

Concrete Technology in Focus

4x4™ Concrete System

A Maturity-Based Method for Estimating In-Place Concrete Pavement Strength

What is the Maturity Method?

The maturity method is a nondestructive technique that is used to estimate the in-place strength of concrete by accounting for the effects of temperature and time on strength development. It is based on the principle that the extent of hydration of a concrete mixture and, therefore, the strength at any age is based on the thermal history of the concrete. Using the thermal history of a concrete mixture and a maturity function, a maturity index that quantifies the combined effects of time and temperature can be calculated and plotted against the strength of the concrete by means of a strength-maturity relationship.

Measuring Concrete Maturity

Concrete maturity can be measured in the laboratory or field using strength test specimens. The maturity method involves the measurement of three key parameters: time, concrete temperature and concrete strength. Using one of two widely-used expressions, a temperature-time factor with units of degree-hour is calculated by multiplying concrete temperature, with respect to a datum, by the elapsed time (in hours) after the concrete was batched. In ASTM C 1074, "Standard Practice for Estimating Concrete Strength by the Maturity Method," 32 °F (0 °C) is recommended as the datum temperature for concrete containing Type I cement. A relationship between degree-hours and actual concrete strength, for a given mixture, can be determined by graphing each actual strength data and the corresponding degree-hours. The advantage of the maturity method is that once a strength-maturity relationship is established for a particular concrete, temperature histories can be used to predict the strengths of samples of the same concrete subjected to different temperature conditions.

Table 1 contains temperature and actual flexural strength data for test specimens cured in different environments for a pavement repair project on Interstate-5 in California using the patented

4x4 Concrete system. The flexural strengths and calculated temperature-time data, in degree-hours, are presented graphically in Figure 1.

When evaluating concrete maturity using small test specimens, it is extremely important to insulate them from heat loss to minimize the time needed to develop the strength-maturity relationship. If small test specimens are not insulated during curing, strength development will be slowed because the volume of concrete is small.

Practical Application of Concrete Maturity

In practice, the maturity-based test method can be used to estimate the strength of in-place concrete at a given point in time. One application for using maturity to estimate concrete strength is in full-depth pavement repairs. After developing the correlation between degree-hours and actual strength, a contractor or transportation agency can use the maturity method to open a newly-repaired concrete pavement to traffic without testing a specimen for strength. Maturity-based testing can reduce project costs by eliminating the need to cast and test compressive or flexural strength specimens.

4x4™ Concrete System

| Concrete Specimen Environment | Elapsed Time (h) | Temp. (°F) | Degree Hours (h) | Flexural Strength (psi) |
|-------------------------------|------------------|------------|------------------|-------------------------|
| Tarp | 4 | 70 | 280 | 105 |
| Tarp | 5 | 77 | 385 | 170 |
| Tarp | 6 | 79 | 474 | 305 |
| Box | 4 | 78 | 312 | 115 |
| Box | 5 | 85 | 425 | 270 |
| Box | 6 | 88 | 528 | 355 |
| Cooler | 4 | 85 | 340 | 175 |
| Cooler | 5 | 96 | 480 | 300 |
| Cooler | 6 | 100 | 600 | 440 |

Table 1

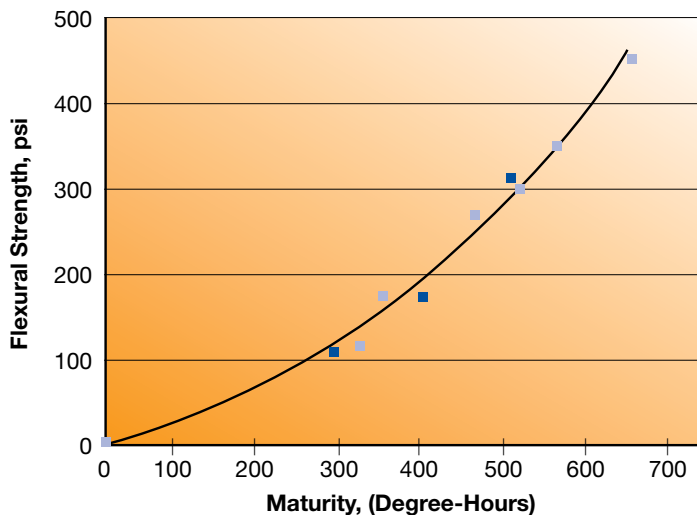


Figure 1: 4x4 Concrete: I-5 in Los Angeles

Using Concrete Maturity to Estimate 4x4 Concrete Strength

- 1) Develop a 4x4 Concrete mixture to achieve the desired level of compressive or flexural strength at a specified time period.
- 2) Perform a field trial placement and measure the degree-hours and corresponding strength of test specimens at different time intervals (usually through a 24-hour time period).

- 3) Insert temperature probes directly into the strength specimens and in-place concrete and record the temperature manually or through a data logger system. Alternatively, a temperature gun can be used to determine the concrete temperature.
- 4) Insulate the specimens during testing using coolers or moldable insulation to minimize heat loss and effectively simulate in-place concrete field performance. As the 4x4 Concrete system begins to generate heat, it will progressively develop greater strength.
- 5) Evaluate test specimens for strength at 3, 4, 5, 6, 7, & 24 hours after the water comes in contact with the cement during batching.
- 6) Graph the degree-hour and strength data as shown in Figure 1.

The strength and degree-hour relationship will vary by different mix proportions and material selection. Therefore, this relationship must be established for a given concrete mix before a specific project begins. This will allow the project engineer to estimate the degree-hours needed to obtain the required strength. Maturity testing can provide an alternative to strength testing in determining when a concrete pavement can be opened to traffic. Without this relationship, an unnecessary delay in returning concrete to service might occur based on the concern that the specified strength has not been obtained.

There are, however, limitations to using either test specimens or the maturity method to determine the in-place concrete strength. With the maturity method, a change in cement performance during a project (due to different loads or lots of material) could produce variability in results. Test specimens on the other hand may contain flaws or lose heat during curing and not be representative of in-place concrete performance. Until sufficient experience has been obtained with a given mix, the most reliable way to determine concrete strength is to use both strength and maturity measurements to determine concrete strength.

More Information

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