Designation: C 1074 – 98

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

This standard is issued under the fixed designation C 1074; 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.

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 the standard.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)[3]

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory[2]

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance[2]

C 511 Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes[3]

C 684 Test Method for Making, Accelerated Curing, and Testing of Concrete Compression Test Specimens[2]

C 803/C 803M Test Method for Penetration Resistance of Hardened Concrete[2]

C 873 Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds[2]

C 900 Test Method for Pullout Strength of Hardened Concrete[2]

C 918 Test Method for Measuring Early-Age Compressive Strength and Projecting Later-Age Strength[2]

C 1150 Test Method for the Break-Off Number of Concrete[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *datum temperature*—the temperature that is subtracted from the measured concrete temperature for calculating the temperature-time factor according to Eq 1.

3.1.2 *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.

3.1.3 *maturity*—the extent of the development of a property of a cementitious mixture.

3.1.3.1 *Discussion*—While the term is used usually to describe the extent of relative strength development, it can also be applied to the evolution of other properties that are dependent on the chemical reactions that occur in a cementitious mixture. At any age, maturity is dependent on the curing history.

3.1.4 *maturity function*—a mathematical expression that uses the measured temperature history of a cementitious mixture during the curing period to calculate an index that is indicative of the maturity at the end of that period. Refer to Appendix X1 for additional discussion of this term.

3.1.5 *maturity index*—an indicator of maturity that is calculated from the temperature history of the cementitious mixture by using a maturity function.

3.1.5.1 *Discussion*—The computed index is indicative of maturity provided there has been a sufficient supply of water for hydration or pozzolanic reaction of the cementitious

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[1] This practice is under the jurisdiction of ASTM Committee C-9 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] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.01.

materials during the time used in the calculation. Two widely used maturity indexes are the *temperature-time factor* and the *equivalent age*.

3.1.6 *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]

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

3.1.8 *temperature-time factor*—the maturity index computed according to Eq 1.

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 the 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 ultimate strength; and (*3*) the method needs to be supplemented by other indications of the potential strength of the concrete mixture.

5.4 The accuracy of the estimated strength depends on properly determining the maturity function for the particular concrete mixture.

6. Maturity Functions

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

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

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

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.

6.3 The other maturity function is used to compute *equivalent age* at a specified temperature as follows **(4)**:

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

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.

6.4 Approximate values of the datum temperature, T_o, and the activation energy divided by the gas constant, Q, are given in Appendix X1. Where maximum accuracy of strength estimation is desired, the appropriate values of T_o or Q for a specific concrete mixture can be determined according to the procedures given in Annex A1.

7. Apparatus

7.1 A device is required to monitor and record the concrete temperature as a function of time. Acceptable devices include thermocouples or thermistors connected to strip-chart recorders or digital data-loggers. The recording time interval 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.

7.2 Alternative devices include commercial maturity instruments, that automatically compute and display either temperature-time factor or equivalent age.

NOTE 1—Commercial maturity instruments use specific 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 X1 for information on correcting the displayed values.

8. Procedure to Develop Strength-Maturity Relationship

8.1 Prepare at least 15 cylindrical specimens according to Practice C 192/C 192M . The mixture proportions and constituents of the concrete shall be similar to those of the concrete whose strength will be estimated using this practice.

8.2 Embed temperature sensors to within ±15 mm of the centers of at least two specimens. Connect the sensors to maturity instruments or to temperature-recording devices such as data-loggers or strip-chart recorders.

NOTE 2—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. The side of the cylinder mold should be tapped with a rubber mallet or the tamping rod to ensure that the concrete comes into contact with the sensor.

8.3 Moist cure the specimens in a water bath or in a moist room meeting the requirements of Specification C 511.

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

8.4 Perform compression tests at ages of 1, 3, 7, 14, and 28 days in accordance with Test Method C 39. 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.

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 according to Eq 1 or Eq 2. Use a time interval (Δt) of ½ h or less for the first 48 h of the temperature record. Longer time intervals may be used for the relatively constant portion of the subsequent temperature record.

NOTE 3—Appendix X2 gives an example of how to evaluate the temperature-time factor or equivalent age from the recorded temperature history of the concrete.

8.6 On graph paper, plot the average compressive strength as a function of the average value of the maturity index. Draw a best-fit curve through the data. 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.

NOTE 4—The strength-maturity relationship can also 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)**.

9. Procedure to Estimate In-Place Strength

9.1 As soon as is practicable after concrete placement, embed temperature sensors into the fresh concrete. When using this practice to allow critical construction operations to begin, install sensors at locations in the structure that are critical in terms of exposure conditions and structural requirements.

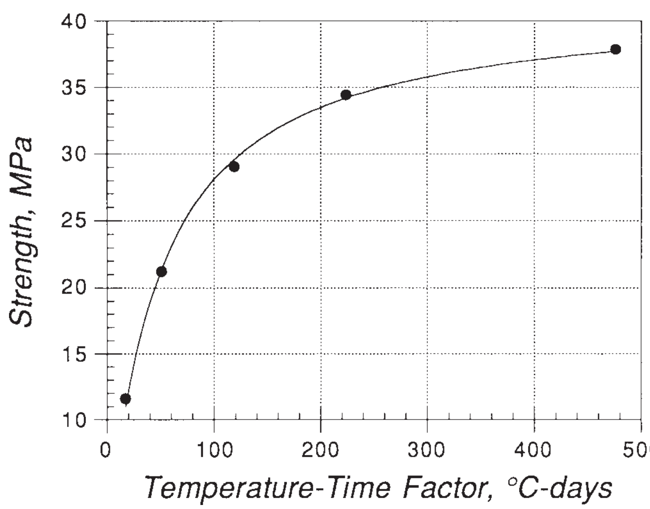

FIG. 1 Example of a Relationship Between Compressive Strength and Temperature-Time Factor

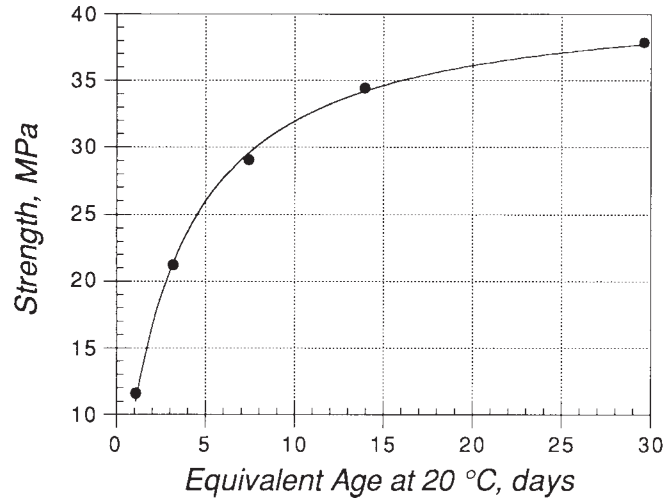

FIG. 2 Example of a Relationship Between Compressive Strength and Equivalent Age at 20°C

NOTE 5—In building construction, exposed portions of slabs and slab-column connections are typically critical locations. The advice of the Engineer should be sought for the critical locations in the particular structure under construction.

9.2 Connect the sensors to maturity instruments or temperature-recording devices and activate the recording devices as soon as is practicable.

9.3 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.

9.4 Using the strength-maturity relationship developed in Section 8, read off the value of compressive strength corresponding to the measured maturity index.

9.5 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 strength that is similar to that of the concrete used to develop the strength-maturity relationship. Appropriate techniques include:

9.5.1 In-place tests that give indications of strength, such as Test Method C 803/C 803M, Test Method C 873, Test Method C 900, or Test Method C 1150.

9.5.2 Early-age compressive strength tests in accordance with Test Method C 918 of standard-cured specimens molded from samples of the concrete as-delivered, or

9.5.3 Compressive strength tests on specimens molded from samples of the concrete as-delivered and subjected to accelerated curing in accordance with Test Method C 684.

10. Precision and Bias

10.1 This practice is used to estimate the in-place strength of concrete based on the measured thermal history at a point in the structure and a previously established strength-maturity relationship. The accuracy of the estimated strength is dependent on several factors, such as the appropriateness of the maturity function for the specific mixture, the early-age temperature history, and the actual mixture proportions. For this reason, it is not possible to write statements about the precision and bias of the estimated strength.

11. Keywords

11.1 maturity method; nondestructive testing; strength; temperature

ANNEX

(Mandatory Information)

A1. DETERMINATION OF DATUM TEMPERATURE OR ACTIVATION ENERGY

A1.1 Procedure

A1.1.1 The testing required to experimentally determine the datum temperature or the activation energy can be performed using mortar specimens, and the results are applicable to the concrete under investigation **(5, 6, 7)**. The basic approach is to establish the compressive strength versus age relationships for mortar specimens cured in water baths maintained at three different temperatures. Two baths should be at the maximum and minimum concrete temperatures expected for the in-place concrete during the period when strengths are to be estimated. The third bath temperature should be midway between the extremes. Depending on the data analysis procedure that is used, the final setting times of the mortar at the three temperatures may also have to be measured.

A1.1.2 Proportion a mortar mixture having a fine aggregate-to-cement ratio (by mass) that is the same as the coarse aggregate-to-cement ratio of the concrete mixture under investigation **(6)**. The paste shall have the same water-to-cementitious materials ratio and the same amounts of admixtures that will be used in the concrete.

A1.1.3 If the strength data will be analyzed using the reciprocal plotting procedure in A1.1.7, final setting times must be measured. Prepare three mortar specimens using containers specified in Test Method C 403/C 403M. Carefully submerge each specimen into its corresponding temperature bath. Determine the time of final setting for each temperature in accordance with Test Method C 403/C 403M. The specimens are removed from the water baths and excess water is removed prior to making penetration measurements. If the data will be analyzed using the regression procedures in A1.1.8, it is not necessary to measure setting times.

A1.1.4 Prepare three sets of 50-mm mortar cubes, with 18 cubes per set. Mold the cubes in accordance with Test Method C 109/C 109M and carefully submerge each set into one of the temperature baths. For each set, remove the molds and return the specimens to their respective baths approximately 1 h before the first series of compression tests.

A1.1.5 For each set of cubes, determine the compressive strength of three cubes in accordance with Test Method C 109/C 109M at an age that is approximately twice the time of final setting. If final setting times were not measured, perform the first test when the compressive strength is approximately 4 MPa. Perform subsequent tests on three cubes from each set at ages that are approximately twice the age of the previous tests. For example, if the time of the first test was 12 h, successive compressive strength tests would be performed at 1, 2, 4, 8, 16, and 32 days.

A1.1.6 The strength versus age data obtained at the three curing temperatures are analyzed to determine the relationship between the rate constant for strength development (*K*-value) and the curing temperature. Different procedures can be used depending on the available computational tools. If the user has the capability to perform only linear regression analysis, use the procedure in A1.1.7 or A1.1.8.2. If the user has a computer program that can perform regression analyses with a general function, use the procedure in A1.1.8.1.

A1.1.7 To use this procedure, the final setting times at the three temperatures must be known. Prepare a graph with the reciprocal of strength as the *y*-axis and the reciprocal of age as the *x*-axis. For each curing temperature, plot the reciprocal of the average cube strength along the *y*-axis and the reciprocal of the age beyond the time of final setting along the *x*-axis. An example of such a plot is shown in Fig. A1.1. Determine the slope and the intercept of the best-fitting straight line through the data for each curing temperature. For each straight-line, divide the value of the intercept by the value of the slope. These quotients are the *K*-values that are used to calculate the datum temperature or the activation energy.

A1.1.8 As an alternative to the procedure in A1.1.7, the *K*-values can be estimated by either of the following methods. In these cases, the final setting times do not have to be measured.

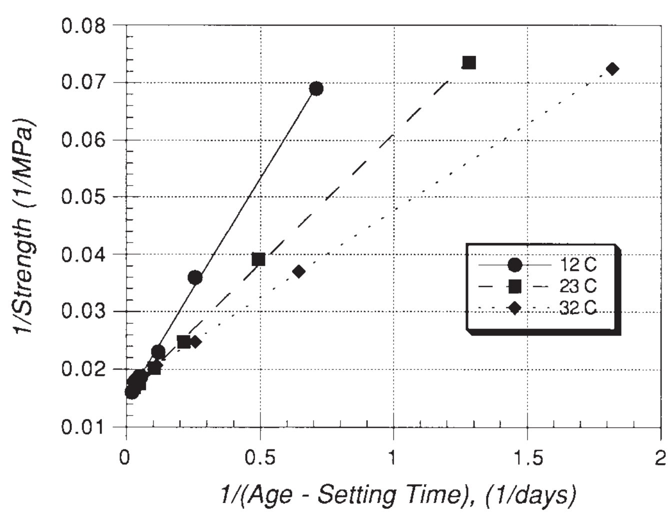

FIG. A1.1 Reciprocal of Strength Versus Reciprocal of Age Beyond Time of Final Setting

A1.1.8.1 If the user has access to a computer program that will permit the fitting of a general equation to a set of data, determine the *K*-values by fitting the following equation to the strength-age data for each curing temperature:

$$S = S_u \frac{K(t - t_o)}{1 + K(t - t_o)} \quad \text{(A1.1)}$$

where:

S = average cube compressive strength at age t,
t = test age,
S_u = limiting strength,
t_o = age when strength development is assumed to begin, and
K = the rate constant.

The computer program will calculate the best-fit values of S_u, t_o, and K.

A1.1.8.2 The *K*-values can also be estimated by the following method **(5, 8)**.

(1) Using the strength-age data for the last four test ages, plot the reciprocal of strength (*y*-axis) versus the reciprocal of age (*x*-axis). Determine the *y*-axis intercept. The inverse of the intercept is the limiting strength, S_u. Repeat this procedure for each curing temperature.

(2) For each curing temperature, use the strength-age data at the four earliest test ages and the value of S_u to compute the values of *A* for each strength, where *A* is given by the following equation:

$$A = \frac{S}{(S_u - S)} \quad \text{(A1.2)}$$

(3) For each curing temperature, plot the values of *A* versus age. Determine the slopes of the best-fit straight lines for each curing temperature. These slopes are the *K*-values.

A1.2 Determination of Datum Temperature

A1.2.1 Plot the *K*-values as a function of the water bath temperatures (Fig. A1.2). Determine the best-fitting straight line through the three points and determine the intercept of the line with the temperature axis. This intercept is the datum temperature, T_o, that is to be used in computing the temperature-time factor according to Eq 1.

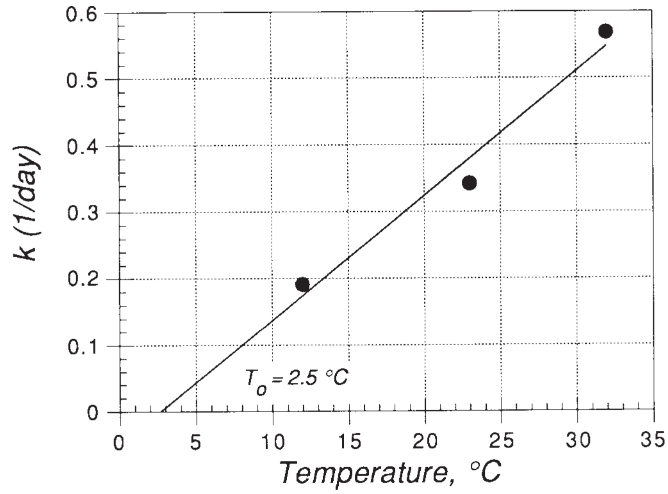

FIG. A1.2 Example of Plot of *K*-Values Versus Curing Temperature for Determining the Datum Temperature

A1.3 Determination of Activation Energy

A1.3.1 Calculate the natural logarithms of the *K*-values, and determine the absolute temperatures (in kelvin) of the water baths (kelvin = Celsius + 273).

A1.3.2 Plot the natural logarithm of the *K*-values as a function of the reciprocal absolute temperature (Fig. A1.3). Determine the best-fitting straight line through the three points. The negative of the slope of the line is the value of the activation energy divided by the gas constant, *Q*, that is to be used in computing equivalent age according to Eq 2.

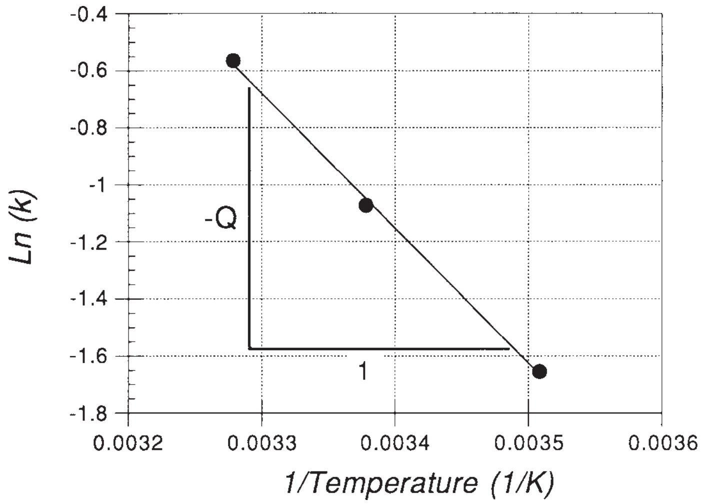

FIG. A1.3 Example of Plot of the Natural Logarithm of *K*-Values Versus the Inverse Absolute Temperature for Determining the Value of *Q* used in Calculating Equivalent Age

APPENDIXES

(Nonmandatory Information)

X1. MATURITY FUNCTIONS

X1.1 General

X1.1.1 A maturity function is a mathematical expression to account for the combined effects of time and temperature on the strength development of a cementitious mixture. The key feature of a maturity function is the representation of how temperature affects the rate of strength development. There are two widely-used approaches; one assumes that the rate of strength development is a linear function of temperature, and the other assumes that rate of strength development obeys the exponential Arrhenius equation **(3, 4, 5)**.

X1.2 Temperature-Time Factor

X1.2.1 The assumption that the rate of strength development is is a linear function of temperature leads to the maturity function given in Eq 1, that is used to compute the temperature-time factor. To compute the temperature-time factor, it is necessary to know the appropriate value of the datum temperature for the specific materials and conditions. The datum temperature may depend on the type of cement, on the type and the dosage of admixtures or other additives that affect hydration rate, and on the temperature range that the concrete will experience while hardening **(5, 7)**. For Type I cement without admixtures and a curing temperature range from 0 to 40°C, the recommended datum temperature is 0°C **(5)**. For other conditions and when maximum accuracy of strength estimation is desired, the appropriate datum temperature can be determined experimentally according to the procedures in Annex A1.

X1.2.2 Some types of maturity instruments that compute temperature-time factor may not employ the appropriate datum temperature, and therefore may not indicate the true value of the factor. The value of the temperature-time factor displayed by the instrument can be corrected for the datum temperature as follows:

$$M_c = M_d - (T_o - T_d)\, t \quad \text{(X1.1)}$$

where:

- M_c = the corrected temperature-time factor, degree-days or degree-hours,
- M_d = the temperature-time factor displayed by the instrument, degree-days or degree-hours,
- T_o = the appropriate datum temperature for the concrete, °C,
- T_d = the datum temperature incorporated into the instrument, °C, and
- t = the elapsed time from when the instrument was turned on to when a reading was taken, days or h.

X1.3 Equivalent Age

X1.3.1 The assumption that the rate of strength development obeys the Arrhenius equation leads to the maturity function given in Eq 2, that is used to compute equivalent age at a specified temperature. Note that in using Eq 2, the temperature must be in kelvin (kelvin = Celsius + 273). To compute equivalent age it is necessary to know the activation energy for the specific materials and conditions. It has been shown that the activation energy depends on the type of cement, the type and the dosage of admixtures that affect the rate of strength development, and the water-to-cementitious materials ratio **(7)**. In general, for Type I cement without admixtures or additions, values of activation energy in the range of 40 000 to 45 000 J/mol have been reported **(6)**. Thus an approximate value of Q, the activation energy divided by the gas constant for use in Eq 2, is 5000 K. (The value of the gas constant is 8.31 J/(K-mol)). For other conditions and when maximum accuracy of strength estimation is desired, the appropriate value for Q can be determined experimentally according to the procedures in Annex A1.

X1.3.2 The calculation of equivalent age also requires a specified temperature, T_s. Traditionally, a value of 20°C has been used **(4)**, but any other convenient temperature, such as 23°C, is permissible provided that it is reported along with the value of the equivalent age.

X1.3.3 Maturity instruments that compute equivalent age according to Eq 2, are based on specific values of activation energy. The displayed readings cannot be corrected for the appropriate activation energy value of the concrete being used. The user should recognize this limitation when the in-place concrete has an activation energy that is widely different from that incorporated into the instrument. Refer to **(3)** for information on the effect of the activation energy on the computed value of equivalent age.

X2. EXAMPLE MATURITY CALCULATIONS

X2.1 Temperature Record

X2.1.1 Fig. X2.1 shows a hypothetical temperature history for concrete that will be used to illustrate the calculations of temperature-time factor and equivalent age. The temperature values at half-hour intervals are tabulated in column 2 of Table X2.1.

X2.2 Calculation of Temperature-time Factor

X2.2.1 The value of the datum temperature, T_o, is required to compute the temperature-time factor according to Eq 1. For this example, a value of 2.5°C is assumed as indicated in Fig. A1.2.

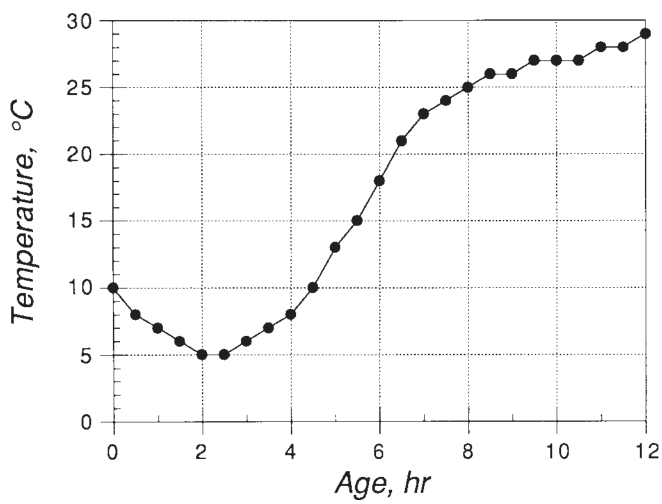

FIG. X2.1 Hypothetical Temperature History used to Illustrate Computations of Temperature-Time Factor and Equivalent Age

X2.2.2 The average temperature during each half-hour interval is computed and the results are given in column 4 of Table X2.1. The datum temperature is subtracted from the average temperature, and the difference is multiplied by the age interval, which in this example is 0.5 h. The product gives the incremental value of the temperature-time factor for that age interval. The incremental values are shown in column 5 of Table X2.1.

X2.2.3 The summation of the incremental temperature-time factors gives the cumulative temperature-time factor at each age. For example, at an age of 12 h the temperature-time factor is 175° C-hours.

X2.3 Calculation of Equivalent Age

X2.3.1 The value of Q
and the value of the specified temperature, T_s, are required to compute the equivalent age according to Eq 2. For this example, the value of Q is assumed to be 4700°K, and the specified temperature is assumed to be 20°C (293 K).

X2.3.2 Using the average temperature, in kelvin, during each age interval, the values of the exponential function in Eq 2 are calculated. These values are given in column 7 of Table X2.1 under the heading Age Factor. The product of each of the age factors and the age interval (0.5 h) gives the incremental equivalent ages at 20°C; the incremental equivalent ages are shown in column 8 of Table X2.1.

X2.3.3 The summation of the incremental equivalent ages gives the cumulative equivalent age at 20°C (column 9 of Table X2.1). For example, at an age of 12 h the equivalent age at 20°C is 11.3 h.

TABLE X2.1 Example Maturity Calculations

(1) Age, h	(2) Temperature, °C	(3) Age Increment, h	(4) Average Temperature,° C	(5) Temp-Time Factor, Increment °C-h	(6) Temp-Time Factor, Cumulative °C-h	(7) Age Factor	(8) Eq. Age at 20°C, Increment h	(9) Eq. Age at 20°C, Cumulative h
0	10	...	...	...	0	...	...	0.0
0.5	8	0.5	9	3.3	3	0.53	0.27	0.3
1.0	7	0.5	7.5	2.5	6	0.49	0.24	0.5
1.5	6	0.5	6.5	2.0	8	0.46	0.23	0.7
2.0	5	0.5	5.5	1.5	9	0.43	0.22	1.0
2.5	5	0.5	5	1.3	11	0.42	0.21	1.2
3.0	6	0.5	5.5	1.5	12	0.43	0.22	1.4
3.5	7	0.5	6.5	2.0	14	0.46	0.23	1.6
4.0	8	0.5	7.5	2.5	17	0.49	0.24	1.9
4.5	10	0.5	9	3.3	20	0.53	0.27	2.1
5.0	13	0.5	11.5	4.5	24	0.62	0.31	2.4
5.5	15	0.5	14	5.8	30	0.72	0.36	2.8
6.0	18	0.5	16.5	7.0	37	0.82	0.41	3.2
6.5	21	0.5	19.5	8.5	46	0.97	0.49	3.7
7.0	23	0.5	22	9.8	55	1.11	0.56	4.3
7.5	24	0.5	23.5	10.5	66	1.21	0.60	4.9
8.0	25	0.5	24.5	11.0	77	1.27	0.64	5.5
8.5	26	0.5	25.5	11.5	88	1.34	0.67	6.2
9.0	26	0.5	26	11.8	100	1.38	0.69	6.9
9.5	27	0.5	26.5	12.0	112	1.42	0.71	7.6
10.0	27	0.5	27	12.3	124	1.45	0.73	8.3
10.5	27	0.5	27	12.3	137	1.45	0.73	9.0
11.0	28	0.5	27.5	12.5	149	1.49	0.75	9.8
11.5	28	0.5	28	12.8	162	1.53	0.77	10.5
12.0	29	0.5	28.5	13.0	175	1.57	0.79	11.3

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