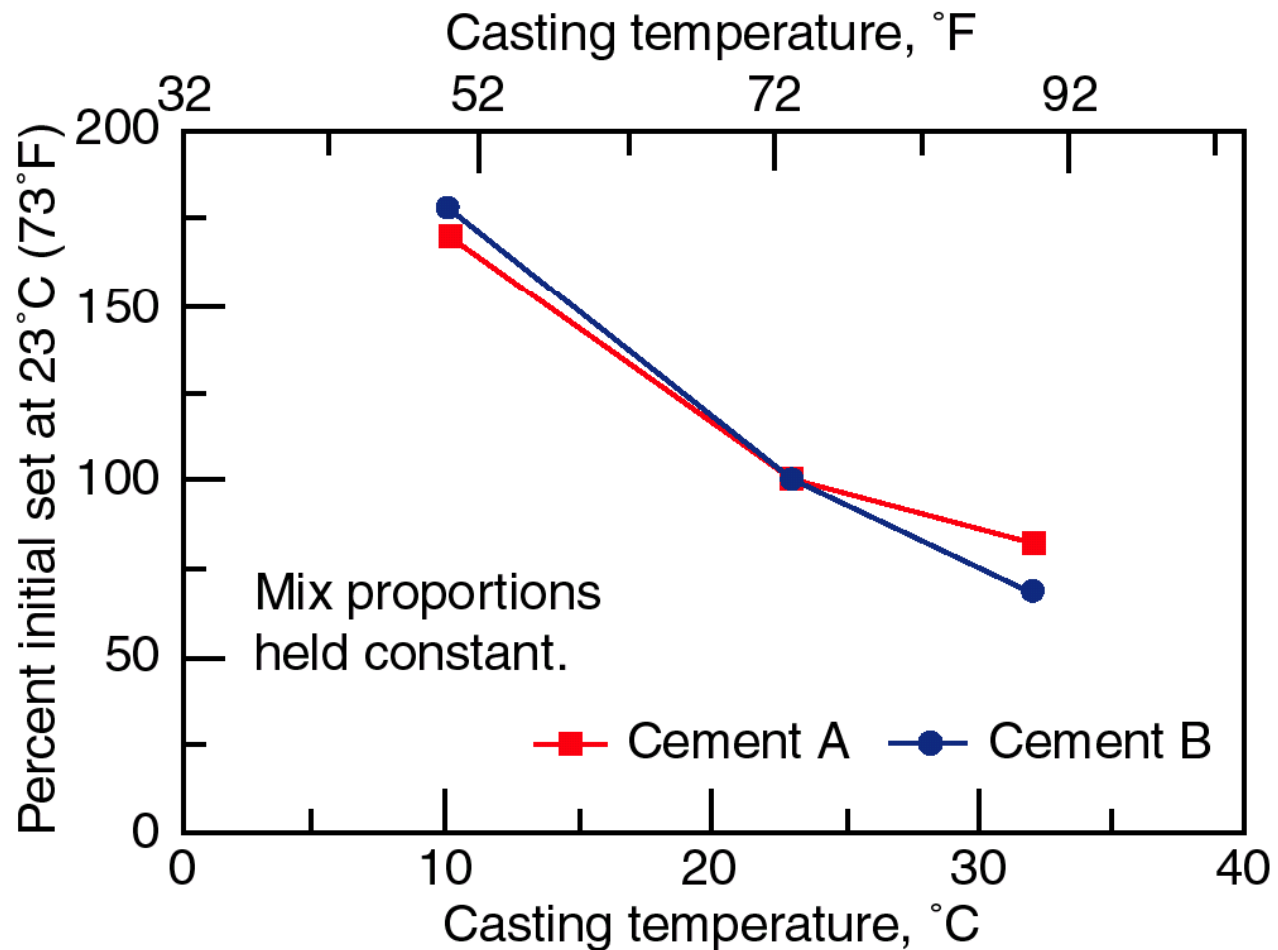
- 1) The average daily air temperature is less than 40° F (5°C)
- 2) And the air temperature is not greater than 50° F (10°C) for more than one-half of any 24-hr period.”

Cold Weather Concreting Problems

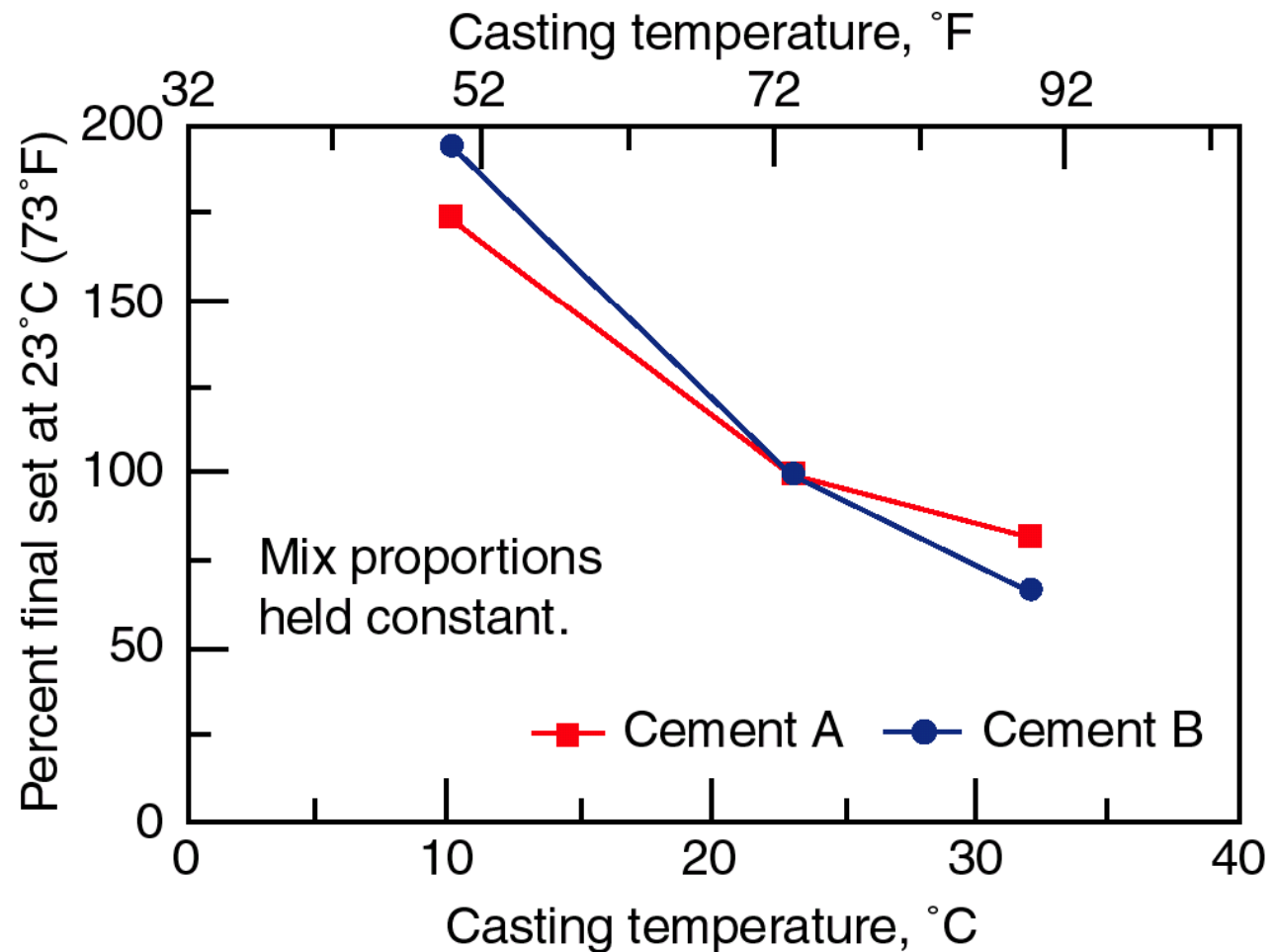


- Freezing
- Dusting, Crazing, Plastic shrinkage
- Slower hydration
- Slower setting times

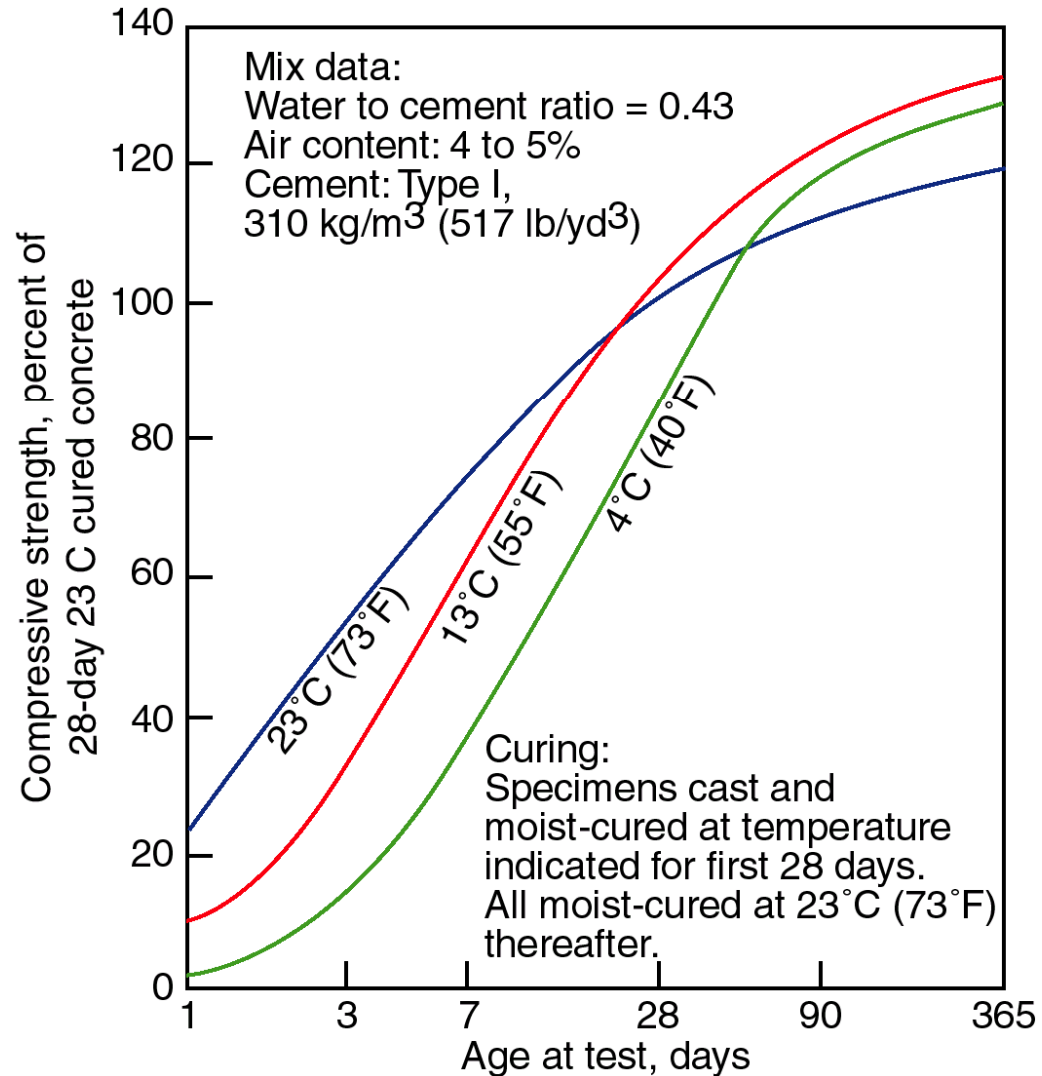
Time Relationship Between Initial Set and Casting Temperature



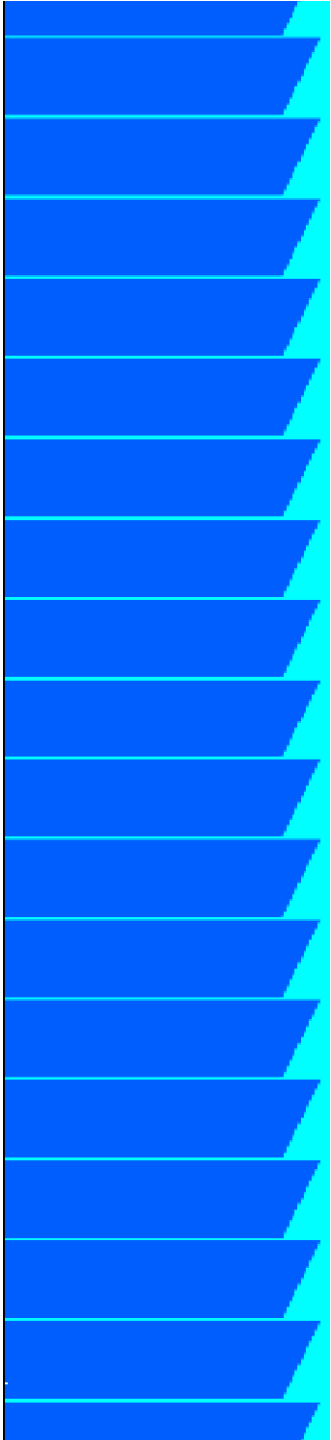
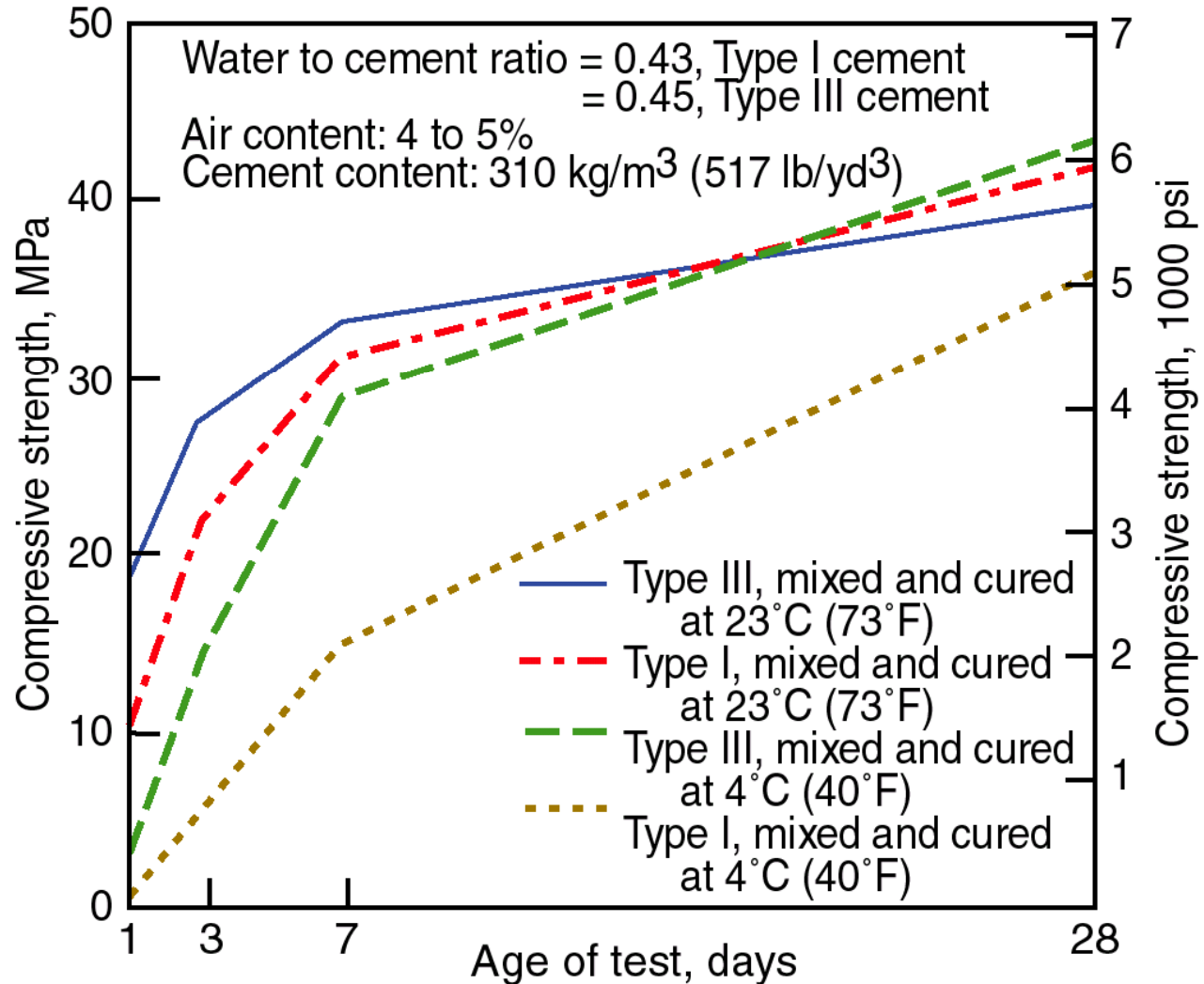
Time Relationship Between Final Set and Casting Temperature



Effect of Low Temperature on Strength



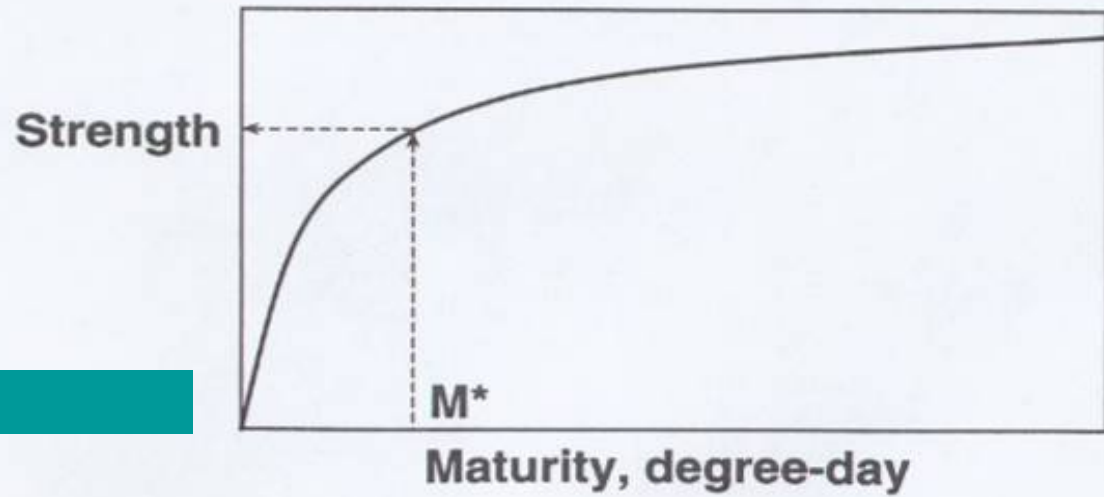
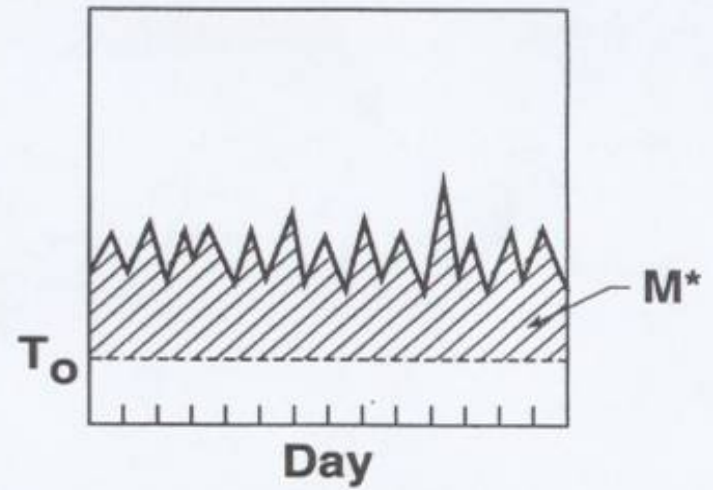
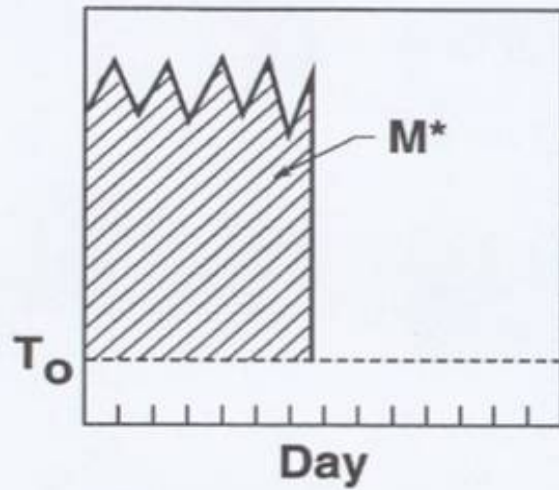
Temperature Effect on Early-Age Strength





What is Maturity?

- Method to estimate in-place concrete strength
- Based on TIME and TEMPERATURE
- Increased strength gain at elevated temperatures
- Slower strength gain at lower temperatures



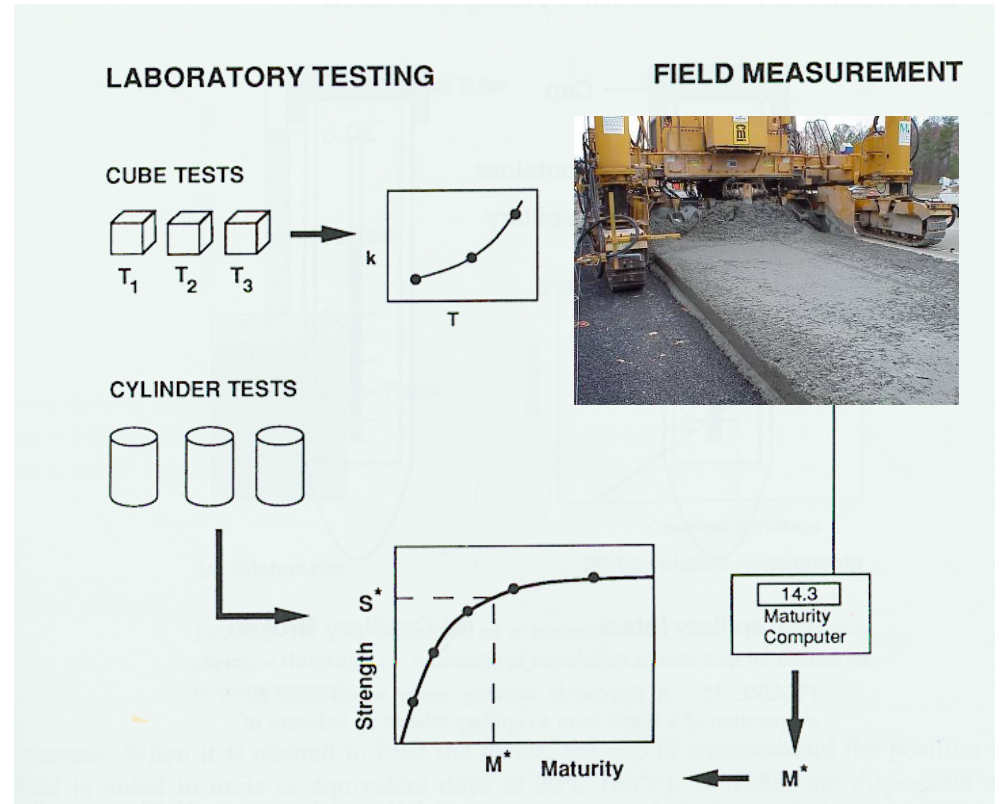
Why Use Maturity?

- Reduces construction time
- Replaces temperature-matched curing of cylinders in thermal control plans
- Required information is mostly available
- Simple and very popular!



Maturity Approach

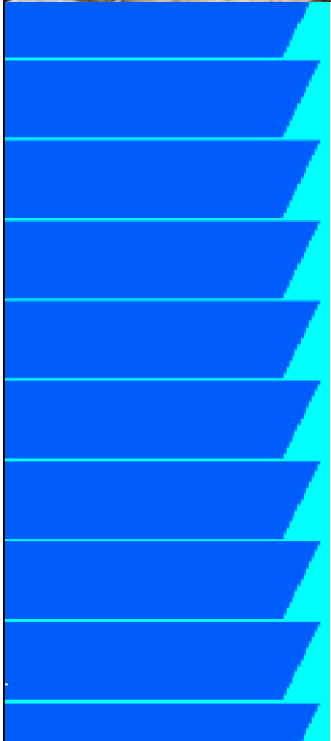
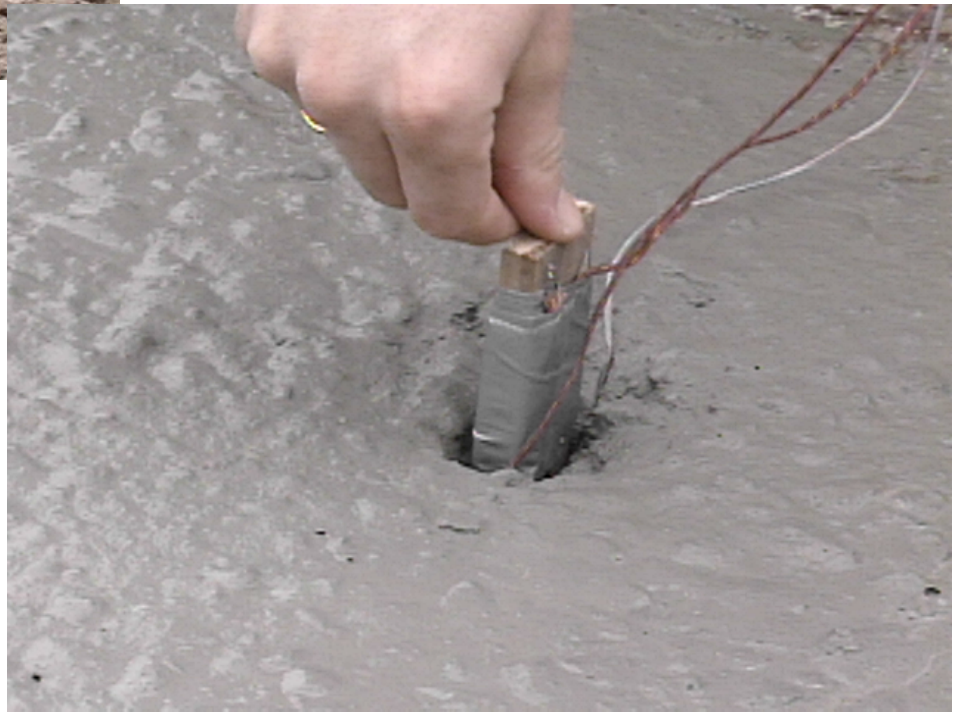
- Laboratory testing, using project materials, is required to develop a relationship
- Concrete is monitored using temperature probes



Note: Maturity testing does not indicate quality of concrete, only that it has reached strength



Establish Curve





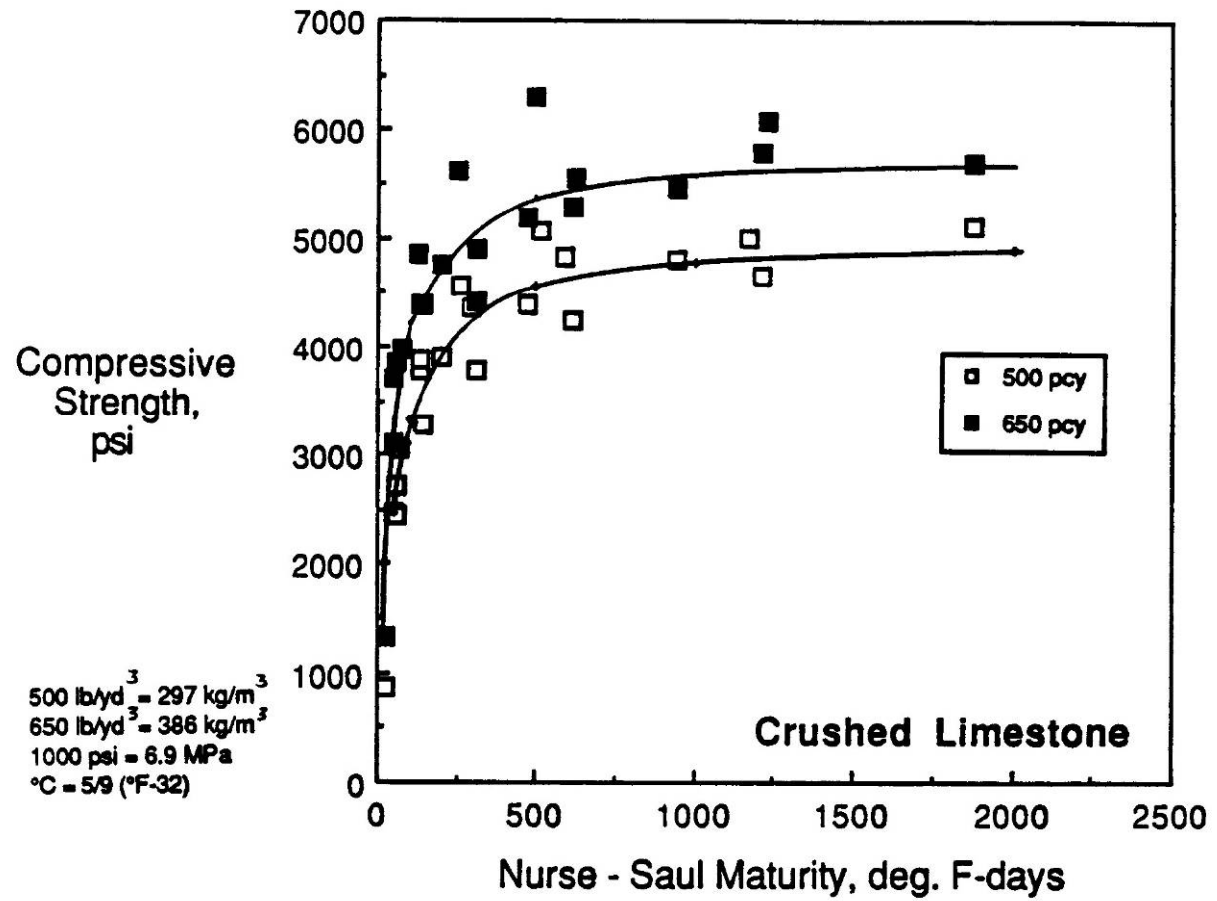
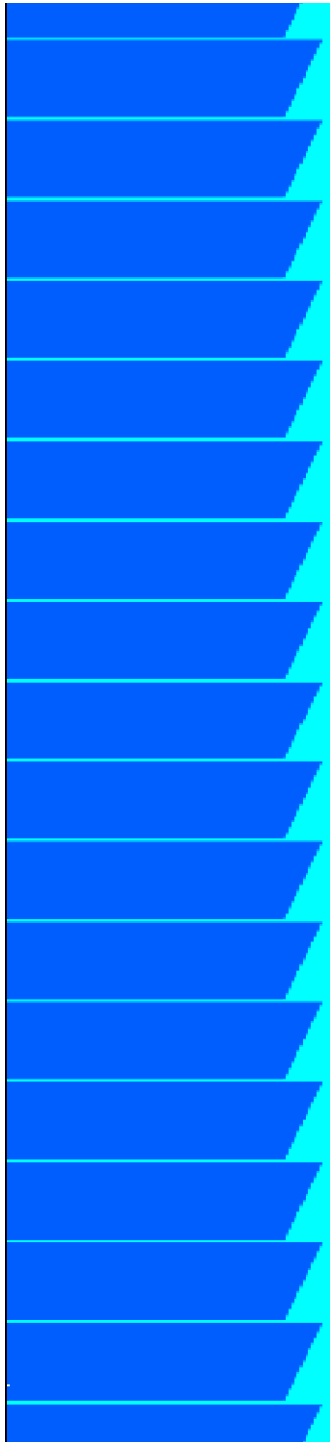
ASTM C1074 Maturity

- Time-Temperature Factor (°F·hr)

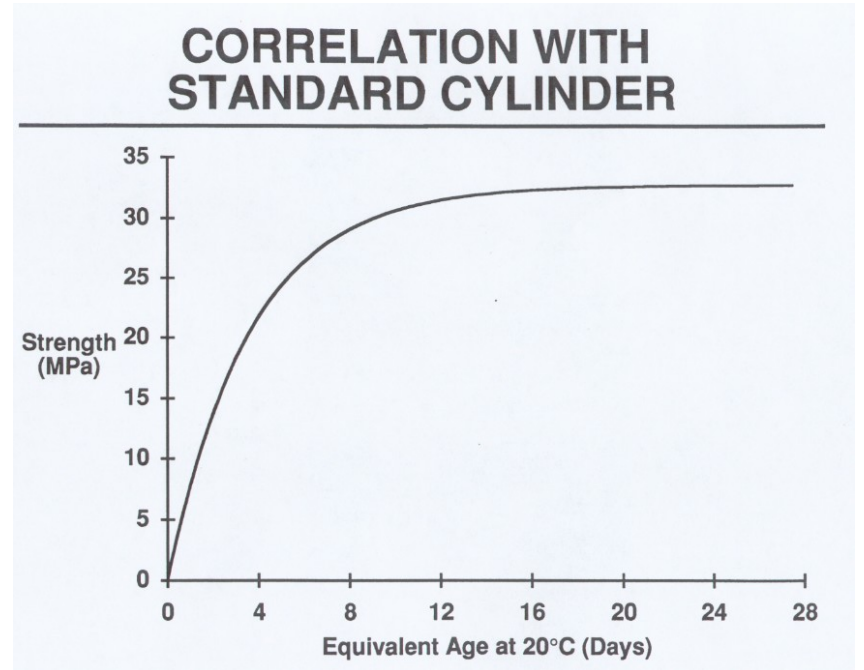
$$M = \sum_{t=0}^t (T - T_o) \Delta t$$

- Equivalent Age (days)

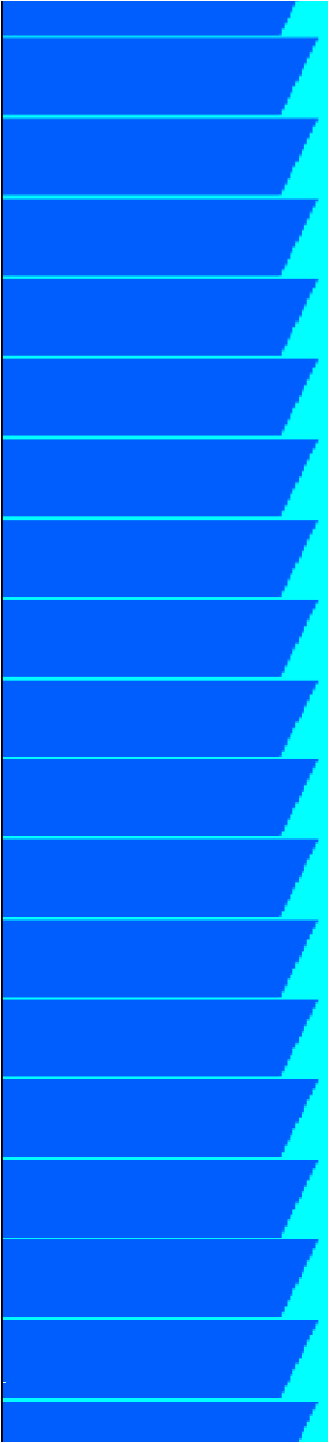
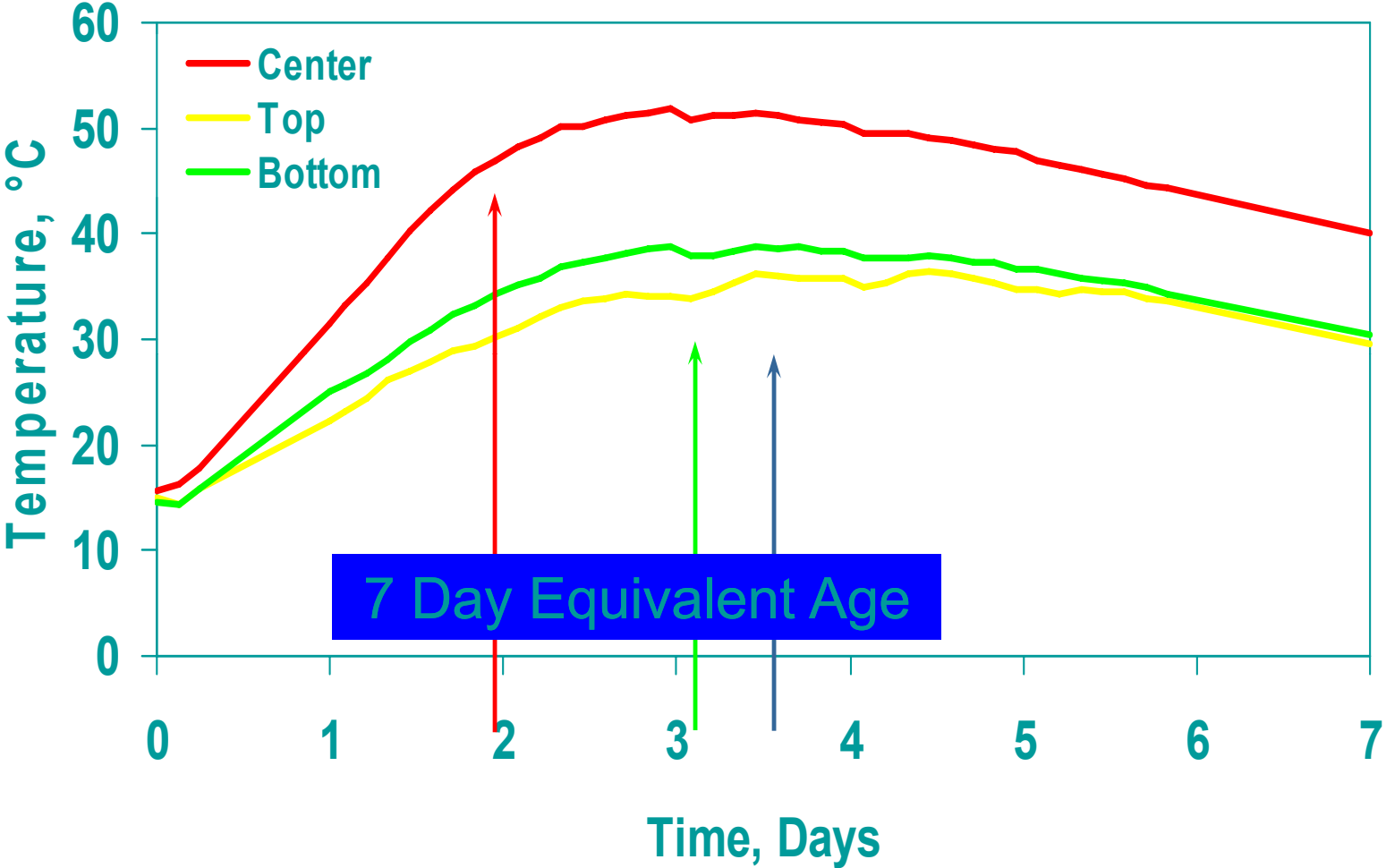
$$M = \sum_{t=0}^t e^{-Q \left(\frac{1}{T_a} - \frac{1}{T_s} \right)} \Delta t$$



Field Monitoring



Initial Lift in Footing 15E





Pitfalls

- Any changes to the concrete mix requires new maturity relation to be developed
- Its an estimate based on indirect measurements
- Continuous permanent record of strength gain



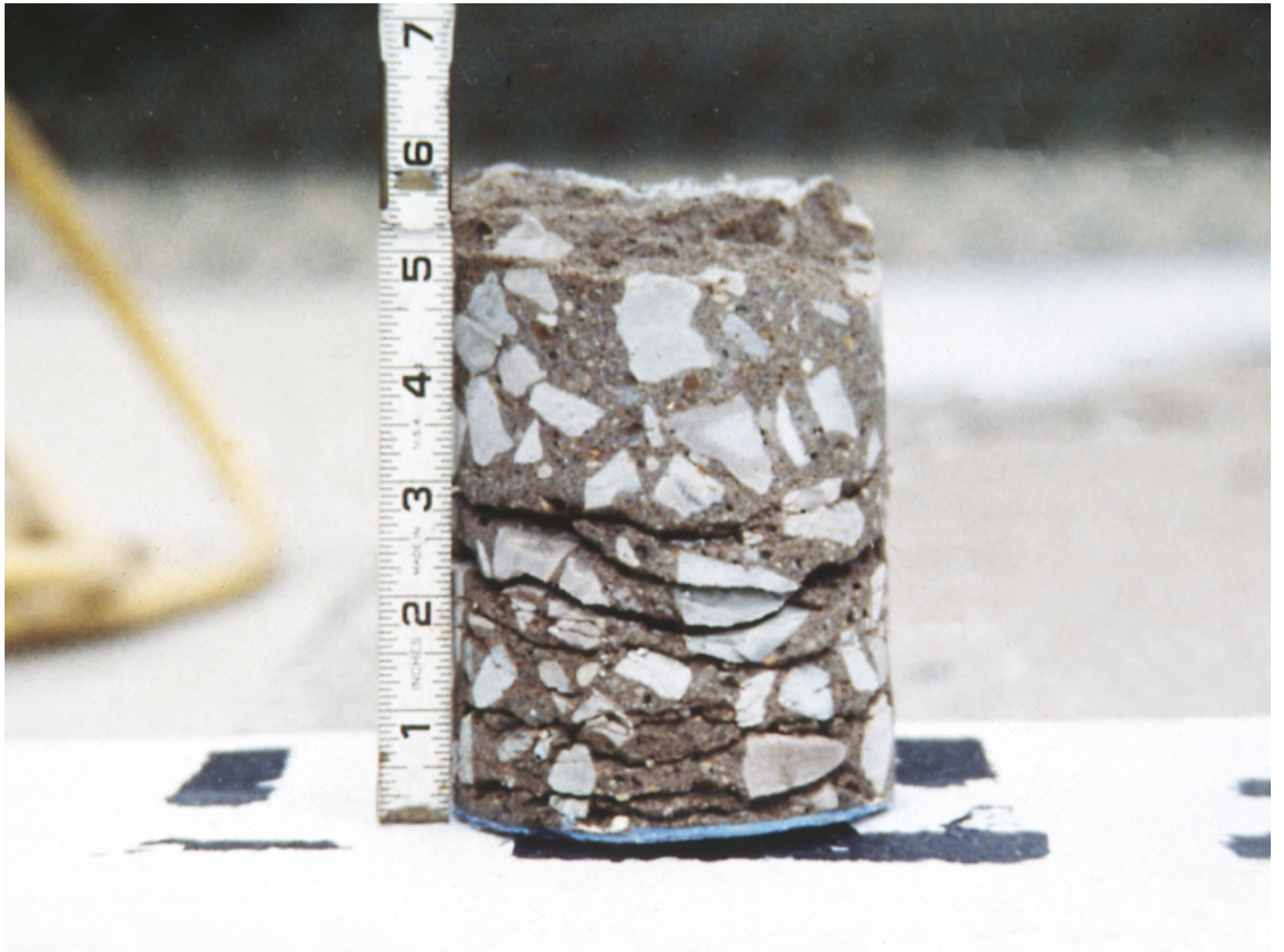
Recap

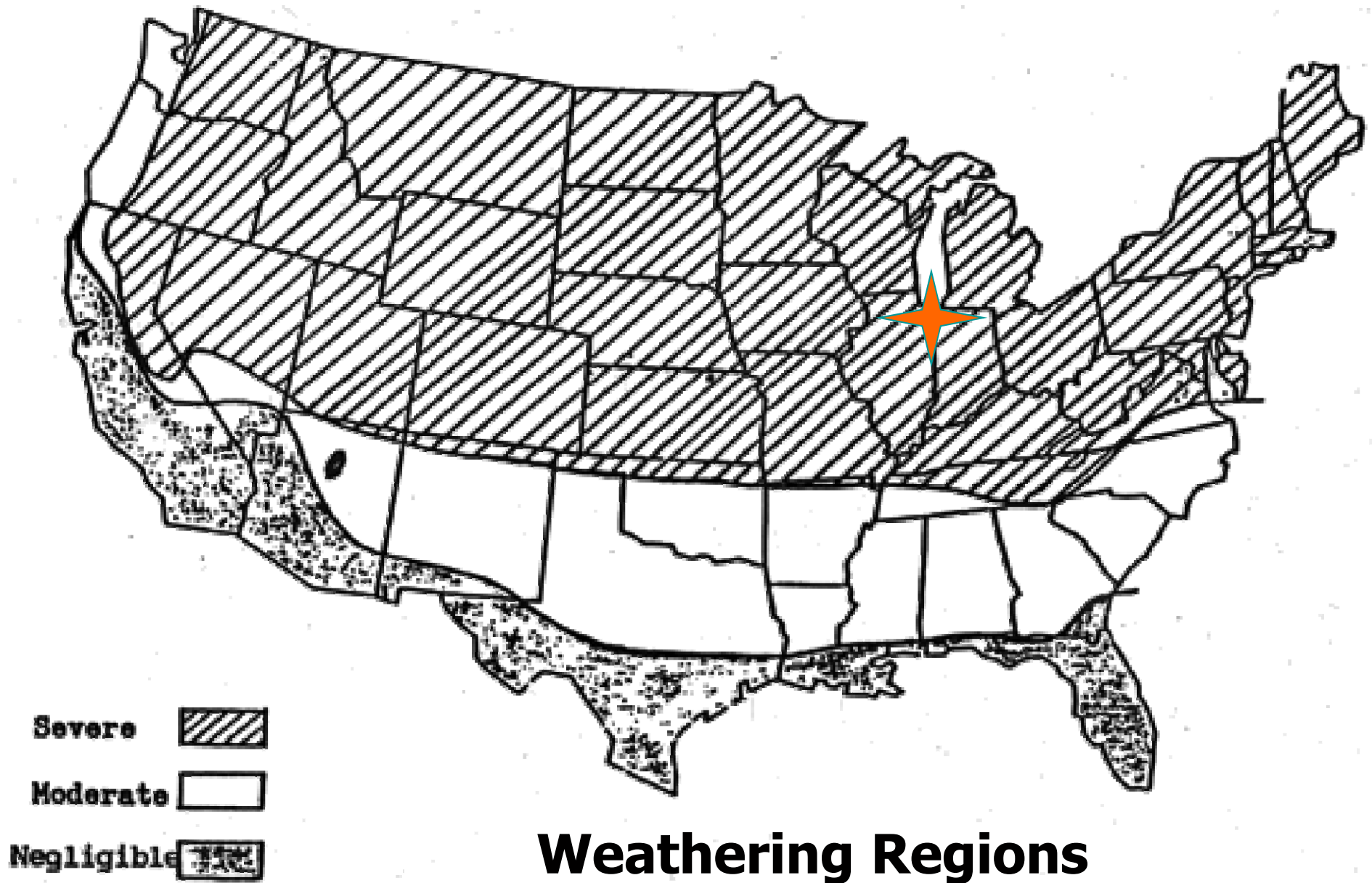
- Method to estimate in-place concrete strength
- Based on **TIME** and **TEMPERATURE**
- Requires upfront laboratory testing
- Eliminates daily testing
- Saves time and effort

Consequences of Freezing Fresh Concrete

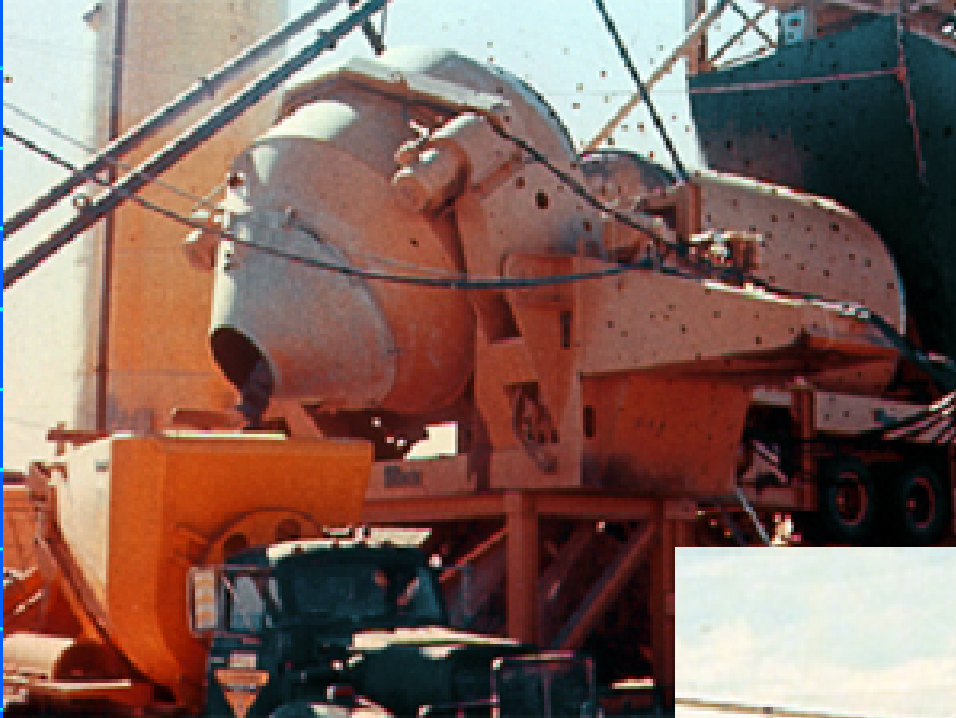


- Up to 50% reduction of ultimate strength can occur if frozen
 - ◆ Within a few hours
 - ◆ Before reaching a strength of 3.5 MPa (500psi)
- Frozen only once at an early age
 - ◆ With curing nearly all strength can be restored
 - ◆ May lower resistance to weathering
 - ◆ Higher permeability





Adjusting The Mix for CWC

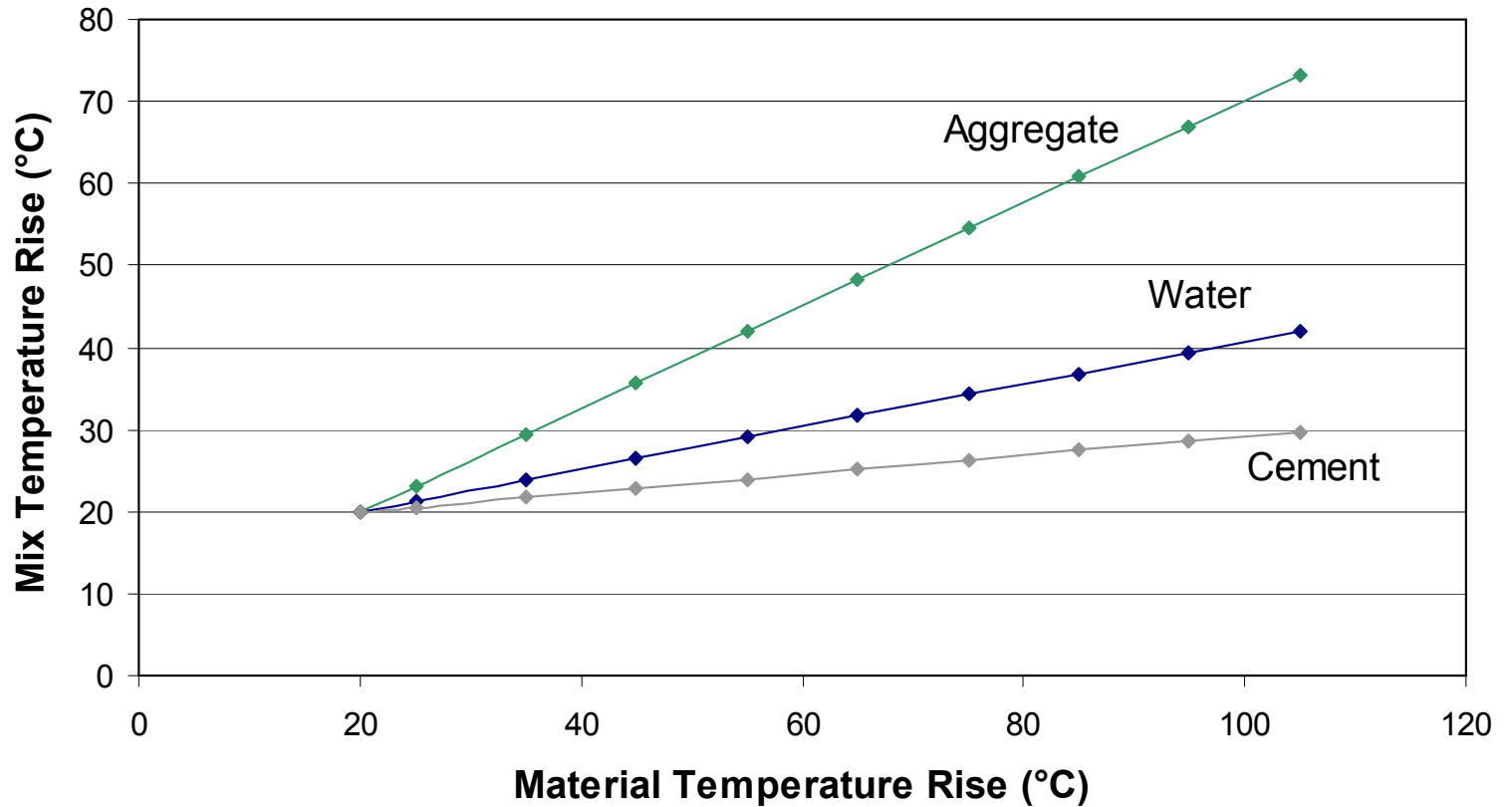


- Consider accelerators
- Increase Cement Content
- Heat the ingredients
 - ◆ Heat the water
 - ◆ Heat the aggregate



Relative Effect of Heating the Concrete Mix

Temperature Rise of Concrete in Relation to Increase in Material Temperatures



Placing and Finishing Concrete in Cold Weather



- Never place concrete on frozen ground
- Use wind breaks
- Protect the concrete temperature with Insulation during curing
- consider heated enclosures in extreme conditions

Hydronic Systems



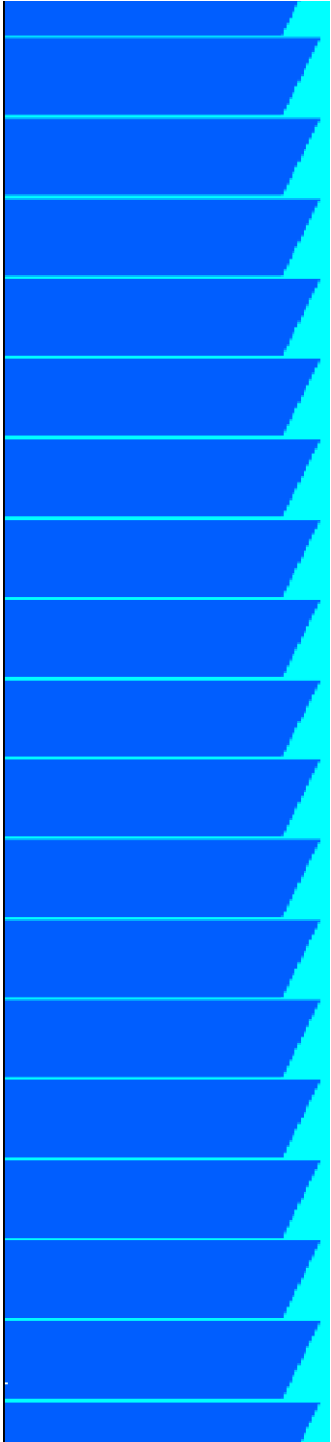
Enclosures



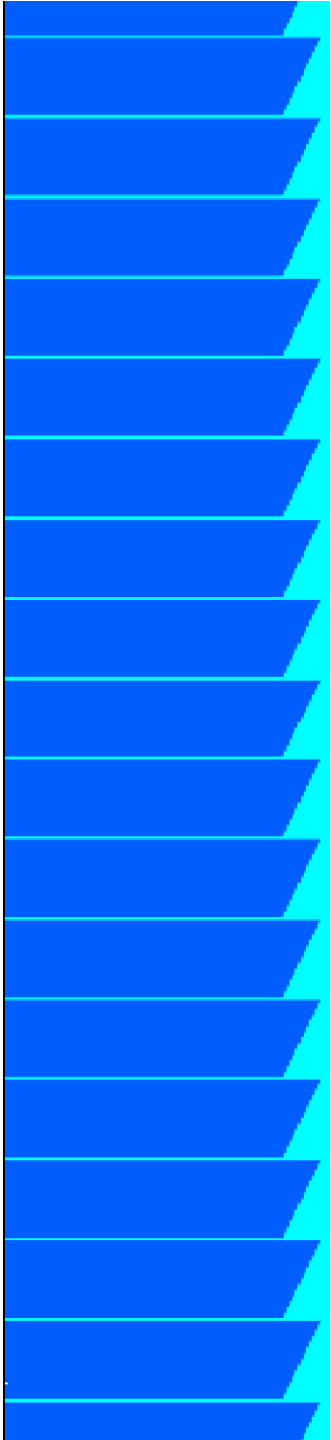
- Wood
- Canvas
- Tarpaulins
- Polyethylene Film







Use Ventilated Heaters



Consider using insulated forming systems





Maximum temperature drop after Protection per 24 hour period

Section size, minimum dimensions, mm (in.)			
Less than 300 (12)	300 to 900 (12 to 36)	900 to 1800 (36 to 72)	Over 1800 (72)
28°C (50°F)	22°C (40°F)	17°C (30°F)	11°C (20°F)

Recommended Protection Period

Air-entrained concrete

Service category	Protection from early-age freezing		For safe stripping strength	
	Convent. concrete, days	High-early strength concrete, days	Convent. concrete, days	High-early-strength concrete, days
No load, not exposed, favorable moist-curing	2	1	2	1
No load, exposed, but later has favorable moist-curing	3	2	3	2
Partial load, exposed			6	4
Fully stressed, exposed			See next slide	

Recommended Duration of Temperature

Fully stressed, exposed, air-entrained concrete

Required percentage of standard-cured 28-day strength	Days at 10°C (50°F)			Days at 21°C (70°F)		
	Type of portland cement			Type of portland cement		
	I or GU	II or MS	III or HE	I or GU	II or MS	III or HE
50	6	9	3	4	6	3
65	11	14	5	8	10	4
85	21	28	16	16	18	12
95	29	35	26	23	24	20



Summary

- ACI 306
- Effects of cold weather
- Precautionary methods

