PCA

Concrete Technology and Codes

Curing

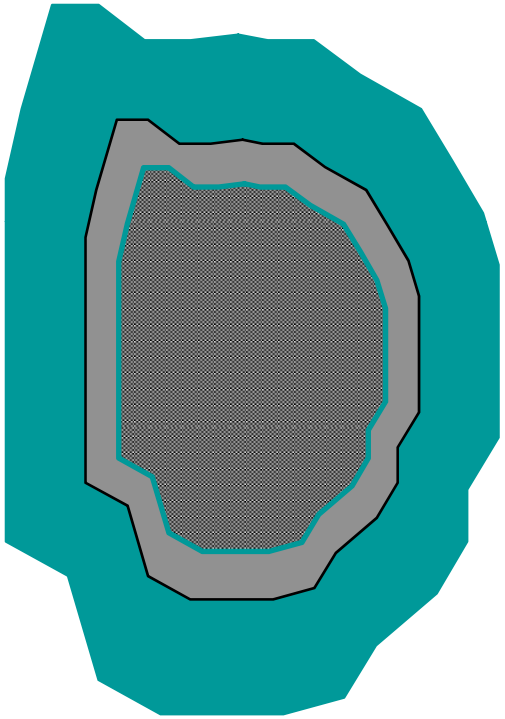
Definition of Curing

Curing – maintenance of a satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that desired properties may develop

Important for all concrete, but particularly when:

- Placing conditions result in rapid drying of fresh concrete
- Concrete exhibits little bleeding (e.g. silica fume concrete)
- Concrete develops properties slowly (e.g. fly ash concrete)

Hydration of cement



Portland cement is a hydraulic cement: its components, mainly calcium silicates, react with water to form other components called calcium silicate hydrates-CSH (hydration). Hydration stops when internal humidity is lower than 80% or temp. falls below 14ºF

Bulletin 2

Structural Materials Research Laboratory
Lewis Institute
Chicago

Effect of Curing Condition on the Wear and Strength of Concrete

By

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Professor in Charge of Laboratory

(Authorized Reprint from the Proceedings of the American Railway Engineering Association, Vol. 20, 1919)

Abrams, 1919

EFFECT OF CURING CONDITION ON THE WEAR AND STRENGTH OF CONCRETE

By Duff A. Abrams.

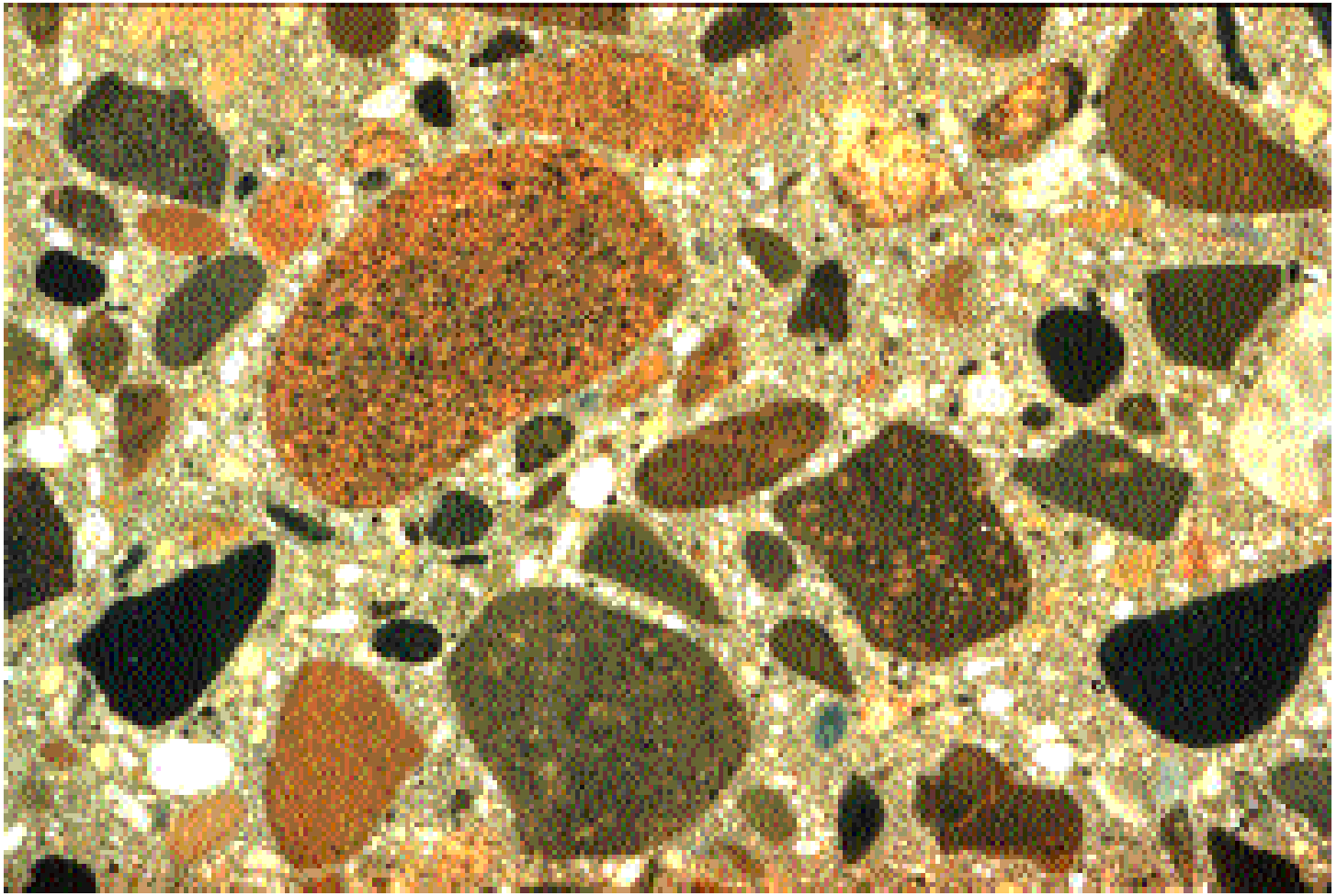
Introduction.

The necessity for careful restriction on the quantity of mixing water used in concrete, and the importance of proper curing conditions during the period of setting and hardening are not generally appreciated by engineers and contractors doing concrete work.

Still holds in 2009?

Why cure concrete?

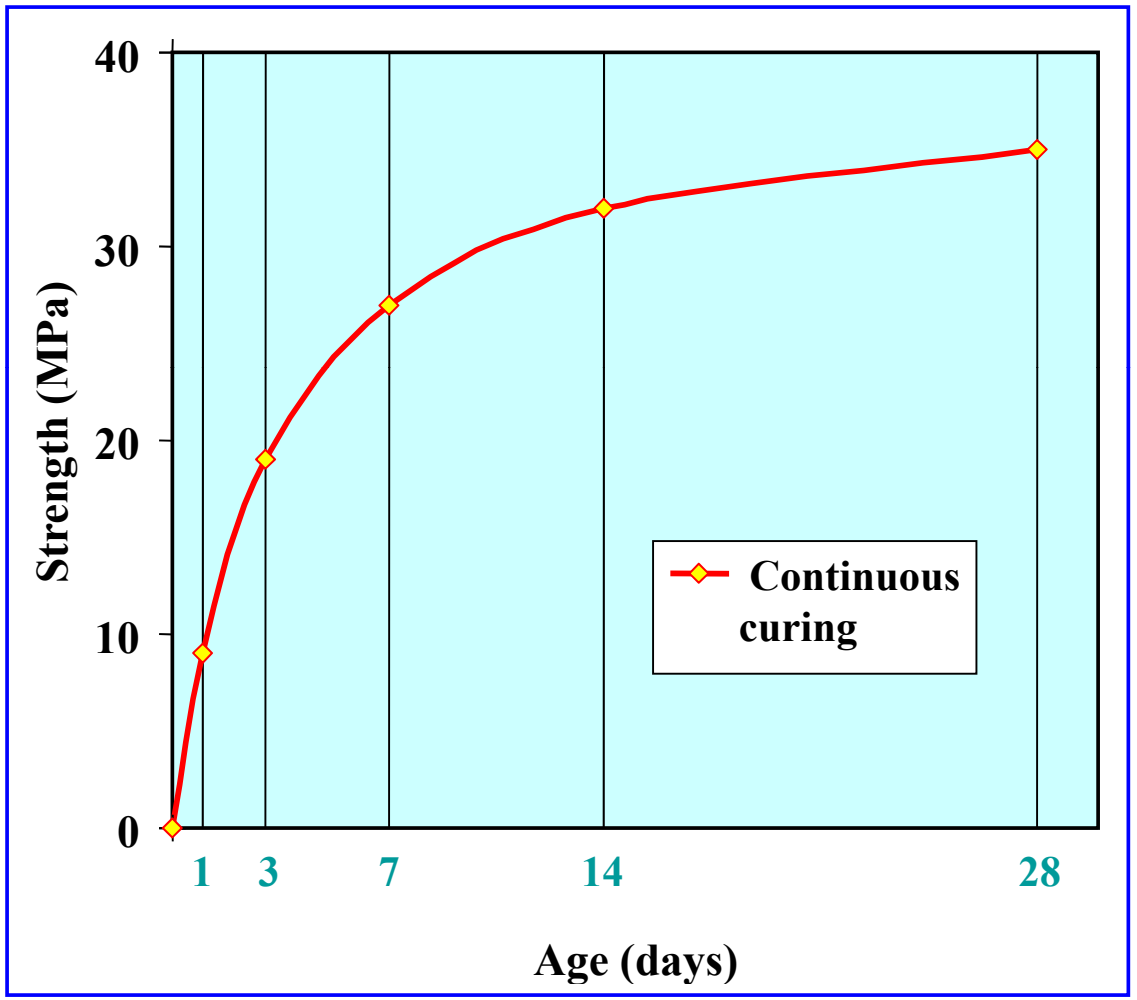
- To allow cement hydration progress and the concrete to develop its desired properties
- To prevent moisture loss from the plastic concrete (protect against plastic shrinkage cracking)
- To minimize moisture loss from the concrete after setting (drying shrinkage)



Effect of the Duration of Moist-Curing on the Strength Development for Concrete

Strength gain of concrete stored in fog room (or immersed in lime water)

- i.e. continuously cured

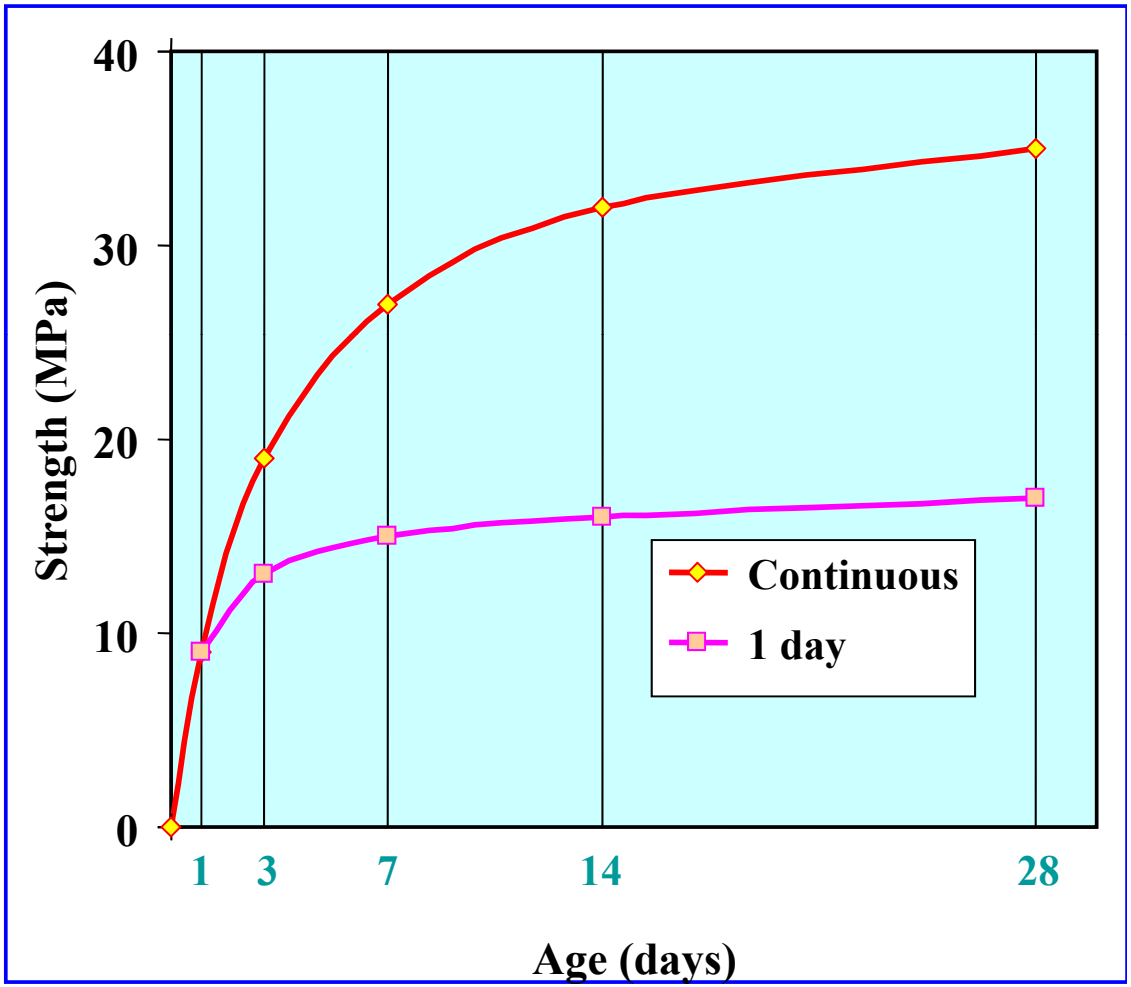


Effect of the Duration of Moist-Curing on the Strength Development for Concrete

If concrete is not cured for a sufficient period of time, it will not develop its full potential in terms of compressive strength (and other properties).

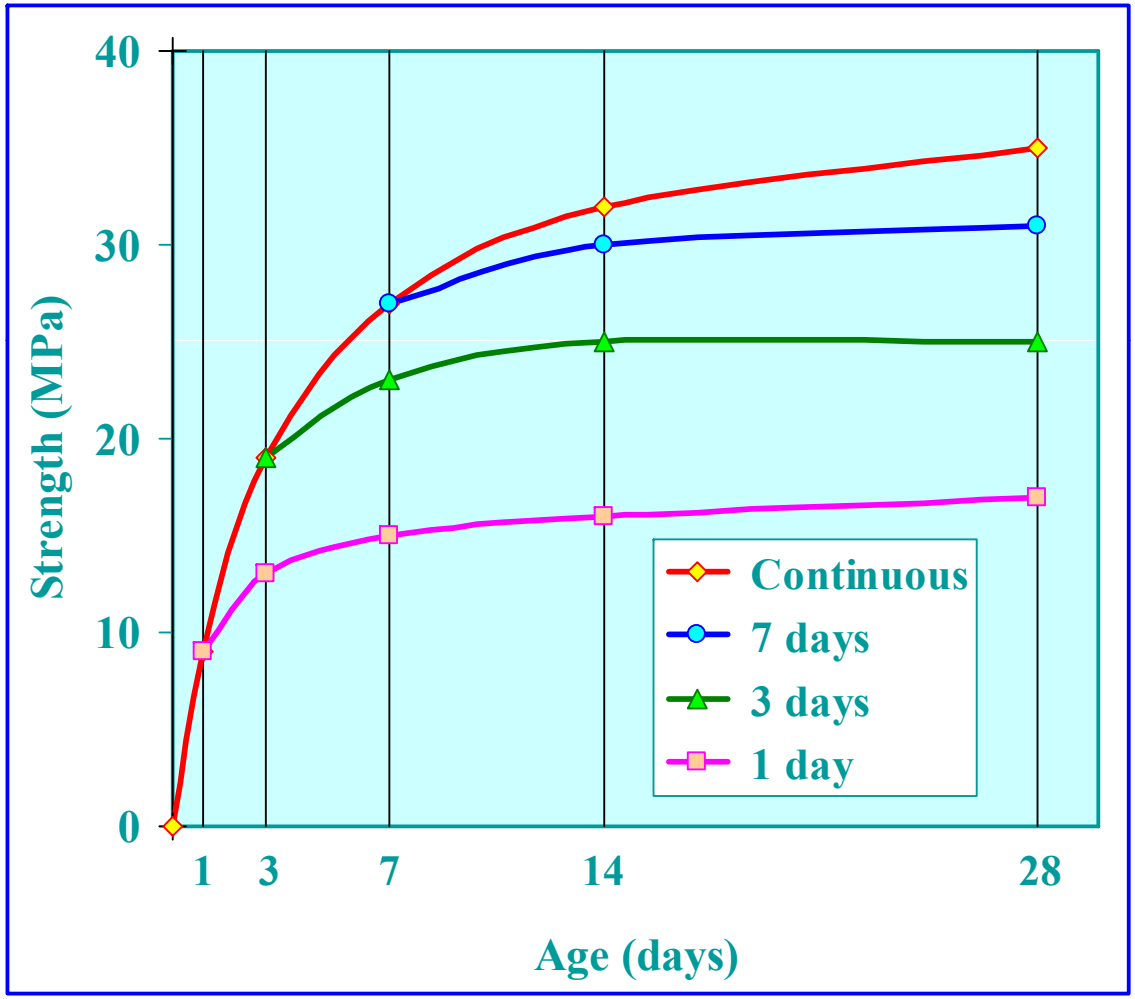
The properties of concrete close to the surface are particularly sensitive to curing effects.

Concrete at depth will lose its moisture at a slower rate when the surface is not protected.



Effect of the Duration of Moist-Curing on the Strength Development for Concrete

As the duration of moist curing is extended – concrete achieves a greater proportion of its maximum potential strength



Curing Requirements – ACI 308R-01

Basic Curing Period

7 days above 50°F

or

Time to reach 100% of specified performance, including post-curing gains

Additional Curing Requirements Based on Exposure

Curing Requirements – ACI 308R-01 (Continued)

Structural Safety

Curing period extended until 70% of specified strength is reached

Reinforced Mass Concrete

7 days or until 70% of specified strength is reached

Unreinforced Mass Concrete

2 weeks without SCMs, 3 weeks with SCMs

Methods of Curing

1. Ponding or continuous sprinkling
2. Absorptive mat or fabric continuously wet
3. Wet sand or straw
4. Spray curing compounds
5. Waterproof paper or plastic film
6. Vapor mist bath (precast)
7. Forms in contact with concrete surface
8. Others, approved by the Owner

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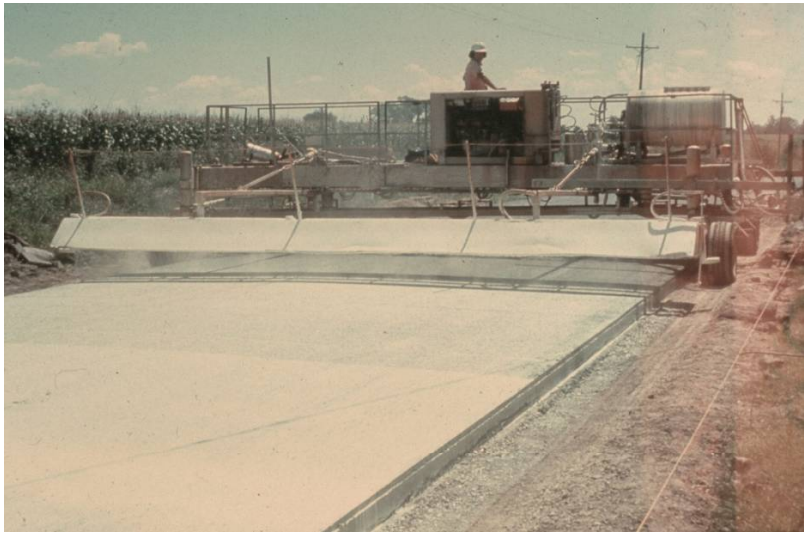

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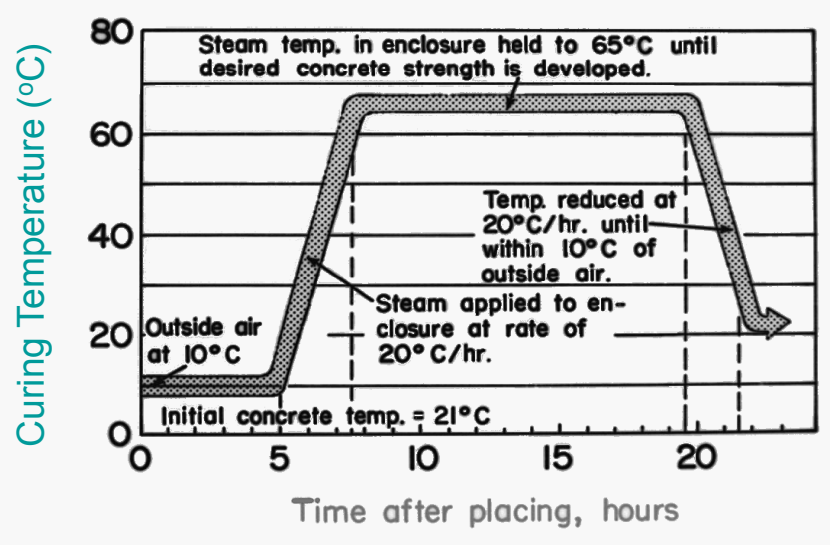

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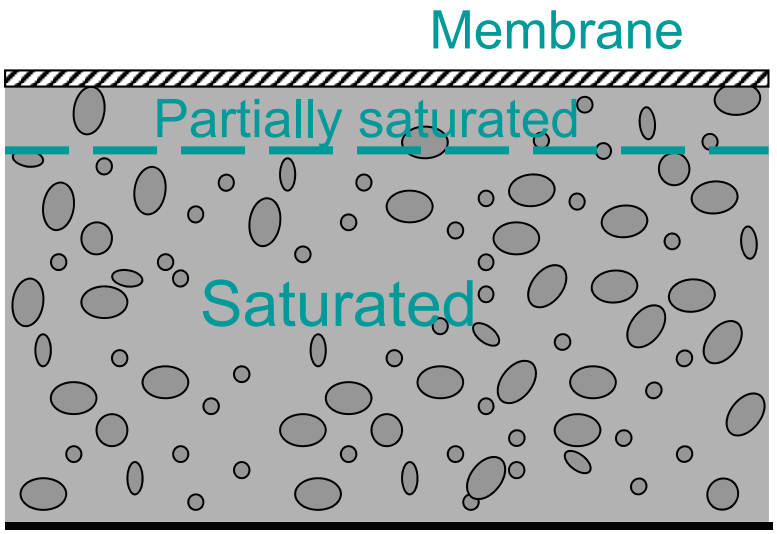
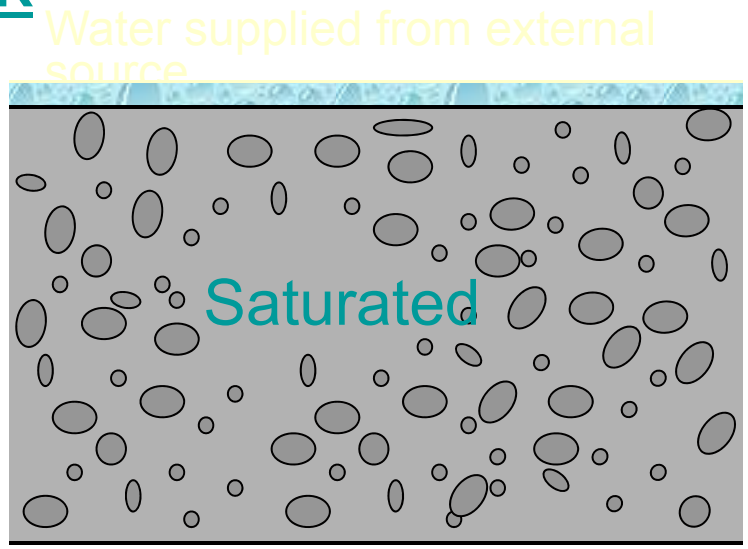
METHODS OF CURING

- **SEAL IN MIXING WATER**
  - Spray curing compound
  - Waterproof paper
  - Polyethylene sheets

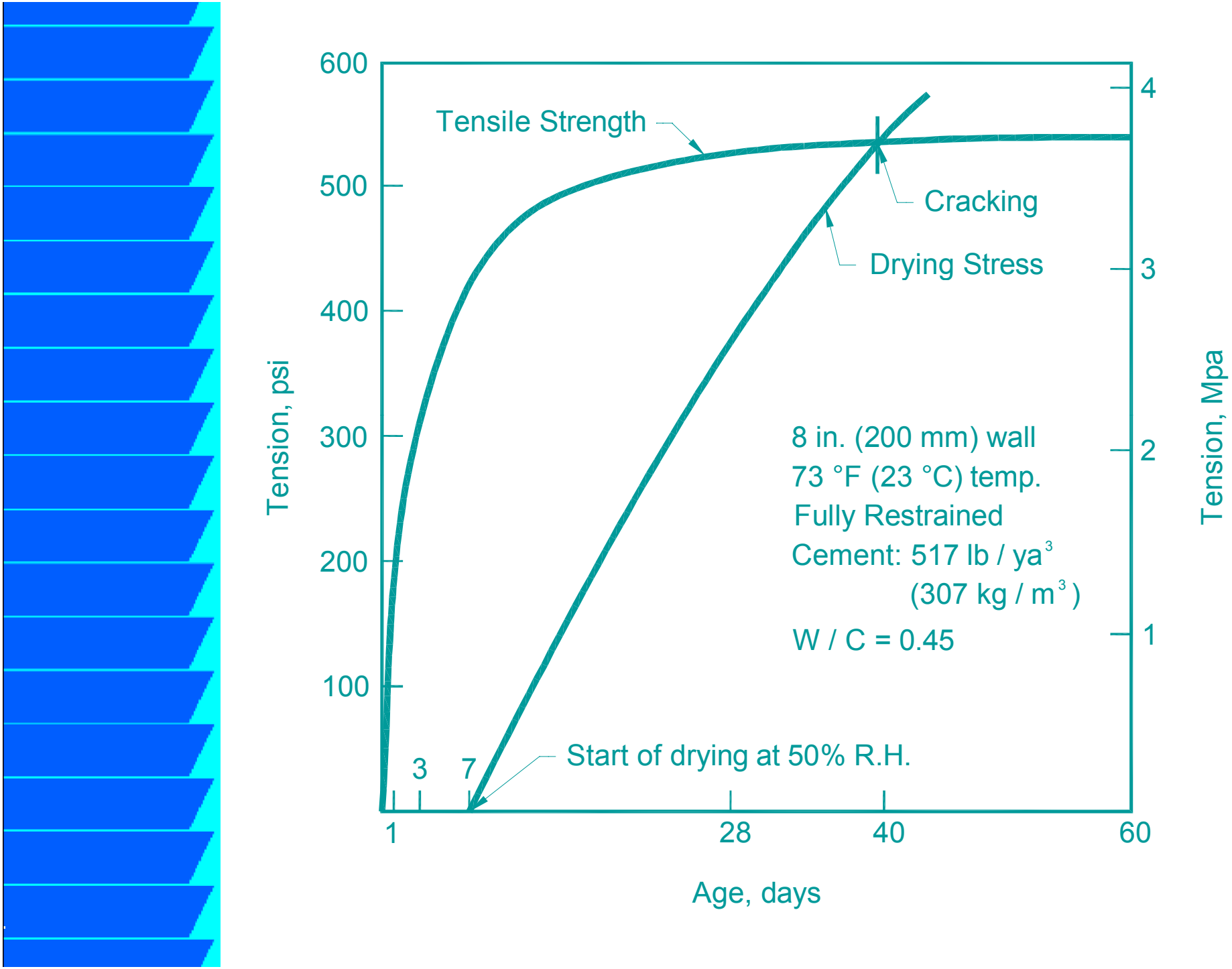


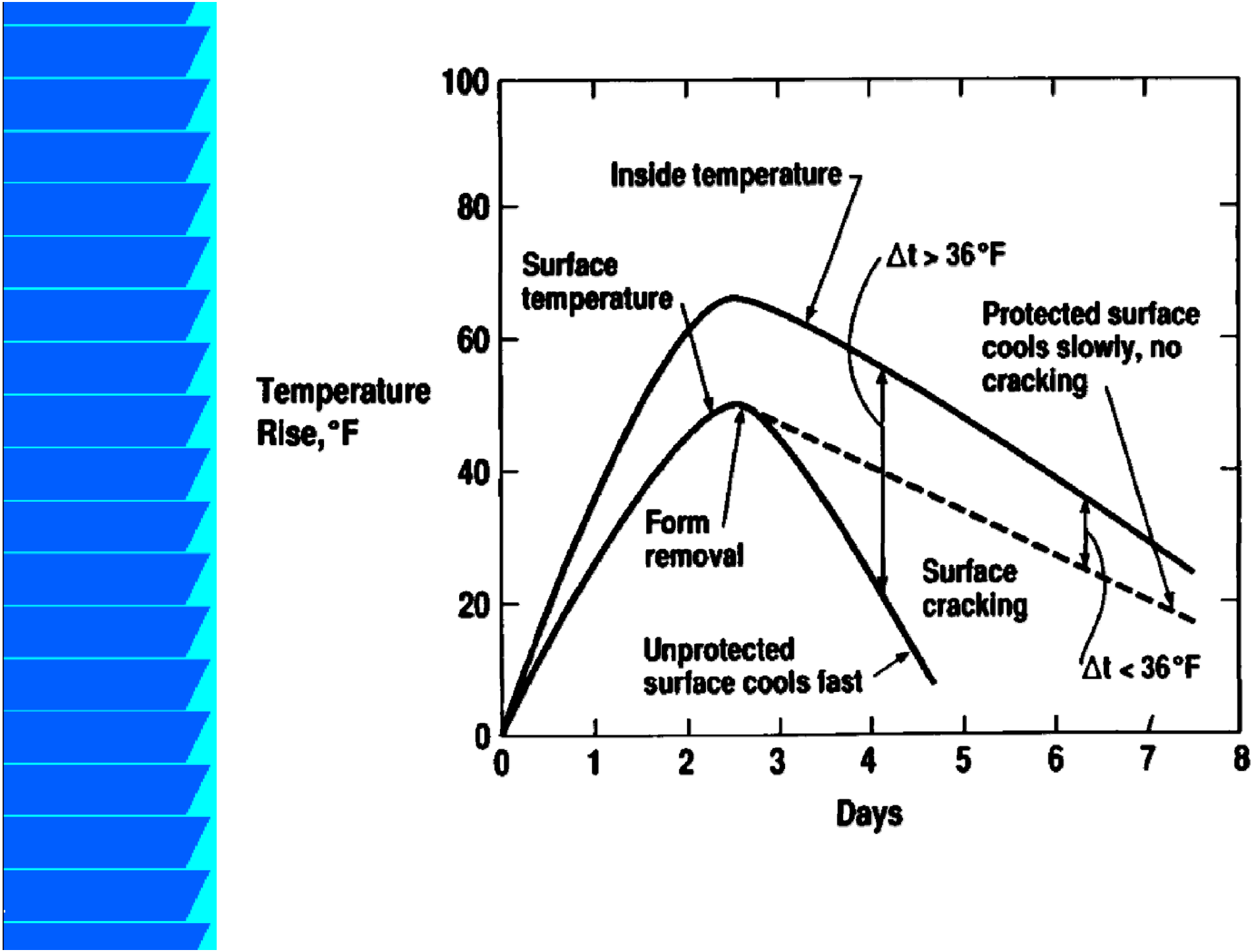
- **SUPPLY ADDITIONAL WATER**
  - Ponding
  - Soaker hose
  - Wet sand
  - Wet burlap
  - Immersion (precast)
  - Steam curing (saturated air)



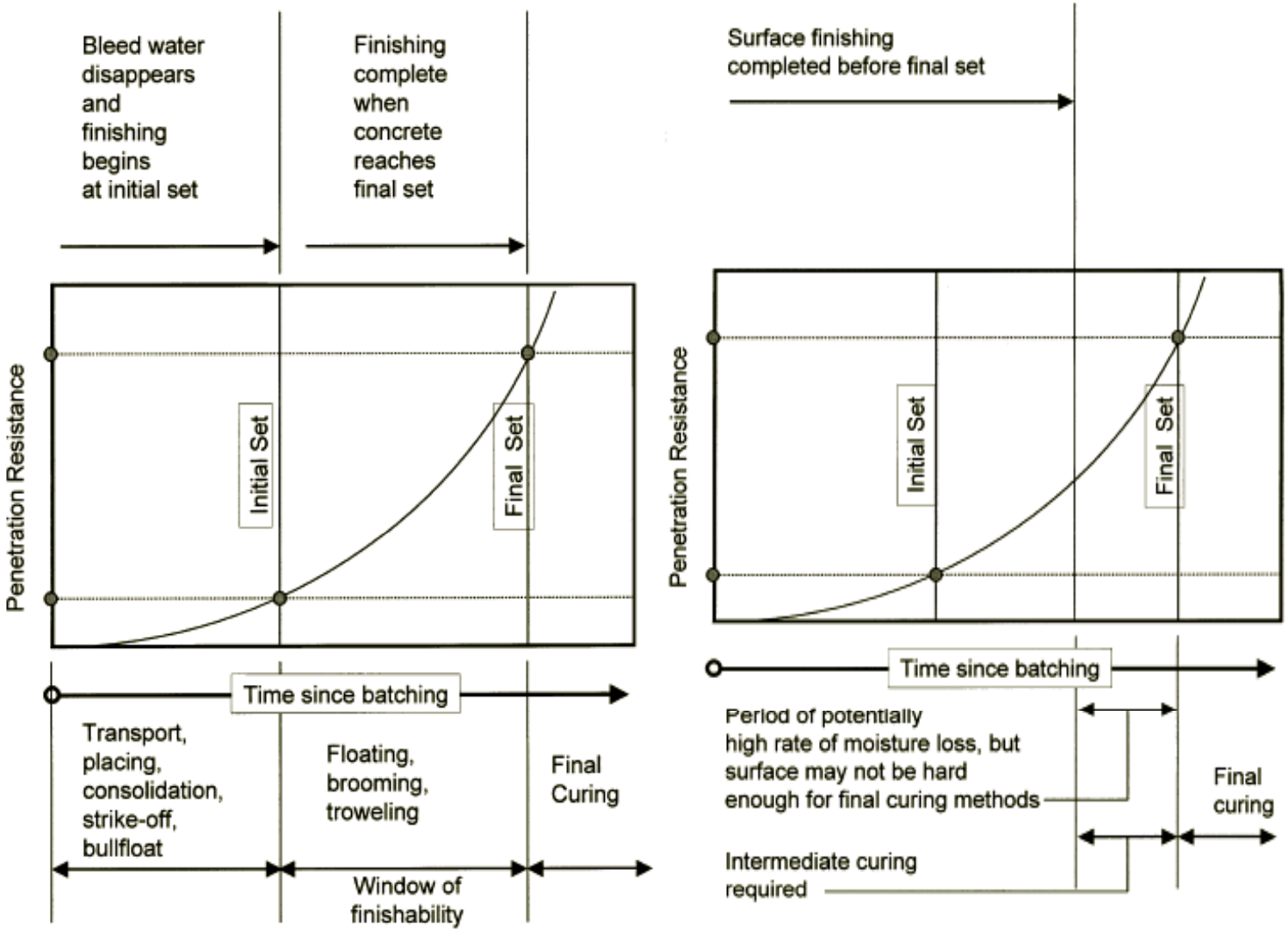
EFFECT OF ADEQUATE CURING ON HARDENED CONCRETE

Early Cracking	→ eliminated
Strength Gain	→ accelerated
Wear Resistance	→ greatly Improved
Durability	→ greatly Improved
Watertightness	→ greatly Improved

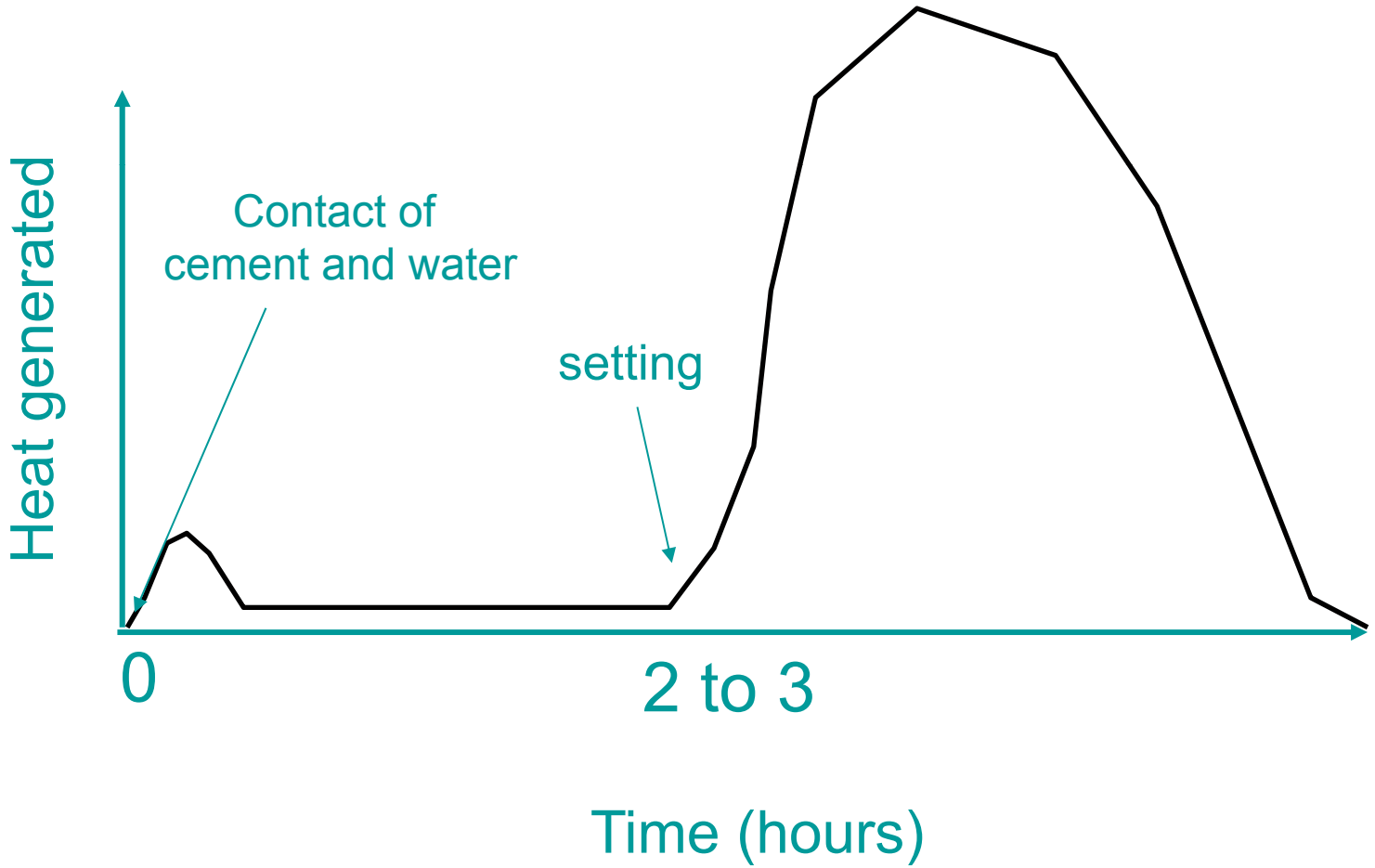

600
500
400
300
200
100
Tension, psi
4
3
2
1
Tension, Mpa
Tensile Strength
Cracking
Drying Stress
8 in. (200 mm) wall
73 °F (23 °C) temp.
Fully Restrained
Cement: 517 lb / ya3
(307 kg / m3)
W / C = 0.45
Start of drying at 50% R.H.
3
7
1
28
40
60
Age, days


Temperature Rise, °F
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
Days
Inside temperature
Surface temperature
Δt > 36°F
Protected surface cools slowly, no cracking
Form removal
Surface cracking
Unprotected surface cools fast
Δt < 36°F

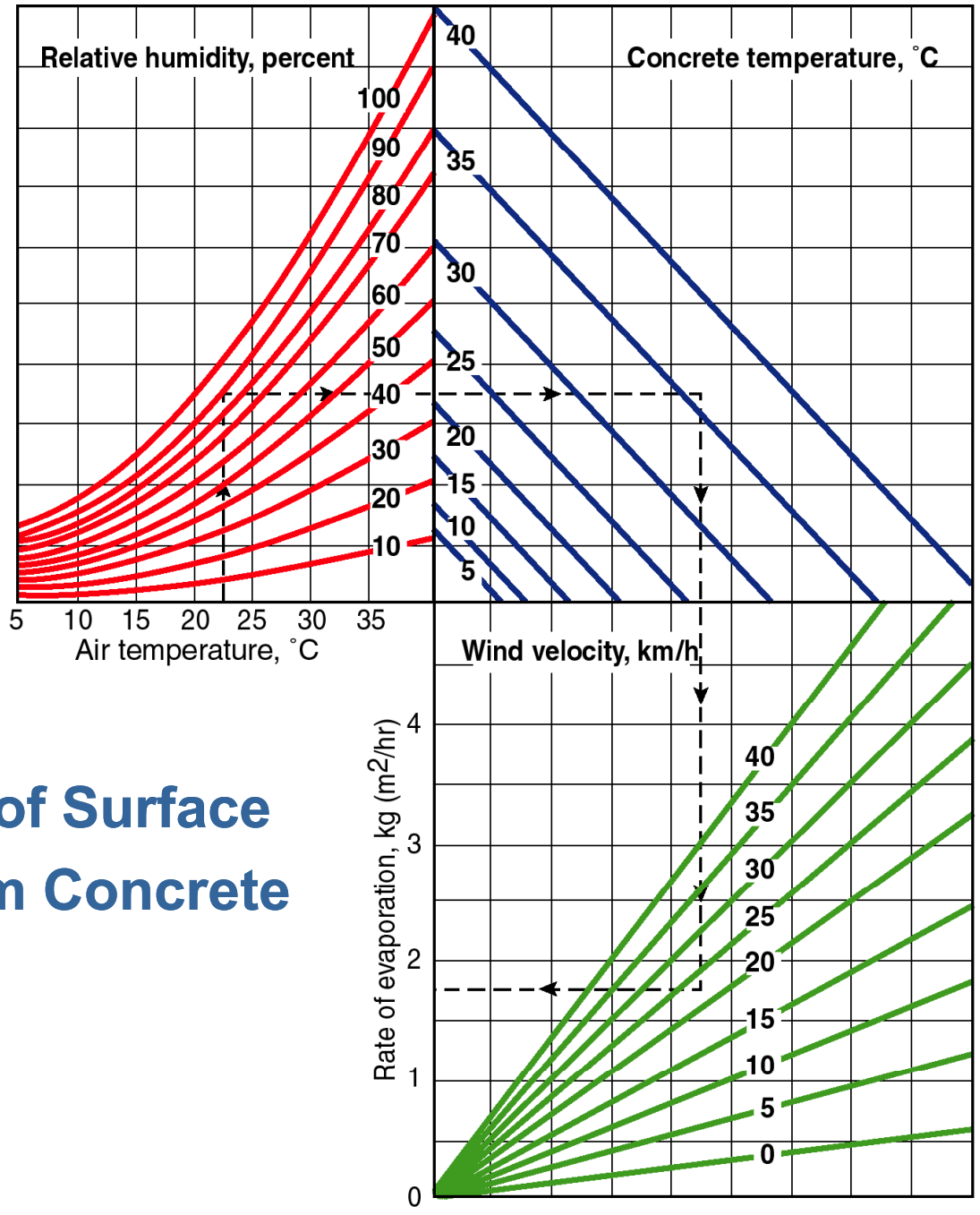
Timing of Operations



Heat Development



Evaporation of Surface Moisture from Concrete



Precautions to Minimize Plastic Shrinkage Cracking

- Moisten aggregates
- Cool aggregates and mixing water
- Dampen subgrade
- Erect temporary windbreaks and sunshades
- Cover concrete
- Fog slab immediately after placing
- Add plastic fibers

Fogging

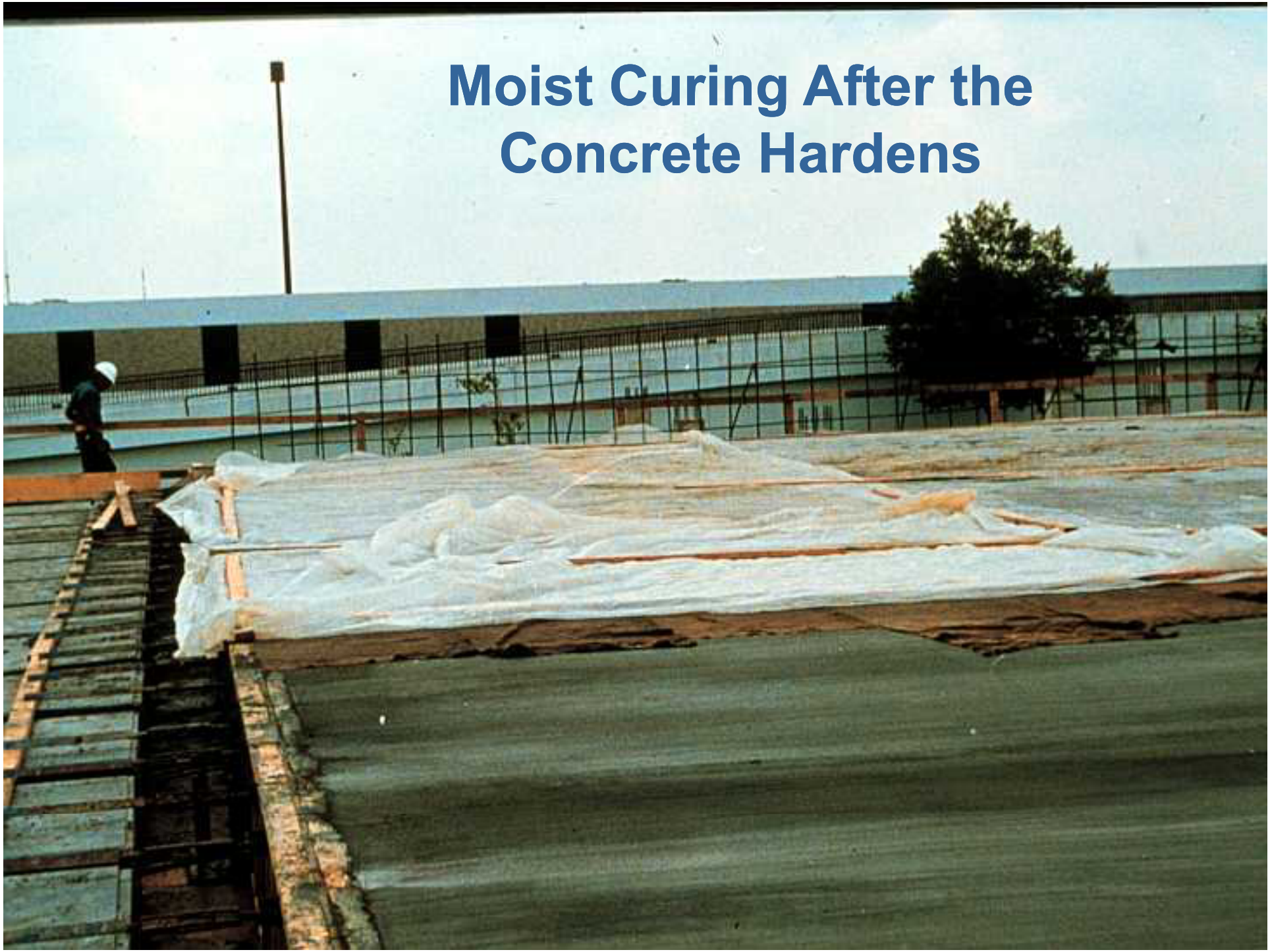
Good Fogging

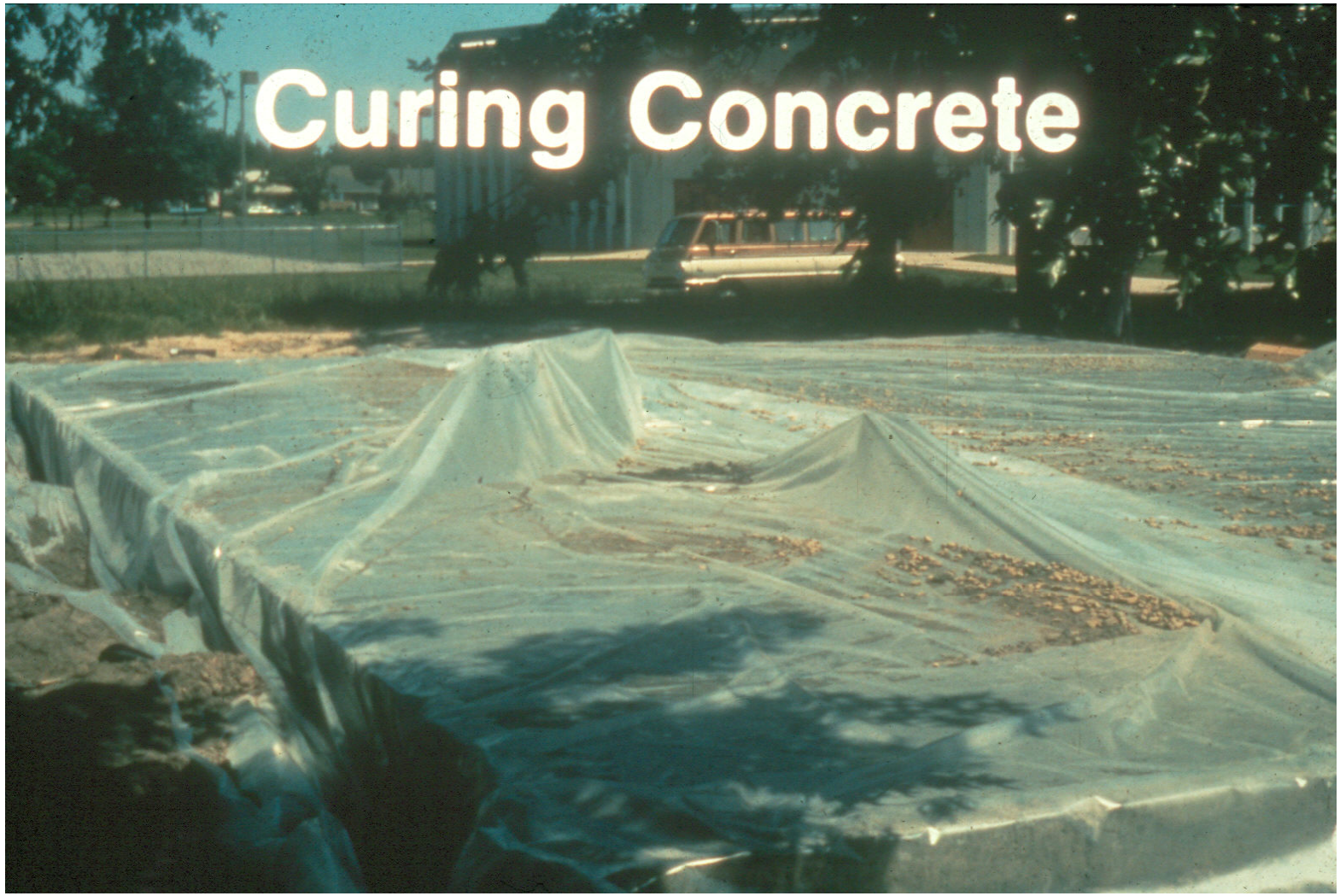

Bad Fogging

Evaporation Retarders

Curing Compound Applied to Fresh Concrete

Moist Curing After the Concrete Hardens





Adequate curing is essential

Wet burlap & plastic

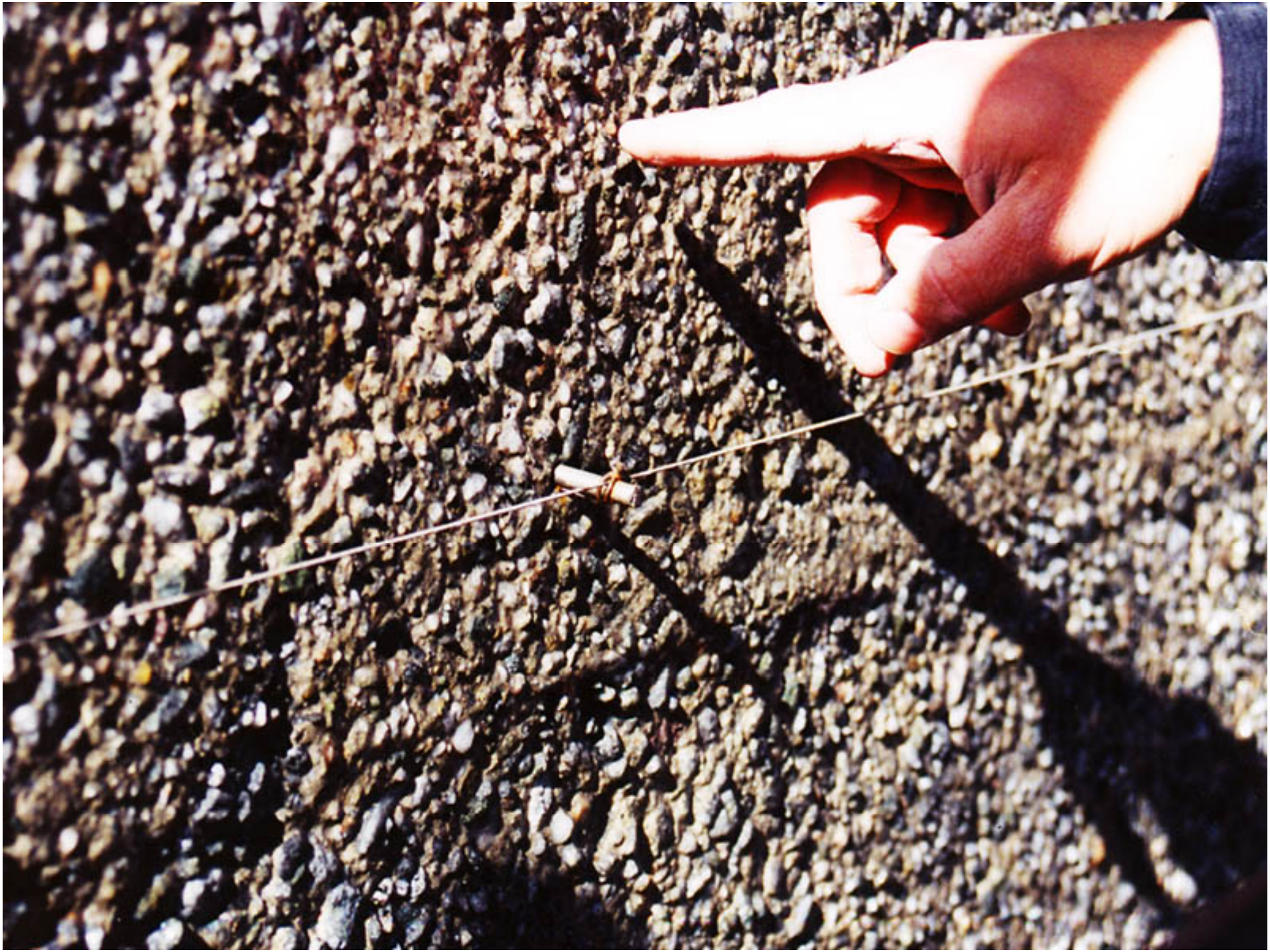
Curing Membrane

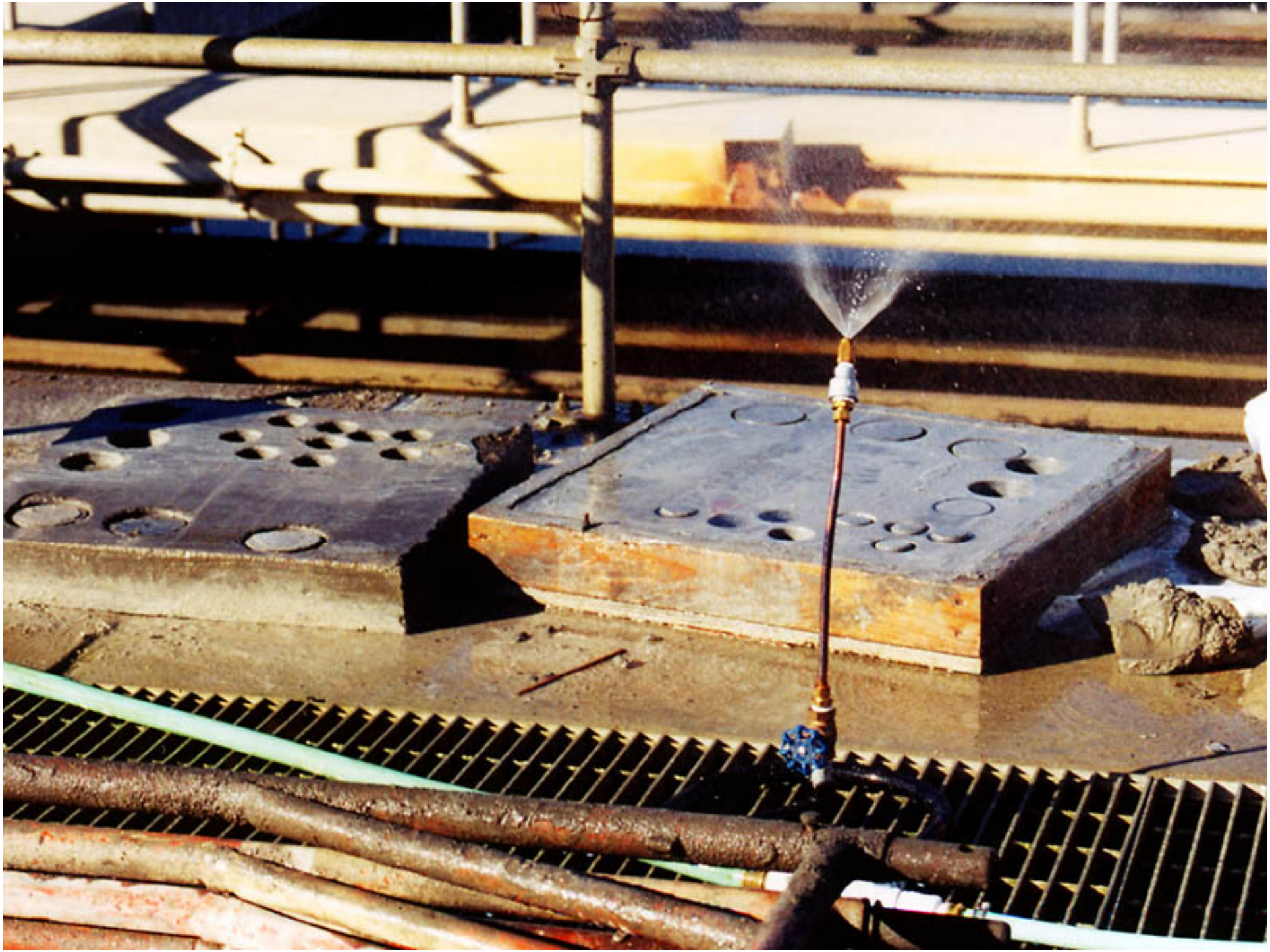
Ensuring Adequate Curing

- Curing should be a separate pay item in the contract
- Contractor should submit a curing plan
- The various tasks – initial, intermediate & final curing – have to made someone's specific responsibility
- Adequate inspection required
- Problems with curing-membrane systems?
  - Proper coverage/application
  - No thermal benefit (+/-)
  - Bonding of subsequent overlay materials

Field example, If time allows…

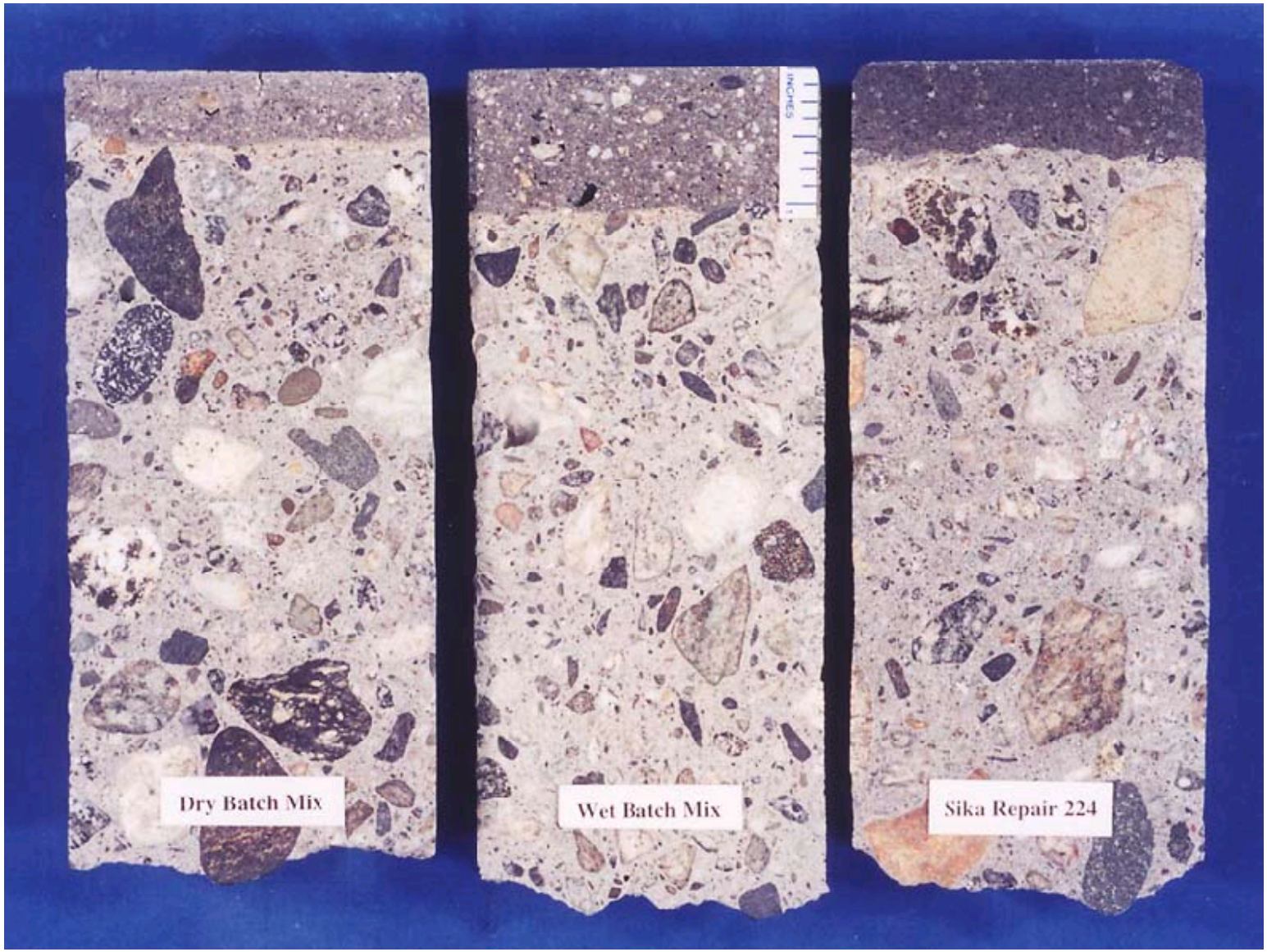
- Example where curing was critical on thin low permeability shotcrete overlay:
- Specification
  - ½ - in. thick
  - 6000 psi at 28 days
  - Less then 1500 coulombs rating (low permeability)
  - Bond strength of 200 psi
  - Project Climate: frequently hot and windy conditions



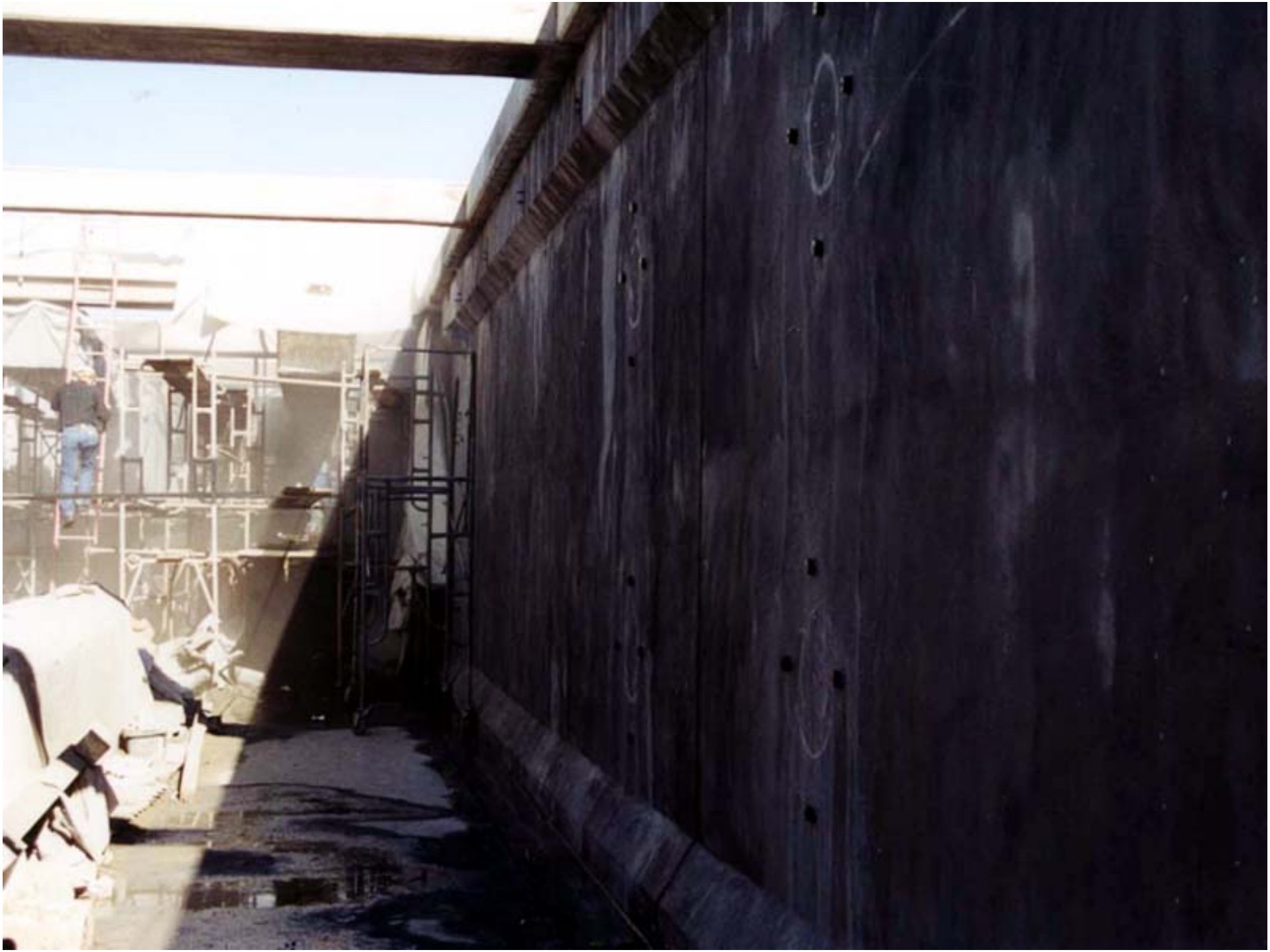


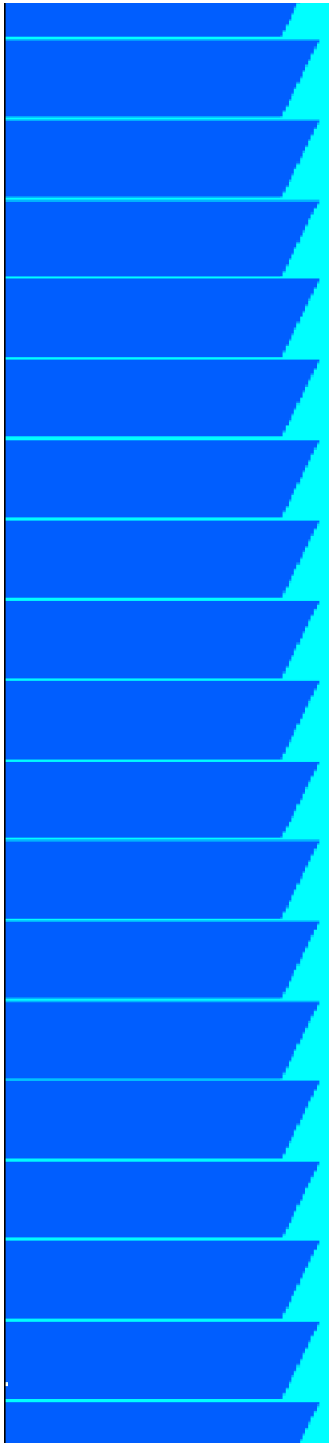

AUTO PAR


DRY
MIX


Dry Batch Mix
Wet Batch Mix
Sika Repair 224


dryvit





Questions….