
Standard Method of Test for

Estimating the Early Opening Strength of Concrete Pavements by Maturity Tests

AASHTO Designation: T 413-24¹

First Published: 2024

Technical Subcommittee: 3c, Hardened Concrete



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1. SCOPE

- 1.1. This standard provides procedures for estimating the early concrete strength for pavement opening only through the use of a maturity index. For other uses of maturity for concrete strength estimation use T 276, T 325, or both.
- 1.2. This standard requires determination of the strength–maturity relationship of the approved concrete job mix and determination of the temperature history subsequent to placement in the field.
- 1.3. The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in parentheses. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.
- 1.4. *This standard may involve hazardous materials, operations, and equipment. It does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*
- 1.5. *The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
 - M 201, Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
 - M 339M/M 339, Thermometers Used in the Testing of Construction Materials
 - R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
 - R 100M/R 100, Making and Curing Concrete Test Specimens in the Field
 - T 22M/T 22, Compressive Strength of Cylindrical Concrete Specimens

- T 97M/T 97, Flexural Strength of Concrete (Using Simple Beam with Third Point Loading)
- T 152, Air Content of Freshly Mixed Concrete by the Pressure Method
- T 276, Measuring Early-Age Compression Strength and Projecting Later-Age Strength
- T 325, Estimating the Strength of Concrete in Transportation Construction by Maturity Tests

2.2. *ANSI Standard:*

- ISA-MC96.1, Temperature Measurement Thermocouples

2.3. *ASTM Standards:*

- C125, Standard Terminology Related to Concrete and Concrete Aggregates
- C1074, Standard Practice for Estimating Concrete Strength by the Maturity Method
- E230/E230M, Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples

2.4. *International Electrotechnical Commission Standard:*

- IEC 60584-1:2013, Thermocouples - Part 1: EMF Specifications and Tolerances

3. TERMINOLOGY

3.1. *Definitions of Terms Specific to This Standard:*

- 3.1.1. *maturity*—the extent of development of concrete properties that are dependent on cement hydration and pozzolanic reactions.
- 3.1.2. *maturity function*—a mathematical expression that converts the temperature history of concrete to an index, which indicates its maturity.
- 3.1.3. *maturity index*—an index, calculated by using a maturity function, which can be used as an indicator of strength development in concrete which is represented by the area under the time-temperature curve.
- 3.1.4. *maturity method*—a technique for estimating concrete strength that is based on the assumption that samples of a given concrete mixture attain equal strengths if they attain equal values of the maturity index.
- 3.1.5. *strength-maturity relationship*—an empirical relationship between concrete strength and its maturity index, usually determined by comparing the strength of concrete specimens, made from a specific concrete mix, to their maturity index at time of strength testing.
- 3.1.6. *temperature sensor*—the device on a maturity meter or data logger that is inserted into the concrete and provides a measure of temperature
- 3.1.7. *time-temperature factor (TTF)*—a value that describes, for a given age, the sum of temperature changes from the start of testing to the given age, typically presented in units of degree-hours.
- 3.2. See ASTM C125 for further terminology.

4. SIGNIFICANCE AND USE

- 4.1. This maturity method standard can be used to estimate the early strength of concrete placed in pavements. These estimates provide guidance useful in making decisions concerning opening to

traffic. Existing agency practices that base opening time on strength can be supplemented with this standard so that field strength specimens are optional.

- 4.2. This standard differs from T 276 and T 325 in that the concrete age of interest is early and that testing is designed to address interpretation of strength data at early ages for opening to traffic determinations. This standard cannot be used to determine the 28-day strength value of concrete mixtures.
- 4.3. The most critical limitations of the procedures presented are (1) batching or placement errors that are not detected, (2) curing errors other than those that affect temperature that are not detected, and (3) the actual strength of the concrete that is not measured.

Note 1—Concrete must be cured in a condition that supports cement hydration/pozzolanic reactions.

- 4.4. *This standard provides technical personnel with a coordinated procedure for:*
- 4.4.1. Developing a strength–maturity relationship for the approved concrete job mix at the plant;
- 4.4.2. Determining the temperature history of the in-place concrete;
- 4.4.3. Determining the maturity index of the in-place concrete; and
- 4.4.4. Using the strength–maturity relationship and the maturity index to estimate the strength of the in-place concrete.

- 4.5. The hydration of cementitious materials and gain in strength of the concrete depends on both curing time and temperature. Thus, the strength of the concrete may be expressed as some function of time and temperature. This information can then be used to determine the strength of concrete without conducting physical tests. The time–temperature function commonly used is the maturity concept proposed by Nurse-Saul (ASTM C1074):

$$M = \sum [(T - T_0) \Delta t] \quad (1)$$

where:

M = maturity, °C-h (°F-h) (M is also termed the time–temperature factor (TTF));

Δt = time interval, h (or days);

T = average concrete temperature during the time interval Δt ; and

T_0 = datum temperature at which concrete ceases to gain strength with time. The T_0 value of -10°C (14°F) is most commonly used. As a result, Equation 1 becomes:

$$M = \sum [(T + 10) \Delta t] \text{ (SI units)} \quad (2)$$

$$M = \sum [(T - 14) \Delta t] \text{ (inch-pound units)} \quad (3)$$

Note 2—This standard uses the Nurse-Saul function to calculate TTF. SHRP researchers recommend that all maturity meters used for highway pavement and structures should use the Arrhenius function, because the Arrhenius function is better able to represent the effects of temperature on strength development than the Nurse-Saul function. However, since the scope of this standard is only for early age strength, there is not a significant impact on the estimated strength using either method, and thus the simpler method is selected.

5. APPARATUS

- 5.1. *Thermometers/Sensors for Laboratory and Field Use*—Thermometer sensors for test specimens are embedded in the center of the concrete beam or cylinder. Sensors for field use can be tied to