ATLANTIC TESTING LABORATORIES

Concrete Maturity In Cold Weather

ACI 306.1-90

ASTM C1074

Client / Event
Date

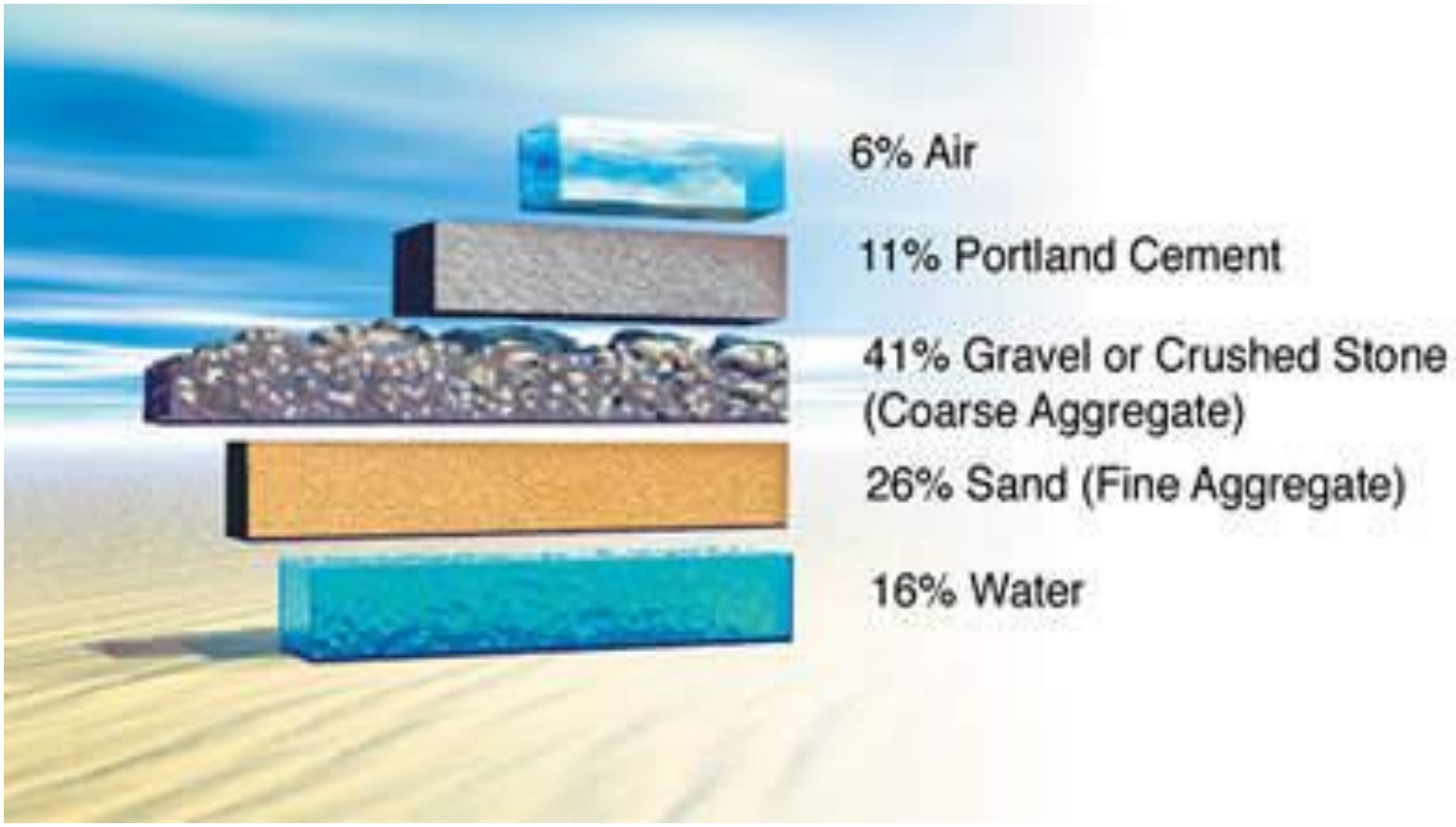
Topics

1. Introduction – Concrete,
   - the Bread of the Construction Industry
   - Five Essentials of Quality Concrete

2. Concrete in Cold Temperatures
   - ACI 306.1-90, 306R-10

3. Concrete Maturity ASTM C1074

the **BREAD** of the construction industry



5 Essentials of Quality Concrete

Suitable Materials
Proportioning, Mixing & Transportation
Placing & Consolidation
Finishing & Jointing
Curing

Cold Weather Concreting

ACI 306.1-90 & 306R-10

COLD WEATHER

For 3 consecutive days

- Average temperature below 40^{o}F and
- <50^{o}F for half of any 24hr period

ACI 306.1-90 & 306R-10

- Air entrained if exposed to freezing during construction period (slabs & flatwork)
- Minimum temperature of embedments 32^{o}F
- Thawed subgrade and reinforcement


THAWZALL
THE HEAT MACHINE

ACI 306.1-90 & 306R-10

	Condition		Thickness of Section (in)			
			< 12”	12-<36”	36-72”	>72”
1	Minimum Temperature of Fresh Concrete as Mixed for Air temp Indicated	Above 30°F	60	55	50	45
2		0 – 30°F	65	60	55	50
3		Below 0°F	70	65	60	55
4	Minimum Temperature of Fresh Concrete as Placed and maintained		55	50	45	40

ACI 306.1-90 & 306R-10

- 500psi
- provides **one** cycle of freeze-thaw protection
- Below critical saturation point
- No external supply of moisture

ACI 306R-10

Service Category	Protection Period (days)
No Load – Not Exposed	2
No Load – Exposed	3
Partial Load – Exposed	6
Full Load	In-place strength criteria

ACI 306.1-90 & 306R-10

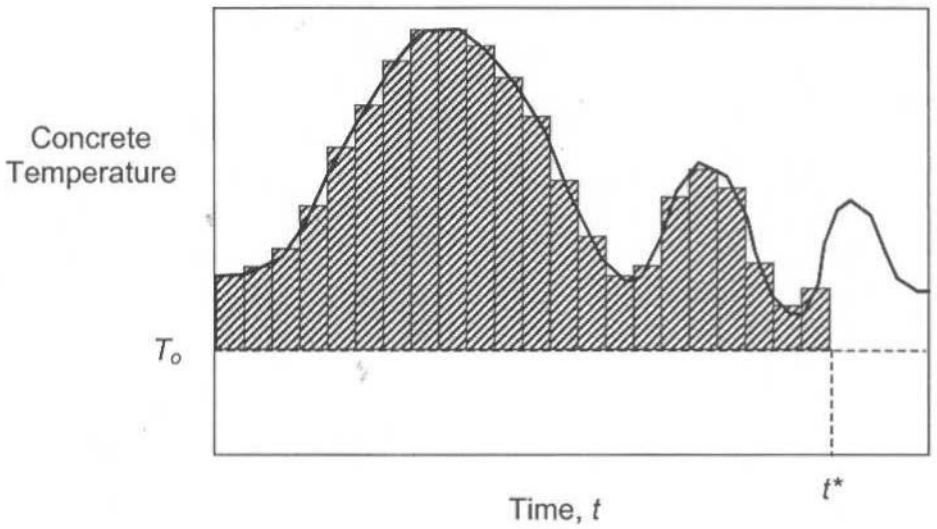
Maximum Allowable Temperature Drop (^{o}F) Per 24 hr Period After End of Protection Period			
Section Size, minimum dimensions (in)			
<12”	12-<36”	36-72”	>72”
50^{o}	**40^{o}**	**30^{o}**	**20^{o}**

Maturity Method

Maturity

TEMPERATURE-TIME FACTOR

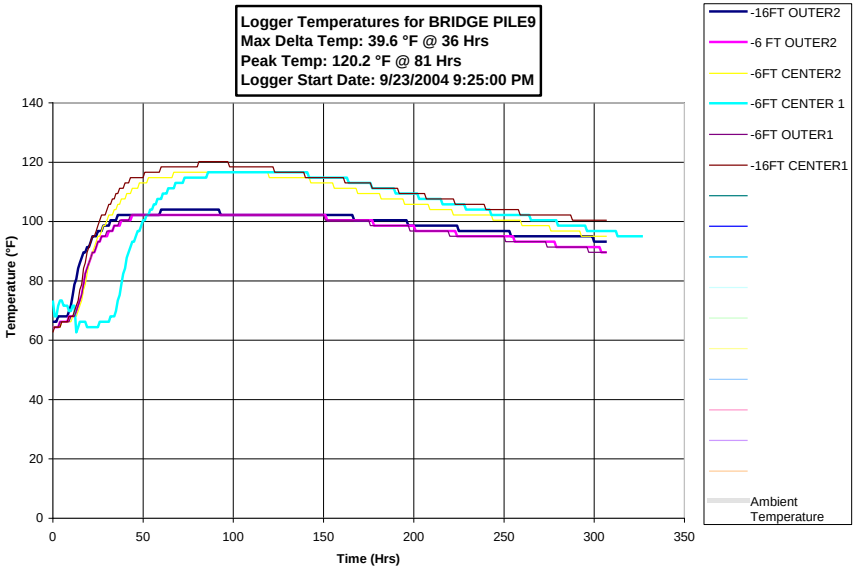
"Concrete of the same mix at the same maturity (reckoned in temperature-time) has approximately the same strength whatever combination of temperature and time go to make up that maturity." [Saul, 1951]

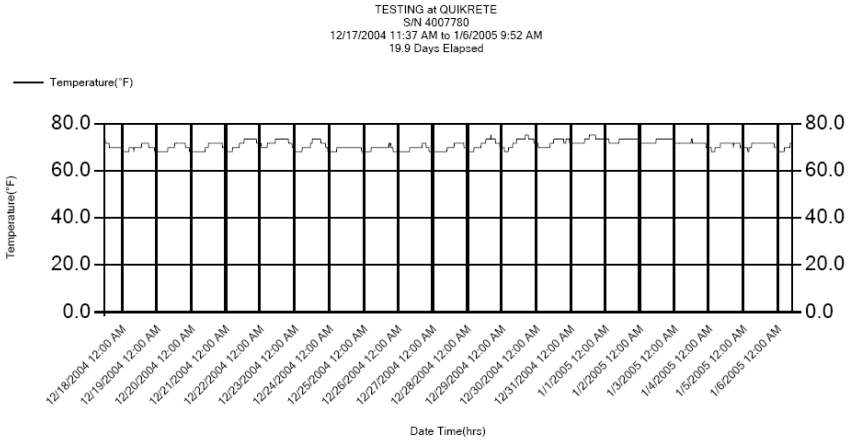


Maturity Method

$M = \Sigma(T - T_o)\,\Delta t$ ***Nurse-Saul***

$M_i = (44^o\text{-}14^o\text{F})\ 1\text{hr} = 30^o\text{hr}$



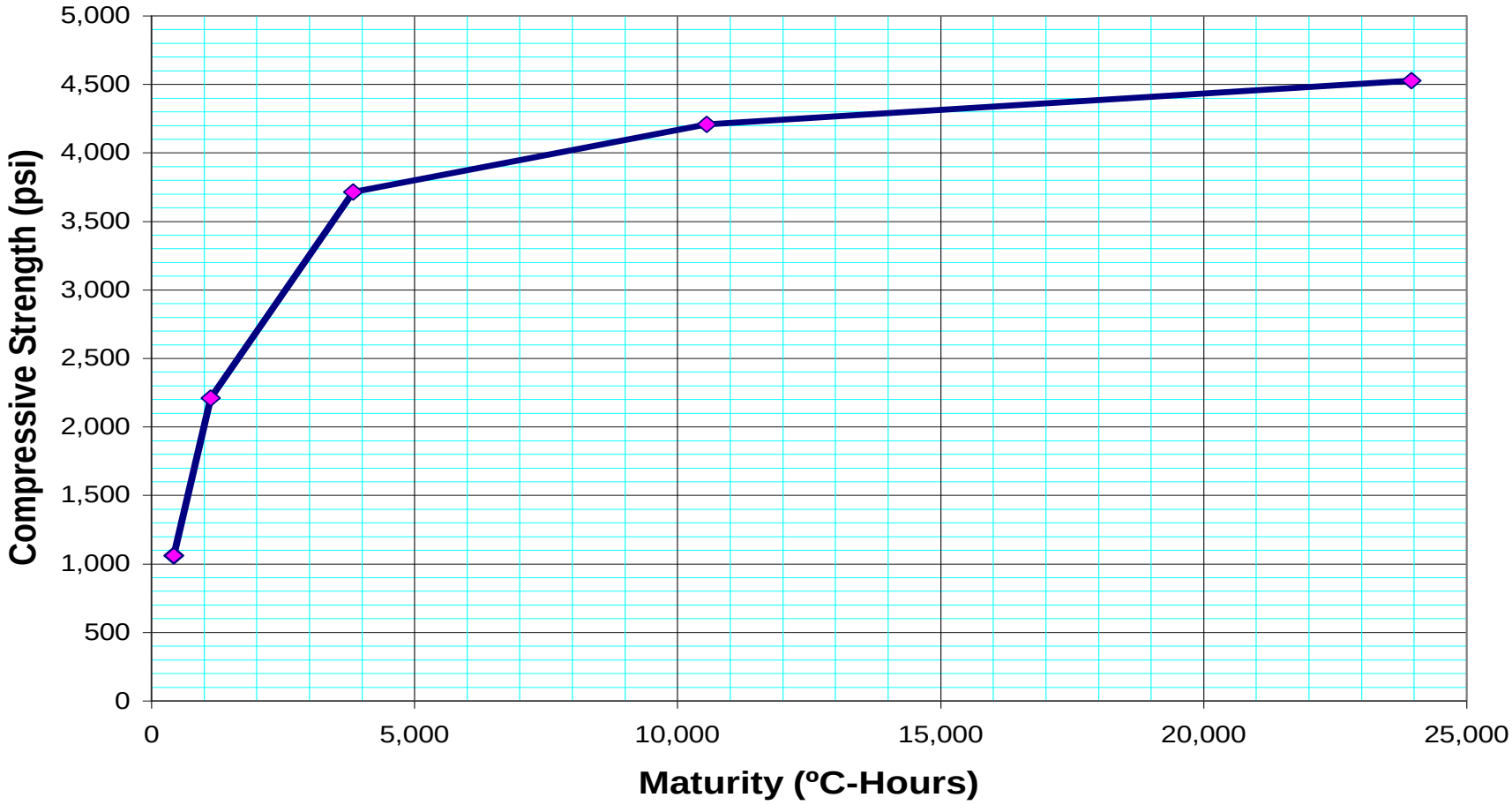


Maturity Method

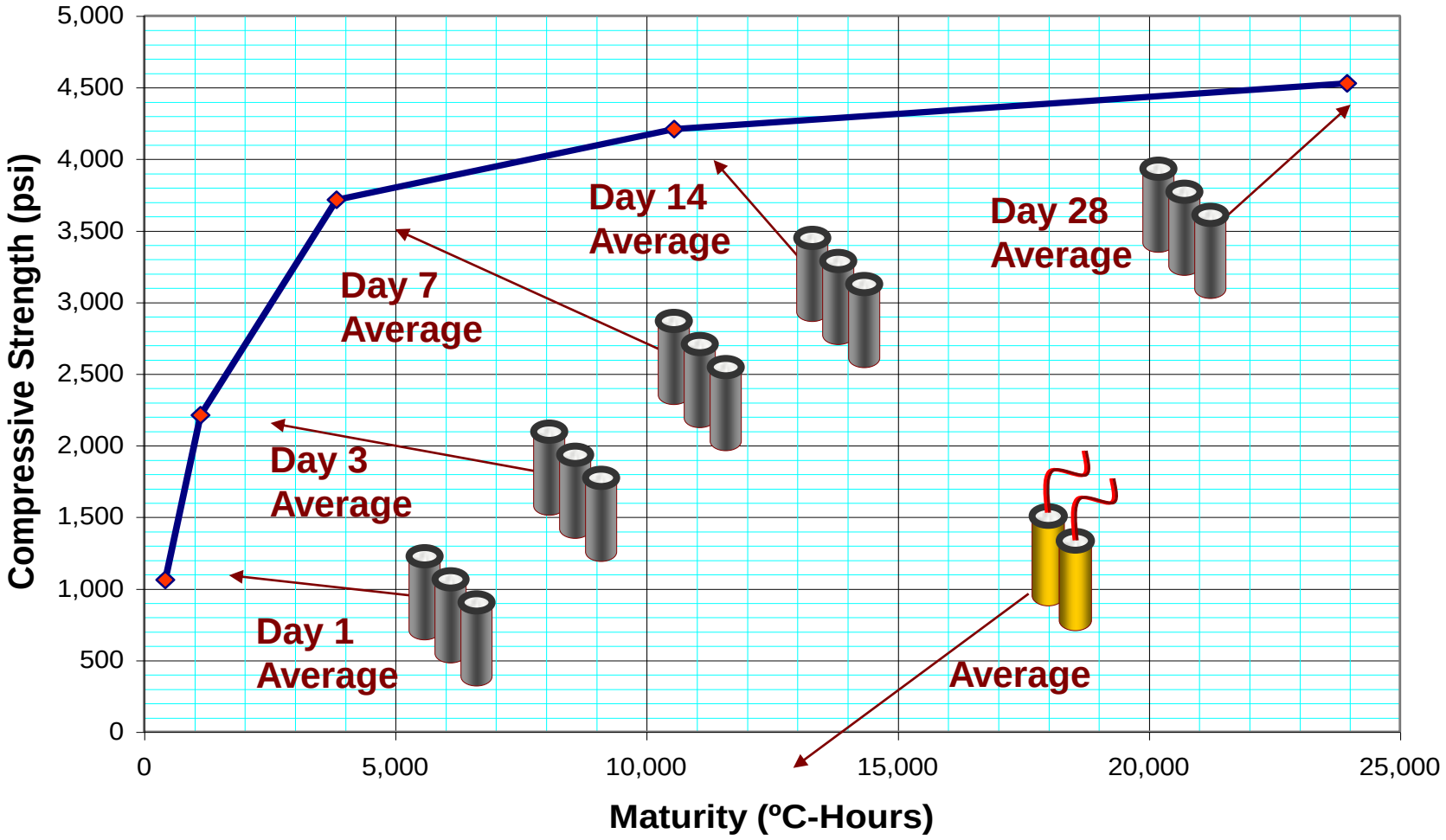
$T_o = 2.5^oC$

AGE (hr)	TEMP (^oC)	AGE INCREMENT	AVG TEMP	TEMP-TIME FACTOR	CUMULATIVE TEMP-TIME FACTOR
0	**10**	**…**	**…**	**…**	**0**
0.5	**8**	**0.5**	**9**	**3.3**	**3**
1.0	**7**	**0.5**	**7.5**	**2.5**	**6**
1.5	**6**	**0.5**	**6.5**	**2.0**	**8**
2.0	**5**	**0.5**	**5.5**	**1.5**	**9**
2.5	**5**	**0.5**	**5.0**	**1.3**	**11**
3.0	**6**	**0.5**	**5.5**	**1.5**	**12**
3.5	**7**	**0.5**	**6.5**	**2.0**	**14**
4.0	**8**	**0.5**	**7.5**	**2.5**	**17**

Maturity Method



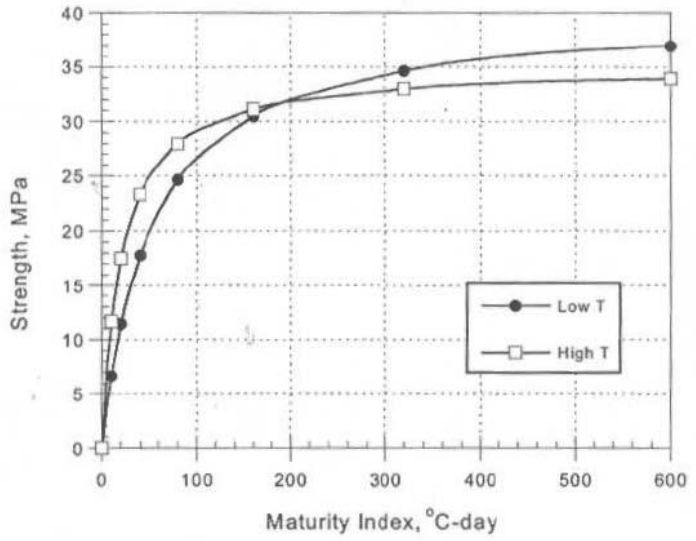
Maturity Method

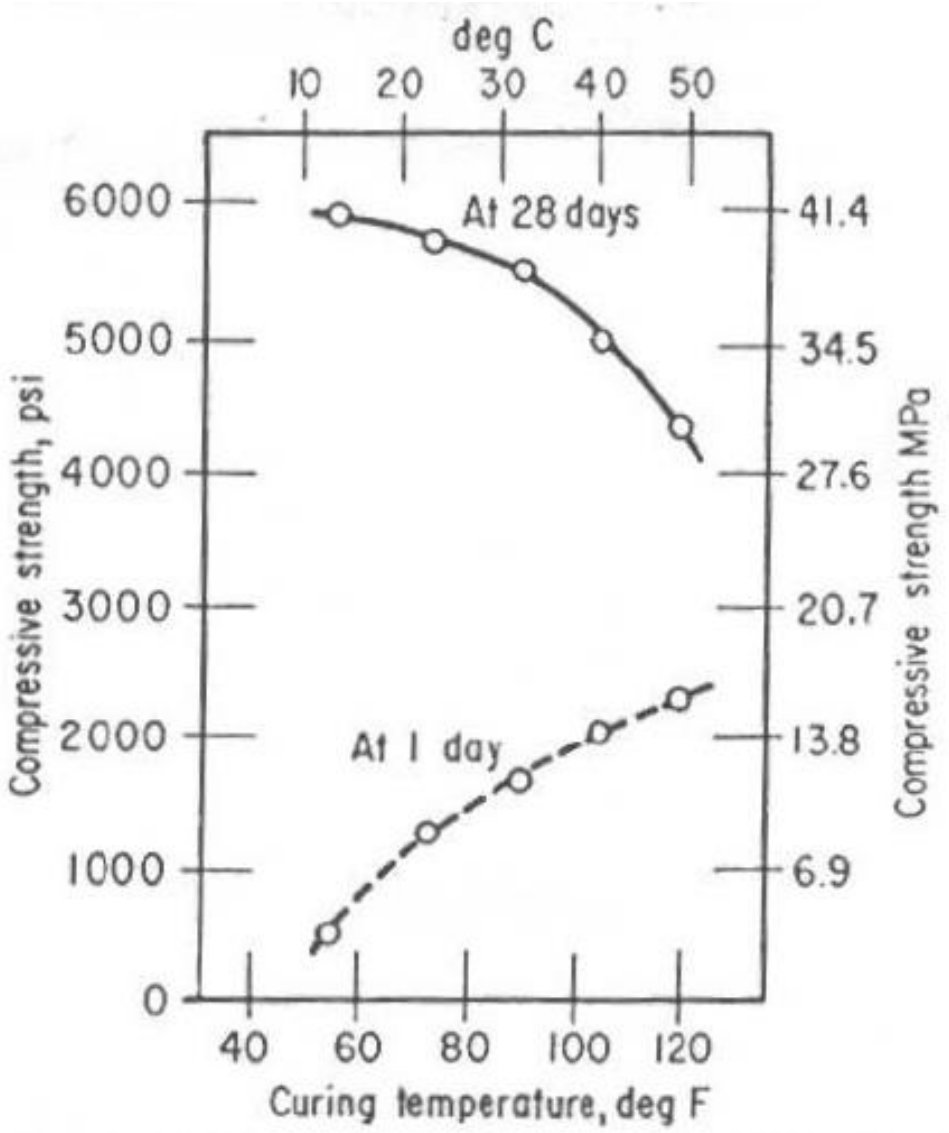


Maturity Method

LIMITATIONS

Long term strength is dependent upon curing temperature.





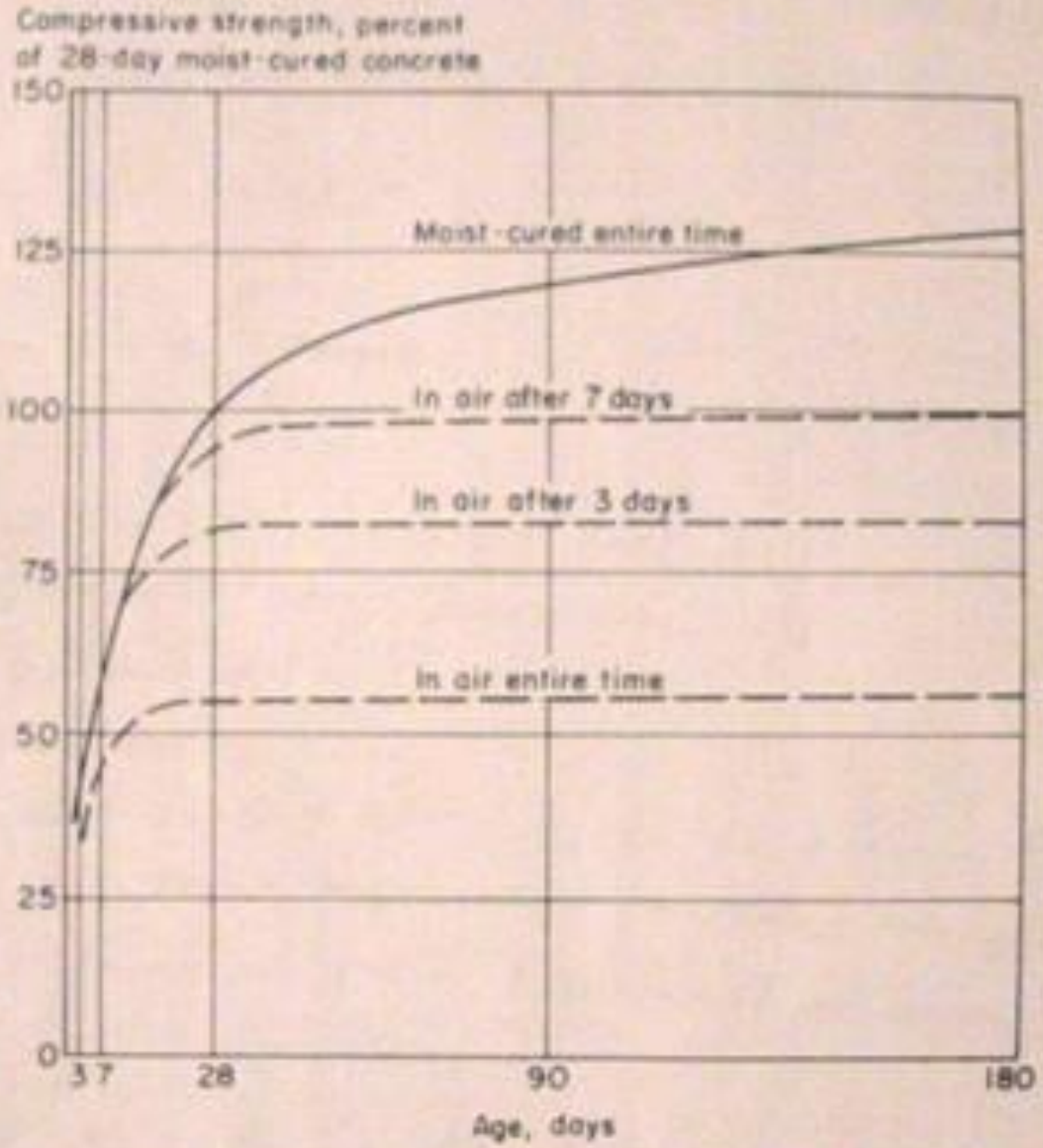


Fig. 1-4. Concrete strength increases with age as long as moisture and a favorable temperature are present for hydration of cement. Adapted from Reference 1-15, Fig. 9.

Maturity Method

LIMITATIONS

"Samples of a given mixture which have the same **equivalent age** and which have had a sufficient supply of moisture for hydration will have developed equal fractions of their **limiting strength** irrespective of their actual temperature histories." (Carino, Lew)

EQUIVALENT AGE

The number of days or hours at a specified temperature required to produce a maturity equal to the maturity achieved by a curing period at temperatures different from the specified temperature.

Review

Review

Does ACI 306.1 allow concrete to be placed on frozen sub-grade?

Review

ACI 306.1 requires concrete that will be subjected to freezing during the construction period to be air entrained?

Review

Do we need to control the rate at which we allow the temperature to drop at the end of the protection period?

Review

The gases given off by direct fired heaters used during cold weather concrete placement may be harmful to workers, but have no harmful effect on the concrete.

Review

What are the two parameters that we measure and graph to determine concrete maturity?
i.e. What are the two factors in the Nurse-Saul equation?

Question & Answer