Determination of the strength of in-place concrete is obviously important to contractors.

Decisions such as when to strip forms, when to post-tension, when to remove shores, and when to terminate cold-weather protection are based on reaching a minimum level of concrete strength.

Waiting too long to perform these operations is expensive, but acting prematurely may cause the structure to crack or collapse.
Using Maturity Method to Predict Concrete Strength

- The information used to make these decisions is usually obtained from field-cured cylinders, pullout tests, or penetration testing.
- The maturity method is another technique that can be used to estimate the strength of in-place concrete.
- This nondestructive method has not been widely used in the U.S. The adoption of ASTM standard practice for estimating concrete strength by maturity method (ASTM 1074) has increased its use.
Using Maturity Method to Predict Concrete Strength

The Strength-Maturity Relationship

- The maturity method is simply a technique for predicting concrete strength based on the temperature history of the concrete.
- Strength increases as cement hydrates. The amount of cement hydrated depends on how long the concrete has cured and at what temperature.
- Maturity is a measure of how far hydration has progressed.

Using Maturity Method to Predict Concrete Strength

The Strength-Maturity Relationship

- The most common expression used for maturity is the maturity temperature-time factor $M(t)$:

$$M(t) = \sum (T_a - T_0)\Delta t$$

- where:
  - $T_a$ = average concrete temperature during each time interval
  - $T_0$ = temperature below which cement hydration is assumed to cease.
  - $\Delta t$ = time intervals, days or hours
  - $\Sigma$ = summation of all the intervals of time multiplied by temperature.
Using Maturity Method to Predict Concrete Strength

The Strength-Maturity Relationship

- The temperature below which cement hydration is assumed to cease may depend on admixture type and dosage, cement type, and temperature range that the concrete experiences while hardening.
- A value of 32°F is recommended for concrete made with Type I cement, no admixture, and a curing temperature range of 32° to 104°F.
- For other conditions, the value can be determined experimentally.

Using Maturity Method to Predict Concrete Strength

The Strength-Maturity Relationship

- When using this equation, the maturity factor is expressed as degree-days or degree-hours.
- For example, a maturity of 400 degree-hours might be required before stripping forms.
- Samples of a given concrete mix exposed to different time and temperature conditions are assumed to attain equal strengths if they attain equal maturity values.
Using Maturity Method to Predict Concrete Strength

The Strength-Maturity Relationship

- Direct reading maturity devices are preset for an assumed temperature below which cement hydration ceases.
- The displayed values may have to be corrected if this assumed temperature differs from the true temperature below which hydration ceases. ASTM standard practice tells how to make the corrections.

Procedure to Develop Strength-Maturity Relationship

1. Prepare at least 15 cylindrical concrete specimens. The mix proportions and constituents of the concrete shall be similar to those of the concrete whose strength will be estimated using this practice.
Using Maturity Method to Predict Concrete Strength

Procedure to Develop Strength-Maturity Relationship

2. Embed temperature sensors at the centers of at least two specimens. Connect sensors to maturity instruments or to temperature-recording devices.

3. Moist cure the specimens in a water bath or in moist room.

4. Perform compression tests at ages of 1, 3, 7, 14, and 28 days. Test two cylinders at each age and compute the average strength.
Using Maturity Method to Predict Concrete Strength

- Procedure to Develop Strength-Maturity Relationship

5. At each test age record the average maturity index for the instrumented specimens.

6. On graph paper, plot the average compressive strength as a function of the average value of the maturity index. Draw the best-fit curve through the data. The resulting curve is the strength-maturity relationship to be used for estimating the strength of the concrete.
Using Maturity Method to Predict Concrete Strength

- **Procedure to Estimate Strength of In-Place Concrete**
  1. As soon as practicable after concrete placement, embed temperature sensors into the fresh concrete.
  2. Connect sensor to maturity instruments or temperature-recording devices and activate the recording devices as soon as practicable.

- **Procedure to Estimate Strength of In-Place Concrete**
  3. When the strength at the location of a sensor is to be estimated, read the value of the maturity index from the maturity instrument or evaluate the maturity index from the temperature record.
  4. Using the strength-maturity relationship developed before, read off the value of compressive strength corresponding to the measured maturity index.
Using Maturity Method to Predict Concrete Strength

Procedure to Estimate In-Place Strength

- Prior to performing critical operations, such as formwork removal or post-tensioning, supplement determination of the concrete maturity with other tests to ensure that the concrete in the structure has a potential strengths that is similar to that of the concrete used to develop the strength-maturity relationship. Appropriate techniques include:
  - In-place test that give indications of strength
  - Early-age compressive strength tests of standard cured specimens, and $f'_c$ tests on concrete as delivered.

Maturity Meter Example

- In a concrete wall construction, the contractor can remove the forms once the compressive strength of 2,500 psi is reached. Estimate the approximate length of time that the contractor has to wait before removing the forms.
- Assume the cement hydration will cease at 14°F and the temperature of the concrete at the time of opening is 67°F.
- The strength-maturity relationship for the concrete mix used in the project is given.
Maturity Meter Example

- From the strength-maturity relationship curve:
  - \( TTF \leq 1450 \text{ Deg-Hours} \)

\[
TTF = M(t) = \sum (T_a - T_0) \Delta t
\]

\[
TTF = 1450 = (T_a - T_0) \Delta t \Rightarrow (67 - 14) \Delta t = 1450 \Rightarrow \Delta t = \frac{1450}{53} = 27.4 \text{ hours}
\]

- The contractor has to wait at least 27 hours and 21 minutes after the concrete is placed before removing the forms.