

ACI 305.1-14

An ACI Standard

Specification for Hot Weather Concreting

Reported by ACI Committee 305



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Specification for Hot Weather Concreting

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An ACI Standard

Reported by ACI Committee 305

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This reference specification provides requirements for hot weather concreting that the architect/engineer can apply to any construction project involving hot weather concreting by citing it in the project specification. Checklists are provided to assist the architect/engineer in supplementing the provisions of this reference specification as needed by designating or specifying customized project requirements.

This specification includes hot weather requirements for production preparations, delivery, placement, finishing, bleed-water evaporation, curing, and concrete protection. Provisions governing a preplacement conference, concrete mixture proportions, maximum allowable concrete temperature, rate of surface evaporation measurements, evaporation control measures, and acceptance of a concrete mixture from past field experience or preconstruction testing are also included.

The materials, processes, quality control measures, and inspections described in this document should be tested, monitored, or performed as applicable only by individuals holding the appropriate ACI Certifications or equivalent.

Keywords: bleeding; curing; evaporation; finishing; mixture proportioning; plastic shrinkage cracking; protection period; trial batch.

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Reference to this document shall not be made in contract documents. If items found in this document are desired by the Architect/Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.

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(nonmandatory portion follows)

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1.1.1 This specification covers requirements for hot weather concrete construction.

1.1.2 This specification supplements the contract documents and provides requirements for the Contractor.

1.1.3 This specification governs for construction within its scope, but the contract documents govern if there is a conflict.

1.1.4 This specification governs if there is a conflict with its reference standards.

1.1.5 The Contractor is permitted to submit written alternatives to a provision in the specification.

1.1.6 Do not use this specification in conjunction with ACI 301, 350.5, 522.1, or ACI 530.1 unless contract document states that this specification governs for work covered by 1.1.1.

1.1.7 Ignore provisions of the specification that are not applicable to the work.

1.1.8 Values to this specification are stated in inch-pound units. A companion specification in SI units is also available.

1.1.9 The Notes to Specifier are not part of this specification.

1.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, “ACI Concrete Terminology,” <http://concrete.org/Tools/ConcreteTerminology.aspx>. Definitions here compliment that resource.

hot weather—one or a combination of the following conditions that tends to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise causing detrimental results: high ambient temperature, high concrete temperature, low relative humidity, and high wind speed.

1.3—Reference Standards

Standards of ACI and ASTM cited in this specification are listed by name and designation, including year.

1.3.1 American Concrete Institute

ACI 301-10—Specifications for Structural Concrete

ACI 308.1-11—Specification for Curing Concrete

ACI 350.5-12—Specification for Environmental Concrete Structures

ACI 522.1-08—Specification for Pervious Concrete Pavement

ACI 530.1-11—Building Code Requirements and Specification for Masonry Structures

1.3.2 ASTM International

ASTM C31/C31M-12—Standard Practice for Making and Curing Concrete Test Specimens in the Field

ASTM C39/C39M-14—Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

ASTM C78/C78M-10—Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

ASTM C94/C94M-14—Standard Specification for Ready-Mixed Concrete

ASTM C138/C138M-13—Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

ASTM C143/C143M-12—Standard Test Method for Slump of Hydraulic-Cement Concrete

ASTM C171-07—Standard Specification for Sheet Materials for Curing Concrete

ASTM C173/C173M-14—Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

ASTM C192/C192M-13—Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory

ASTM C231/C231M-10—Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

ASTM C293/C293M-10—Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)

ASTM C1064/C1064M-12—Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

1.4—Submittals**1.4.1 Submittal of concrete proportions**

1.4.1.1 Concrete mixture proportions shall be submitted to the architect/engineer for review.

1.4.1.2 Submittal shall include the constituent materials and proportions of the proposed concrete mixture, in addition to test results obtained from past field experience or preconstruction testing. Test results shall meet all the applicable requirements in the project specification.

1.4.2 Before the preplacement conference, submit procedures for production, placement, finishing, curing, and protection of concrete during hot weather conditions to the architect/engineer for review and comment. Submittals shall indicate which methods will be used for pre- and post-cooling of the concrete, and the order in which they will be initiated when multiple methods are proposed.

1.4.3 Preplacement conference

1.4.3.1 At least 15 days prior to beginning concrete construction, hold a preplacement conference to review hot

weather concreting procedures and the anticipated effect on the proposed mixture proportions.

1.4.3.2 Send a preplacement conference agenda, including hot weather concreting procedures, to representatives of concerned parties not less than 10 days before the scheduled date of the preplacement conference.

1.4.3.3 Preplacement conference attendance shall include, but is not limited to, representatives of the contractor, concrete subcontractor, testing agency, pumping contractor, engineer of record, and ready-mixed concrete producer.

1.4.3.4 Distribute minutes of preplacement conference to representatives of relevant parties within 5 days after the preplacement conference.

1.5—Quality assurance, quality control, and acceptance of work

1.5.1 Documents required on site—Copies of **ACI 305R**, **ACI 305.1**, and **ACI 308.1** shall be available at the project site during concrete construction.

SECTION 2—PRODUCTS

2.1—General

2.1.1 Store all materials and equipment required for curing and protection at or near the project site before hot weather concreting begins.

SECTION 3—EXECUTION

3.1—General

3.1.1 Prepare surfaces against which concrete will be placed to minimize the absorption of water from the fresh concrete. Do not place concrete against surfaces that will introduce free water to the fresh concrete.

3.1.2 Prepare all materials required for evaporation control measures and have them available on site so that accepted measures are performed as necessary.

3.1.3 Accepted evaporation control measures shall provide adequate protection of, and prevent rapid evaporation from, the fresh concrete surface. Control measures shall remain in place while the concrete and air temperatures, relative humidity of the air, and the wind speed have the capacity to evaporate free water from the fresh concrete surface at a rate that is equal to or greater than 0.2 lb/ft²/h, unless otherwise accepted. Determine the evaporation rate of surface water by use of the Uno Equation (Eq. (3.1.3)):

$$E = (T_c^{2.5} - r \cdot T_a^{2.5})(1 + 0.4V) \times 10^{-6} \quad (3.1.3)$$

where

E = mass of water evaporated in lb per ft² of water-covered surface per hour;

T_c = temperature of the evaporating surface taken as the concrete temperature in °F;

r = relative humidity of air surrounding the concrete; expressed as percentage of relative humidity of air divided by 100 (air relative humidity is measured at a level approxi-

mately 4 to 6 ft above the evaporating surface on the windward side and shielded from the sun's rays);

T_a = temperature of the air surrounding the concrete in °F (air temperature is measured at a level approximately 4 to 6 ft above the evaporating surface on the windward side and shielded from the sun's rays); and

V = average wind speed in mph, measured at 20 in. above the evaporating surface.

3.1.3.1 Monitor site conditions, including air temperature, relative humidity, and wind speed, to assess the need for evaporation control measures beginning no later than 1 hour before beginning concrete placing operations. Continue to monitor site conditions at intervals of 30 minutes or less until accepted curing procedures have been applied.

3.1.3.2 For calculating the rate of evaporation of surface water, use equipment or instruments that are certified by the manufacturer as accurate to within 2°F, 5 percent relative humidity, and 1 mph wind speed. Use equipment in accordance with the product manufacturer recommendations.

3.2—Maximum temperature of fresh concrete at time of discharge

3.2.1 The maximum temperature of fresh concrete at time of discharge shall be 95°F.

3.2.2 Measure the fresh concrete temperature at the point and time of discharge in accordance with **ASTM C1064/C1064M**. Frequency of temperature determination shall be in accordance with **ASTM C94/C94M**.

3.2.3 Computer modeling to predict fresh concrete temperature shall not be used as a substitute for preconstruction testing. Computer modeling is permitted only to assist in determining additional control measures for protecting the concrete surface from highly evaporative ambient conditions.

3.3—Qualification of concrete mixture

3.3.1 Qualification of a concrete mixture with a maximum concrete temperature that exceeds 95°F shall be supported by either past field experience or by preconstruction testing.

3.3.2 Acceptance of a proposed maximum fresh concrete temperature that exceeds 95°F, supported by past field experience, shall be based on similar production conditions, materials, constituent proportions and temperatures, and concrete delivery time.

3.3.3 Acceptance of a proposed maximum fresh concrete temperature that exceeds 95°F, supported by preconstruction testing, shall require materials similar to those proposed for use and tested under conditions that simulate the anticipated production and concrete delivery conditions of the project.

3.3.4 Laboratory trial batch—Batch the laboratory concrete trial mixture within 3°F of the proposed maximum fresh concrete temperature and mix in accordance with **ASTM C192/C192M**, except as modified herein. If necessary, move the laboratory mixer into an enclosed, heated, and ventilated space; use heated mixing water; or both, to achieve and maintain the proposed maximum concrete temperature. For drum-type mixers, the concrete mixture shall remain in the mixer for 47 minutes after completing the

3-minute initial mixing period, unless specified otherwise. During the 50-minute period, cover the mixer opening with a nonabsorbent material such as plastic to prevent moisture loss, and rotate the mixer continuously at an agitation speed of 6 to 8 rpm. For laboratory mixers without speed adjustments, simulate agitation by rotating the mixer continuously at a drum angle between 45 and 75 degrees from horizontal. At the end of 50 minutes, mix the concrete mixture at mixing speed as designated by the manufacturer for 2 minutes.

For pan-type mixers, the concrete mixture shall remain in the mixer for 41 minutes after completion of the initial 3-minute mixing period. During the 44-minute period, the mixer shall cycle through periods of rest for 5 minutes, and then mixing for 1 minute. During the rest period, cover the mixer opening with a nonabsorbent material, such as plastic, to prevent moisture loss. At the end of 44 minutes, mix the concrete mixture at full mixing speed as designated by the manufacturer for 2 minutes.

During mixing and agitation periods for both drum-type and pan-type mixers, the addition of water, chemical admixture, or both, to adjust slump is permitted, provided that the specified concrete mixture *w/cm* is not exceeded. Check the slump of the concrete mixture during the middle third of the 50- or 44-minute laboratory trial mixing period and adjust as needed.

3.3.4.1 The proposed concrete mixture shall meet the accepted slump range at the end of the laboratory mixing period and meet the required strength at the specified test age.

3.3.5 Field trial batch—Batch the field concrete trial mixture within 3°F of the proposed maximum concrete temperature in a truck-mixer with a minimum batch size of 4 yd³. The concrete mixture shall be held in the mixer for 90 minutes, unless otherwise accepted. During the entire 90-minute period, agitate the mixer at 1 to 6 rpm. At the end of 90 minutes, mix the concrete mixture at mixing speed for 2 minutes. During mixing and agitation periods, the addition of water, chemical admixture, or both, to adjust slump is permitted, provided that the specified concrete mixture *w/cm* is not exceeded. Check the slump of the concrete mixture during the middle third of the 90-minute mixing period and adjust as needed.

3.3.5.1 The proposed concrete mixture shall be within the specified slump range at the end of the 90-minute field mixing period and meet the required strength at the specified test age in accordance with standard curing practices in **ASTM C31/C31M**.

3.3.6 Testing requirements—The following test results shall be obtained in accordance with the listed ASTM standards:

- a) Slump—**ASTM C143/C143M**
- b) Air content—**ASTM C231/C231M** or **C173/C173M**
- c) Concrete temperature—**ASTM C1064/C1064M**
- d) Density (unit weight)—**ASTM C138/C138M**
- e) Compressive strength—**ASTM C39/C39M**
- f) Flexural strength (if specified)—**ASTM C78/C78M** or **C293/C293M**

3.3.6.1 Slump, air content, and concrete and air temperature measurements shall be performed after initial mixing, intermediately as needed or as desired, and at the conclusion of the mixing period, along with density measurement and fabrication of strength test specimens.

3.3.7 Acceptance of maximum concrete temperature—The request for a maximum concrete temperature that exceeds 95°F shall be submitted to the architect/engineer prior to concrete placement.

3.4—Concrete production and delivery

3.4.1 Concrete shall be produced at a temperature such that its maximum temperature at discharge will not exceed the accepted maximum concrete temperature. Acceptable production methods to reduce the concrete temperature include, but are not limited to, shading aggregate stockpiles, sprinkling water on coarse aggregate stockpiles, using chilled water for concrete production, substituting chipped or shaved iced for portions of the mixing water, and cooling concrete using liquid nitrogen. Substitution of other cooling methods will be considered by the architect/engineer upon written request before concrete placement and accompanied by supporting data.

3.4.2 Unless otherwise specified, concrete shall be delivered in accordance with **ASTM C94/C94M**.

3.5—Concrete placement and finishing

3.5.1 Concrete placement and finishing operations shall proceed as quickly as conditions allow.

3.6—Concrete bleed-water evaporation

3.6.1 Control concrete surface bleed-water evaporation by using materials and methods in accordance with **ACI 308.1**.

3.7—Concrete curing

3.7.1 Cure concrete in accordance with **ACI 308.1**.

3.7.2 Curing concrete test specimens—Comply with standard curing requirements in **ASTM C31/C31M** if test specimens are to be used for acceptance testing.

3.8—Concrete protection

3.8.1 Protection period—Protect the concrete surface from decreases in concrete temperature greater than 40°F during the 24-hour period following placement, unless otherwise accepted.

3.8.2 Protection materials—Acceptable materials for preventing excessive temperature decrease are insulating blankets; batt insulation with moisture-proof covering; and layers of dry porous material such as straw, hay, or multiple layers of impervious paper meeting **ASTM C171**. Application of these protective measures shall take into consideration that additional insulation to protect concrete during the first 24 hours might also result in increased concrete temperature. Timing the removal of these protective measures is critical and shall be implemented in such a way as to avoid thermal shrinkage cracks caused by a rapid decrease in concrete surface temperature upon protection removal.

Nonmandatory portion follows

NOTES TO SPECIFIER

General notes

G1. ACI Specification 305.1 is to be used by reference or incorporation in its entirety in the Project Specification. Do not copy individual parts, sections, articles, or paragraphs into the project specification because taking them out of context may change their meaning.

G2. If sections or parts of ACI Specification 305.1 are copied into the Project Specification or any other document, do not refer to them as an ACI Specification, because the specification has been altered.

G3. A statement such as the following will serve to make ACI Specification 305.1 a part of the project specification:

“Work on (Project Title) shall conform to all requirements of ACI Specification 305.1, ‘Specification for Hot Weather Concreting,’ published by the American Concrete Institute, Farmington Hills, MI, except as modified by these contract documents.”

G4. Each technical Section of ACI Specification 305.1 is written in the three-part Section format of the Construction Specifications Institute, as adapted for ACI requirements. The language is imperative and terse.

G5. If ACI Specification 305.1 is used with another ACI specification that contains overlapping provisions, identify which requirements are in conflict and state in the contract documents which requirements control.

Foreword to checklists

F1. This Foreword is included for explanatory purposes only; it is not part of ACI Specification 305.1.

F2. ACI Specification 305.1 may be referenced by the specifier in the project specification for any building project, together with supplementary requirements for the specific project. Responsibilities for project participants must be defined in the project specification. ACI Specification 305.1 cannot and does not address responsibilities for any project participant other than the contractor.

F3. Checklists do not form a part of ACI Specification 305.1. Checklists assist the specifier in selecting and specifying project requirements in the project specification.

F4. The Optional Requirements Checklist identifies specifier choices and alternatives. The checklist identifies the sections, parts, and articles of the ACI Specification 305.1 and the action required or available to the specifier. The specifier should review items in the checklist and make adjustments to the needs of a particular project by including those selected alternatives as mandatory requirements in the project specification.

F5. *Recommended references*—Documents and publications that are referenced in the checklists of ACI Specification 305.1 are listed below. These references provide guidance to the specifier and are not considered to be part of ACI Specification 305.1.

American Concrete Institute

ACI 305R-10—Guide to Hot Weather Concreting

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/Article	Notes to specifier
General requirements	
1.3	Review applicability of the referenced standards and make exceptions if required.
3.1.3	The default value of 0.2 lb/ft ² /h may be revised by the architect/engineer as applicable. For example, an evaporation rate less than 0.2 lb/ft ² /h may be accepted for concrete mixtures containing conventional or ultra-fine pozzolan or other supplementary cementitious materials. Further guidance is available in ACI 305R.
3.2.1	Generally, the durability of hot-weather concrete will not differ significantly from similar concrete placed at normal temperatures if concrete strengths are satisfactory and curing and protection practices are sufficient to avoid undesirable drying of surfaces. A maximum concrete temperature, at the time of discharge, is often referenced to evaluate strength, durability, plastic-shrinkage cracking, thermal cracking, and drying shrinkage. In certain cases, a change in the maximum allowable concrete temperature may be required. In those cases, the architect/engineer may accept a higher allowable maximum concrete temperature. If so, the higher accepted temperature shall be based on past field experience or preconstruction testing using a concrete mixture known to have been successfully used at the accepted higher concrete temperature.
3.3.4	ACI 305R presents two additional trial batch procedures available for laboratory use. These procedures (A and B) produce slump loss similar to that expected for 30- to 40-minute delivery times. The laboratory trial batch procedure in 3.3.4 is based on delivery time plus holding times approaching 1-1/2 hours total. The architect/engineer may specify a shorter or longer duration for the laboratory batch trial if applicable.
3.3.5	If a maximum field mixing time is required, the field trial batch time should be altered to match the specification.
3.4.2	Any limitations on elapsed time of the concrete mixture prior to discharge may be waived by the purchaser if the concrete is of such slump that it can be placed without the addition of water. With extended set control admixtures, concrete slump is maintained without the addition of water indefinitely with no detrimental effect to the concrete once placed. It is strongly recommended that the mixture and any set-control admixtures are tested prior to use in a project.
3.8.1	Rapid temperature decrease at the concrete surface can lead to thermal shrinkage cracking. The architect/engineer may specify a specific curing schedule that includes the duration required for use of accepted thermal protection and the accepted temperature decrease during that period.

APPENDIX A—EXAMPLE OF UNO EQUATION USED TO DETERMINE SURFACE EVAPORATION RATE OF FRESH CONCRETE

Appendix A is not part of ACI Specification 305.1 and is provided to give an example of the Uno equation (Eq. (A.1)). The Uno equation (Eq. (A.1)) (Uno 1998) used in 3.1.3 combines vapor pressure equations with the Menzel formula (Menzel 1954) to provide a unified equation for estimating the evaporation rate from a free water surface.

Example: Uno equation

Concrete temperature, $T_c = 90^\circ\text{F}$

Air temperature, $T_a = 100^\circ\text{F}$

Relative humidity = 56 percent, $r = 0.56$

Wind Speed, $V = 18$ mph

$$E = (T_c^{2.5} - rT_a^{2.5})(1 + 0.4V) \times 10^{-6} \quad (\text{A.1})$$

$$E = (90^{2.5} - 0.56 \times 100^{2.5}) \times (1 + 0.4 \times 18) \times 10^{-6} \\ = 0.17 \text{ lb/ft}^2/\text{h}$$

In this example, 0.17 lb/ft²/h is less than the accepted evaporation rate of the concrete-free surface water of 0.20 lb/ft²/h, as listed in 3.1.3. When an increase in the temperature, wind speed, or both, or a decrease in the relative humidity results in an evaporation rate greater than the value reported by this specification, measures to reduce the evaporation rate need to be implemented. For some mixtures, however, this evaporation rate could result in plastic shrinkage cracking, which is why a lower evaporation rate may be required as discussed in the Optional Requirements Checklist (3.1.3).

REFERENCES

Menzel, C. A., 1954, "Causes and Prevention of Crack Development in Plastic Concrete," *Proceedings, PCA Annual Meeting*, pp. 130-136.

Uno, P. J., 1998, "Plastic Shrinkage Cracking and Evaporation Formulas," *ACI Materials Journal*, V. 95, No. 4, July-Aug., pp. 365-375.

APPENDIX B—EXAMPLE OF NRMCA NOMOGRAPH FOR ESTIMATING SURFACE EVAPORATION RATE ON THE BASIS OF MENZEL FORMULA

Figure B.1 provides a graphic method of estimating the loss of surface water for various weather conditions by following four steps. If the rate of evaporation approaches 0.2 lb/ft²/h, precautions against plastic-shrinkage cracking are necessary (Lerch 1957). Wind speed is the average horizontal air or wind speed in mph and should be measured at a level approximately 20 in. higher than the evaporating surface. Air temperature and relative humidity should be measured at a level approximately 4 to 6 ft higher than the evaporating surface on its windward side shielded from the sun's rays (Menzel 1954).

The modified National Ready Mixed Concrete Association (NRMCA) Nomograph for Estimated Surface Evaporation Rates is intended as a graphical guide to determine an approximate solution of the Menzel formula. The nomograph in Appendix B is not a part of ACI Specification 305.1. It is intended only to assist in field estimations of surface evaporation rates and does not replace the Uno equation for meeting the requirements of 3.1.3.

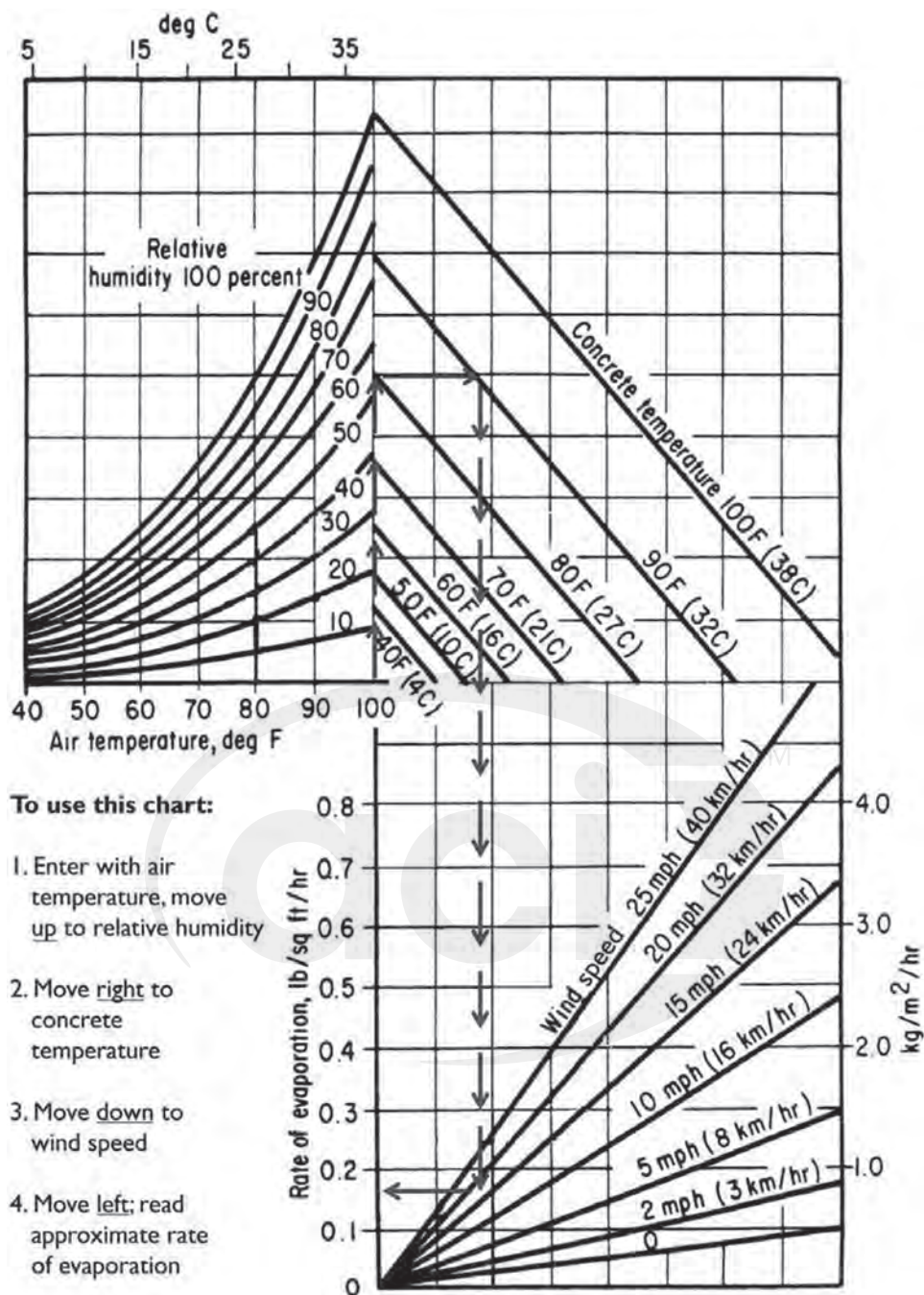


Fig. B1—Effect of concrete and air temperatures, relative humidity, and wind speed on the rate of evaporation of surface water from concrete.

REFERENCES

Lerch, W., 1957, "Plastic Shrinkage," *ACI Journal Proceedings*, V. 53, No. 8, Feb., pp. 79-80.

Menzel, C. A., 1954, "Causes and Prevention of Crack Development in Plastic Concrete," *Proceedings, PCA Annual Meeting*, pp. 132-133.



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