Designation: C1074 – 19$^{\varepsilon 1}$

Standard Practice for Estimating Concrete Strength by the Maturity Method[1]

This standard is issued under the fixed designation C1074; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Placement of Fig. X1.2 and Fig. X1.3 was editorially corrected in January 2021.

1. Scope*

1.1 This practice provides a procedure for estimating concrete strength by means of the maturity method. The maturity index is expressed either in terms of the temperature-time factor or in terms of the equivalent age at a specified temperature.

1.2 This practice requires establishing the strength-maturity relationship of the concrete mixture in the laboratory and recording the temperature history of the concrete for which strength is to be estimated.

1.3 The values stated in SI units are to be regarded as standard for determining the maturity index. No other units of measurement are included for this purpose. There is, however, no restriction on the system of units for expressing strength in developing the strength-maturity relationship.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C78/C78M Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50 mm] Cube Specimens)
C125 Terminology Relating to Concrete and Concrete Aggregates
C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C803/C803M Test Method for Penetration Resistance of Hardened Concrete
C873/C873M Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds
C900 Test Method for Pullout Strength of Hardened Concrete
C918/C918M Test Method for Measuring Early-Age Compressive Strength and Projecting Later-Age Strength
C1768/C1768M Practice for Accelerated Curing of Concrete Cylinders

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, refer to Terminology C125.

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.64 on Nondestructive and In-Place Testing.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *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 (**1, 2, 3**).[4]

3.2.2 *strength-maturity relationship*—an empirical relationship between concrete strength and maturity index that is obtained by testing specimens whose temperature history up to the time of test has been recorded.

4. Summary of Practice

4.1 A strength-maturity relationship is developed by laboratory tests on the concrete mixture to be used.

4.2 The temperature history of the field concrete, for which strength is to be estimated, is recorded from the time of concrete placement to the time when the strength estimation is desired.

4.3 The recorded temperature history is used to calculate the maturity index of the field concrete.

4.4 Using the calculated maturity index and the strength-maturity relationship, the strength of the field concrete is estimated.

5. Significance and Use

5.1 This practice can be used to estimate the in-place strength of concrete to allow the start of critical construction activities such as: (*1*) removal of formwork and reshoring; (*2*) post-tensioning of tendons; (*3*) termination of cold weather protection; and (*4*) opening of roadways to traffic.

5.2 This practice can be used to estimate strength of laboratory specimens cured under non-standard temperature conditions.

5.3 The major limitations of the maturity method are: (*1*) the concrete must be maintained in a condition that permits cement hydration; (*2*) the method does not take into account the effects of early-age concrete temperature on the long-term strength (see Note 6) (**3, 4**); and (*3*) the method needs to be supplemented by other indications of the potential strength of the field concrete.

5.4 The accuracy of the estimated strength depends, in part, on using the appropriate parameters (datum temperature or value of Q) for the maturity functions described in Section 6.

NOTE 1—Approximate values of the datum temperature, T_o, and the Q-value for use in Eq 1 or Eq 2, respectively, are given in Appendix X2. If maximum accuracy of strength estimation is desired, the appropriate values of T_o or Q for a specific concrete mixture may be determined using the procedures given in Appendix X1.

6. Maturity Functions

6.1 There are two alternative functions for computing the maturity index from the measured temperature history of the concrete. Refer to Note 1.

6.2 One maturity function is used to compute the *temperature-time factor* as follows:

$$M(t) = \sum (T_a - T_o)\,\Delta t \qquad (1)$$

where:

$M(t)$ = the temperature-time factor at age t, degree-days or degree-hours,
Δt = a time interval, days or hours,
T_a = average concrete temperature during time interval, Δt, °C, and
T_o = datum temperature, °C.

If during a time interval Δt the value of T_a is less than T_0, the value $(T_a - T_0)$ shall be taken equal to zero for that time interval.

6.3 The other maturity function is used to compute *equivalent age* at a specified temperature as follows (**5**):

$$t_e = \sum e^{-Q\left(\frac{1}{T_a}-\frac{1}{T_s}\right)}\,\Delta t \qquad (2)$$

where:

t_e = equivalent age at a specified temperature T_s, days or h,
Q = activation energy divided by the gas constant, K,
T_a = average temperature of concrete during time interval Δt, K,
T_s = specified temperature, K, and
Δt = time interval, days or h.

NOTE 2—Temperature used in Eq 2 is expressed using the absolute temperature scale. Temperature in kelvin (K) equals approximately temperature °C + 273 °C.

7. Apparatus

7.1 A device is required to monitor and record the concrete temperature as a function of time and compute the maturity index in accordance with Eq 1 or Eq 2.

NOTE 3—Acceptable devices include commercial maturity instruments that monitor temperature and compute and display either temperature-time factor or equivalent age. Some commercial maturity instruments use fixed values of datum temperature or activation energy in evaluating the maturity index; thus the displayed maturity index may not be indicative of the true value for the concrete mixture being used. Refer to Appendix X2 for information on correcting displayed time-temperature values for another value of datum temperature. Equivalent-age values displayed by a maturity instrument cannot be adjusted for another activation energy value.

7.2 Alternative devices include temperature sensors connected to data-loggers, or embedded digital devices that measure, record, and store temperature data as a function of time. The temperature data are used to calculate the maturity index according to Eq 1 or Eq 2.

7.3 The time interval between temperature measurements shall be ½ h or less for the first 48 h and 1 h or less thereafter. The temperature recording device shall be accurate to within ±1 °C.

8. Procedure to Develop Strength-Maturity Relationship

8.1 Prepare at least 15 cylindrical specimens according to Practice C192/C192M. The mixture proportions and constituents of the concrete shall be similar to those of the concrete whose strength will be estimated using this practice. If two batches are needed to prepare the required number of cylinders, cast an equal number of cylinders from each batch, and test one cylinder from each batch at the test ages given in 8.4.

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.

8.2 After the specimens are molded, embed temperature sensors to within ±15 mm of the centers of at least two specimens (Note 4). After inserting the sensor, tap the side of the cylinder mold with a rubber mallet or the tamping rod so that the fresh concrete comes into contact with the sensor. After tapping is completed, connect the sensors to a maturity instrument or to a temperature-recording device.

NOTE 4—A method to assist in the proper positioning of the sensor is to insert a small diameter rigid rod into the center of the freshly made cylinder. The rod will push aside any interfering aggregate particles. The rod is removed and the sensor is inserted into the cylinder.

8.3 Unless specified otherwise, moist cure the specimens in a water storage tank or in a moist room meeting the requirements of Specification C511.

NOTE 5—Curing under water will aid in reducing temperature differences among test specimens.

NOTE 6—To account for the reduction in long-term concrete strength due to high early-age curing temperatures, the test specifier could require that specimens be moist-cured at an elevated temperature close to the expected average in-place temperature during the first 24 h after placement.

8.4 Unless specified otherwise, perform compression tests at ages of 1, 3, 7, 14, and 28 days in accordance with Test Method C39/C39M. Test two specimens at each age and compute the average strength. If the range of compressive strength of the two specimens exceeds 10 % of their average strength, test another cylinder and compute the average of the three tests. If a low test result is due to an obviously defective specimen, discard the low test result.

NOTE 7—If the concrete mixture has rapid strength development, if strength estimates are to be made at low maturity index values, or if as mentioned in Note 6 specimens are cured at temperatures higher than the standard curing temperature, the first test age should be as soon as practicable after final setting. Subsequent tests should be scheduled to result in approximately equal increments of strength gain between test ages. At least five test ages should be used.

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

8.5.1 If maturity instruments are used, record the average of the displayed values.

8.5.2 If temperature recorders are used, evaluate the maturity index according to Eq 1 or Eq 2. Unless specified otherwise, use a time interval (Δt) of ½ h or less for the first 48 h of the temperature record. Longer time intervals are permitted for the relatively constant portion of the subsequent temperature record.

NOTE 8—Judgement should be used in selecting the initial time intervals to record temperature in mixtures that result in rapid changes in early-age temperature due to rapid hydration. Appendix X3 gives an example of how to evaluate the temperature-time factor or equivalent age from the recorded temperature history of the concrete.

8.6 Plot the average compressive strength as a function of the average value of the maturity index. Draw or calculate a best-fit curve to the data (Note 9). The resulting curve is the strength-maturity relationship to be used for estimating the strength of the concrete mixture cured under other temperature conditions. Fig. 1 is an example of a relationship between compressive strength and temperature-time factor, and Fig. 2 is an example of a relationship between compressive strength and equivalent age at 20 °C.

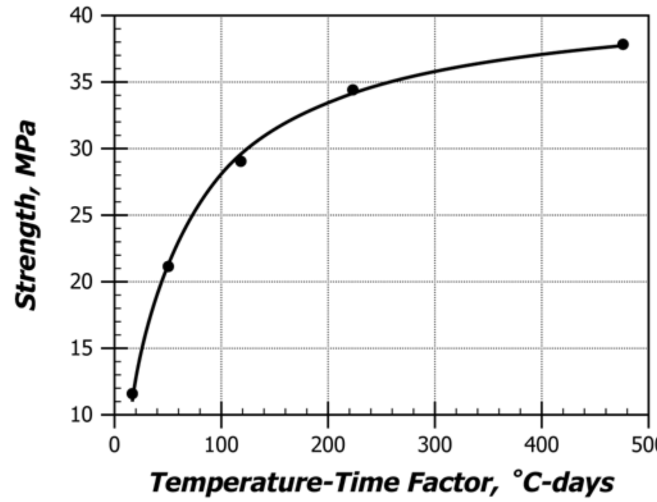

FIG. 1 Example of a Relationship Between Compressive Strength and Temperature-Time Factor

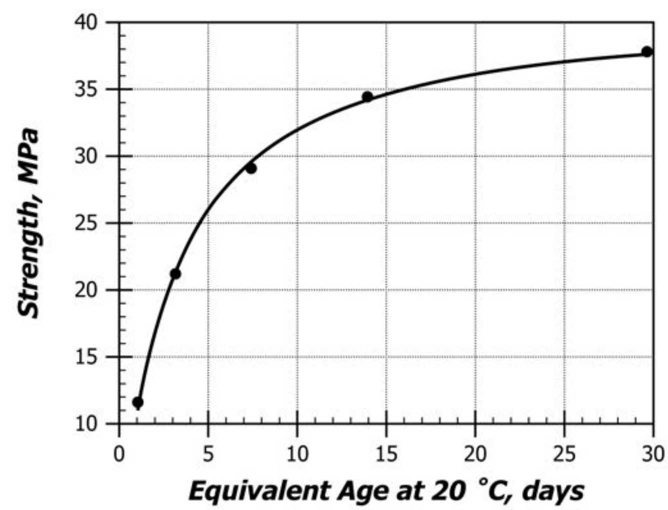

FIG. 2 Example of a Relationship Between Compressive Strength and Equivalent Age at 20 °C

NOTE 9—The strength-maturity relationship can be established by using regression analysis to determine a best-fit equation to the data. Possible equations that have been found to be suitable for this purpose may be found in Ref. (**3**). A popular equation is to express strength as a linear function of the logarithm of the maturity index (see Fig. 3).

8.7 If specified, a flexural strength versus maturity index relationship is permitted. Prepare at least 15 beam specimens in accordance with Practice C192/C192M. If two batches are needed to prepare the required number of specimens, cast an equal number of beams from each batch, and test one beam from each batch at the test ages given in 8.4. Embed temperature sensors in two specimens, one from each batch if two batches are made. Connect the sensors to maturity instruments or temperature recording devices, and moist cure the specimens in a water bath or in a moist room meeting the requirements of Specification C511 (see Note 5). Measure flexural strength in accordance with Test Method C78/C78M at time intervals of 1, 3, 7, 14 and 28 days, or as specified otherwise (see Note 7). Test two specimens at each age and compute the average strength. If the range of flexural strength