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IS 7861-1 (1975): Code of practice for extreme weather concreting, Part 1: Recommended practice for hot weather concreting [CED 2: Cement and Concrete]



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Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

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IS : 7861 (Part 1) - 1975
(Reaffirmed 2011)

Indian Standard

CODE OF PRACTICE FOR
EXTREME WEATHER CONCRETING

PART I RECOMMENDED PRACTICE FOR
HOT WEATHER CONCRETING

(Seventh Reprint OCTOBER 2000)

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NEW DELHI 110002

Indian Standard

CODE OF PRACTICE FOR EXTREME WEATHER CONCRETING

PART I RECOMMENDED PRACTICE FOR HOT WEATHER CONCRETING

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AMENDMENT NO. 1 AUGUST 1991
TO
IS 7861 (Part 1) : 1975 CODE OF PRACTICE FOR
EXTREME WEATHER CONCRETING
PART 1 RECOMMENDED PRACTICE FOR HOT
WEATHER CONCRETING

(*Page 10, clause 6.2, last line*) — Substitute the following for the existing matter:

'S = ratio of the specific heat of cement and aggregate to that of water.'

(*Page 10, clause 6.3*) — Substitute the following for the existing clause :
'6.3 In practice, the ratio of the specific heat of cement and aggregate to that of water shall be taken as 0.22 and $T_{wa} = T_a$.'

(CED 2)

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Indian Standard
CODE OF PRACTICE FOR
EXTREME WEATHER CONCRETING
PART I RECOMMENDED PRACTICE FOR
HOT WEATHER CONCRETING

0. FOREWORD

0.1 This Indian Standard (Part I) was adopted by the Indian Standards Institution on 22 September 1975, after the draft finalized by the Cement and Concrete Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 A great need has been felt for formulating standard recommendations pertaining to extreme weather concreting. This standard is the first Indian Standard on the subject and deals with hot weather concreting. Part II, which is under preparation, will deal with cold weather concreting.

0.3 Special problems are encountered in the preparation, placement and curing of concrete in hot weather. High temperatures result in rapid hydration of cement, increased evaporation of mixing water, greater mixing water demand, and large volume changes resulting in cracks. The problems of hot weather on concrete are further aggravated by a number of factors, such as use of rapid-hardening cements, handling of larger batches of concrete, etc.

0.4 The climatic factors affecting concrete in hot weather are high ambient temperature and reduced relative humidity, the effects of which may be considerably more pronounced with increase in wind velocity. The effects of hot weather are most critical during periods of rising temperature, falling relative humidity, or both. They may occur at any time of the year in warm tropical or arid climates, and generally occur during the summer season in other climates. Precautionary measures required on a calm, humid day will be less strict than those required on a dry, windy day, even if air temperatures are identical.

0.5 The object of this code is to identify the problems of concreting in hot weather and to recommend hot weather concreting practices which will eliminate to a large extent the adverse effects likely to be experienced in the absence of such practices. These recommended practices would result in concrete possessing improved characteristics in the fresh and hardened state. The recommendations apply to more general types of construction, such as buildings, bridges, pavements, heavy foundations and

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other similar structures, but in many cases, such as mass concreting for dams, etc, precautions given in this code will not be enough and additional precautions will have to be applied.

0.6 Damage to concrete caused by hot weather can never be fully alleviated. Since improvisations at site are rarely successful, early preventive measures may be applied with the emphasis on materials, advanced planning and coordination of all phases of work.

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part I) deals with the procedure and precautions to be observed while concreting in hot weather so as to minimize the detrimental effects of hot weather on concreting in general types of construction, such as buildings, bridges, pavements, heavy foundations and similar structures.

NOTE — All requirements of IS : 456-1964† and IS : 1343-1960‡, in so far as they apply, shall be deemed to form part of this code except where otherwise laid down in this code.

2. TERMINOLOGY

2.0 For the purpose of this code, the following definitions shall apply, in addition to the definitions covered in IS : 4845-1968§ and IS : 6461 (Parts I to XII)¶.

*Rules for rounding off numerical values (revised).

†Code of practice for plain and reinforced concrete (second revision).

‡Code of practice for prestressed concrete.

§Definitions and terminology relating to hydraulic cement.

¶Glossary of terms relating to cement concretes:

(Part I)-1972 Concrete aggregates.

(Part II)-1972 Materials (other than cement and aggregate).

(Part III)-1972 Concrete reinforcement.

(Part IV)-1972 Types of concrete.

(Part V)-1972 Formwork for concrete.

(Part VI)-1972 Equipment, tools and plant.

(Part VII)-1973 Mixing, laying, compaction, curing and other construction aspects.

(Part VIII)-1973 Properties of concrete.

(Part IX)-1973 Structural aspects.

(Part X)-1973 Tests and testing apparatus.

(Part XI)-1973 Prestressed concrete.

(Part XII)-1973 Miscellaneous.

2.1 Hot Weather Concreting — Any operation of concreting done at atmospheric temperatures above 40°C or any operation of concreting (other than steam curing) where the temperature of concrete at time of its placement is expected to be beyond 40°C.

2.2 Cold Joint — A joint or discontinuity formed when a concrete surface hardens before the next batch is placed against it, characterized by poor bond unless necessary treatment is given to the joint.

3. EFFECTS OF HOT WEATHER ON CONCRETE

3.1 Effects of hot weather on concrete, in the absence of special precautions, may be briefly described as follows:

- a) *Accelerated Setting* — High temperature increases the rate of setting of the concrete. The duration of time during which the concrete can be handled is reduced. Quick stiffening may necessitate undesirable retempering by addition of water. It may also result in cold joints.
- b) *Reduction in Strength* — High temperature results in the increase of the quantity of mixing water to maintain the workability with consequent reduction in strength.
- c) *Increased Tendency to Crack* — Either before or after hardening plastic shrinkage cracks may form in the partially hardened concrete due to rapid evaporation of water. Cracks may be developed in hardened concrete either by increased drying shrinkage resulting from greater mixing water used or by cooling of the concrete from its elevated initial temperature.
- d) *Rapid Evaporation of Water During Curing Period* — It is difficult to retain moisture for hydration and maintain reasonably uniform temperature conditions during the curing period.
- e) *Difficulty in Control of Air Content in Air-Entrained Concrete* — It is more difficult to control air content in air-entrained concrete. This adds to the difficulty of controlling workability. For a given amount of air-entraining agent, hot concrete will entrain less air than concrete at normal temperatures.

NOTE — A comprehensive note on the effect of hot weather on the properties of concrete is given in Appendix A.

3.2 The harmful effects of hot weather on concreting and concrete may be minimized by a number of practical procedures outlined in 5 to 8. The degree to which their application is justified depends on circumstances and shall be determined appropriately.

4. TEMPERATURE CONTROL OF CONCRETE INGREDIENTS

4.1 The most direct approach to keep concrete temperature down is by controlling the temperature of its ingredients. The contribution of each ingredient to the temperature of concrete is a function of the temperature, specific heat, and quantity used of that ingredient. The aggregates and mixing water exert the most pronounced effect on temperature of concrete. Thus, in hot weather all available means shall be used for maintaining these materials at as low temperatures as practicable.

4.2 Aggregates — Any one of the procedures or a combination of the procedures given in 4.2.1 to 4.2.3 may be used for lowering the temperature or at least for preventing excessive heating of aggregates.

4.2.1 Shading stockpiles from direct rays of the sun.

4.2.2 Sprinkling the stockpiles of coarse aggregate with water and keeping them moist. This results in cooling by evaporation, and this procedure is especially effective when relative humidity is low. Such sprinkling should not be done haphazardly because it leads to excessive variation in surface moisture and thereby impairs uniformity of workability.

4.2.2.1 When coarse aggregates are stockpiled during hot weather, successive layers should be sprinkled as the stockpile is built up.

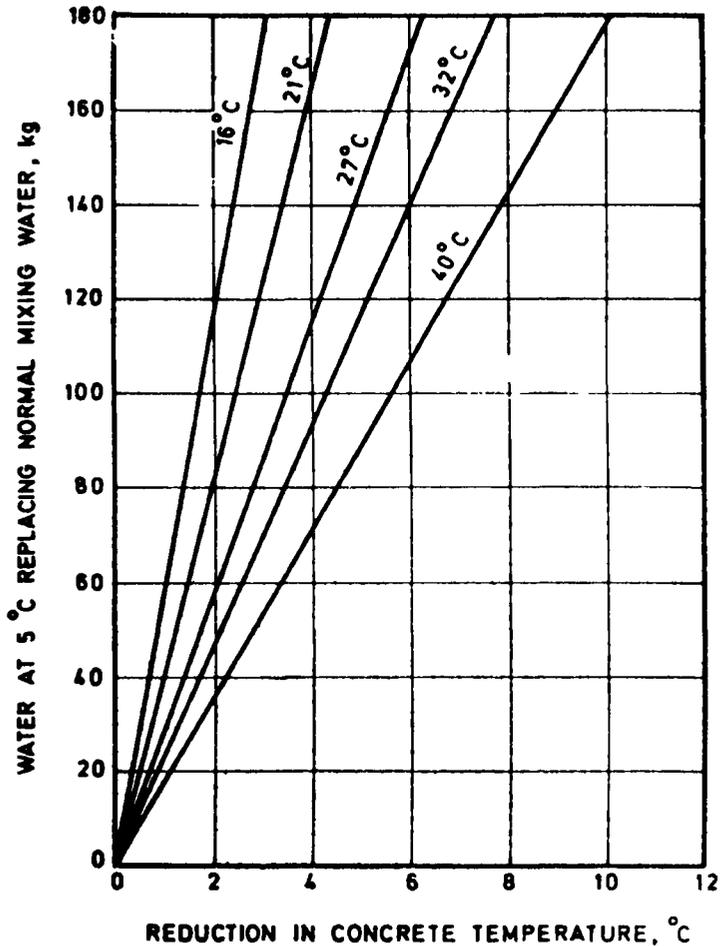
4.2.2.2 If cold water is available, heavy spraying of coarse aggregate immediately before use may also be done to have a direct cooling action.

4.2.3 Coarse aggregates may also be cooled by methods, such as inundating them in cold water or by circulating refrigerated air through pipes or by other suitable methods.

4.3 Water — The mixing water has the greatest effect on temperature of concrete, since it has a specific heat of about 4.5 to 5 times that of cement or aggregate. The temperature of water is easier to control than that of other ingredients and, even though water is used in smaller quantities than the other ingredients, the use of cold mixing water will effect a moderate reduction in concrete placing temperatures. For a nominal concrete mixture containing 336 kg of cement, 170 kg water, 1 850 kg of aggregate per m³, a change in 2°C water temperature will effect a 0.5°C change in the concrete temperature (see Fig. 1).

4.3.1 Efforts shall be made to obtain cold water, and to keep it cold by protecting pipes, water storage tanks, etc. Tanks or trucks used for transporting water shall be insulated and/or coloured and maintained white & yellow.

4.3.2 Under certain circumstances, reduction in water temperature may be most economically accomplished by mechanical refrigerator or mixing with crushed ice. Use of ice as a part of the mixing water is highly effective



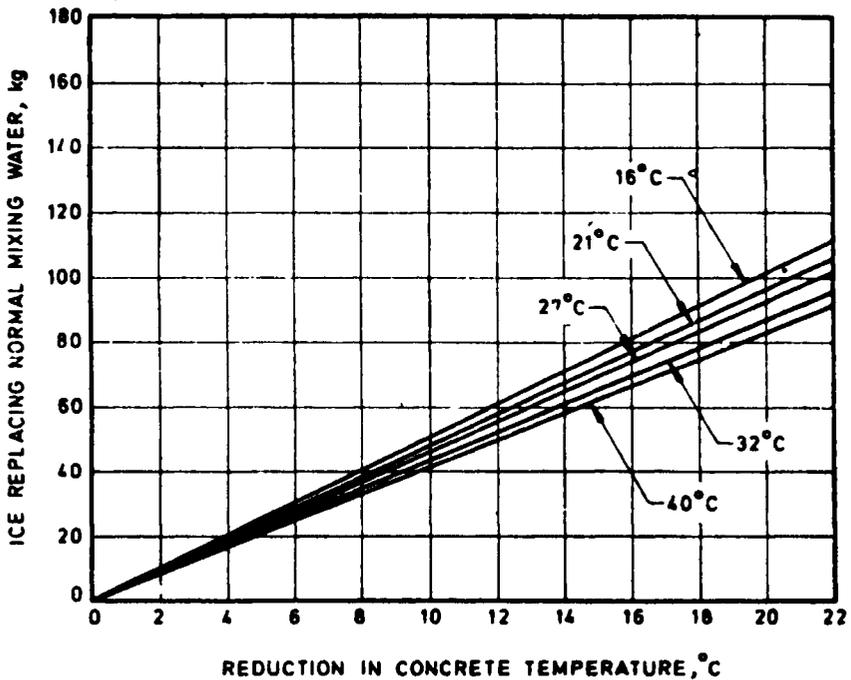
NOTE — Temperatures are normal mixing water temperatures. These values are applicable to average mixes made with typical natural aggregates. Quantity of cooled water cannot exceed mixing water requirement, which will depend on moisture content of aggregate and mix proportions.

FIG. 1 EFFECT OF COOLED MIXING WATER ON CONCRETE TEMPERATURE

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in reducing concrete temperature since, on melting alone, it takes up heat at the rate of 80 kcal/kg. To take advantage of heat of fusion, the ice shall be incorporated directly into the concrete as part of the mixing water. Conditions shall be such that the ice is completely melted by the time mixing is completed. Figure 2 shows possible reduction in concrete temperature by the substitution of varying amounts of ice for mixing water at temperatures shown.

NOTE — If the ice is not melted completely by the time mixing is completed, there can be a possibility of ice melting after consolidation of concrete and thus leaving hollow pockets in concrete, with detrimental effects.



NOTE — Temperatures are normal mixing water temperatures. These values are applicable to average mixes made with typical natural aggregates. Quantity of ice added cannot exceed mixing water requirement, which will depend on moisture content of aggregate and mix proportions.

FIG. 2 EFFECT OF ICE IN MIXING WATER ON CONCRETE TEMPERATURE

4.4 Cement — The temperature has a direct effect on the rate of hydration of cement. High concrete temperature increases the rate of hydration, the rate of stiffening and generally results in increased water demand thus contributing to reduced strength and to plastic shrinkage. Temperature has a definite effect on setting time, and the magnitude of the effect varies with the cement composition when a set-controlling admixture is used. The change in temperature of cement produces significantly less change in the temperature of fresh concrete than the other ingredients. However, it does exert an effect and it is considered prudent to place a maximum limit on temperature of cement as it enters the concrete. Cement shall preferably not be used at temperatures in excess of about 77°C.

5. PROPORTIONING OF CONCRETE MIX MATERIALS AND CONCRETE MIX DESIGN

5.1 The quantity of cement used in the mix affects the rate of increase in temperature. As such, the mix should be designed to have minimum cement content consistent with other functional requirements. As much as possible, cements with lower heat of hydration shall be preferred instead of cements having greater fineness and high heat of hydration.

5.2 In hot weather, hydration of cement is accelerated by high temperature and this acceleration is generally considered responsible for the increase in water requirement of concrete. When the temperature is such as to increase mixing water demand or reduce workability significantly, water-reducing and set-retarding admixtures may be used to offset the accelerating effects of high temperatures and to lessen the need for increase in mixing water.

5.3 Any admixture shall, however, be used only on the basis of competent technical advice or, when practicable, advance testing with the cement and other materials involved.

6. TEMPERATURE OF CONCRETE AS PLACED

6.1 In hot weather, wherever necessary, the ingredients of concrete should be cooled to the extent necessary to maintain the temperature at the time of placing below 40°C.

6.2 The temperature of the concrete at the time of leaving the mixer or batching plant, may be calculated from the following formulae when the temperatures of all constituents are known. The actual change of temperature from the time it leaves the mixer/batching plant to the time of placing should be estimated, but may be taken as 2°C in the absence of any other information in this respect.

a) Cold water as mixing water (without ice)

$$T = \frac{S (T_a W_a + T_c W_c) + T_w W_w + T_{wa} W_{wa}}{S (W_a + W_c) + W_w + W_{wa}}$$

b) With ice added to the mixing water

$$T = \frac{S (T_a W_a + T_c W_c)}{S (W_a + W_c) + W_w + W'_1 + W_{wa}} + \frac{(W_w - W_1) T_w + W_{wa} T_{wa} - 79.6 W_1}{S (W_a + W_c) + W_w + W_1 + W_{wa}}$$

where

T = temperature of freshly mixed concrete ($^{\circ}\text{C}$);

T_a, T_c, T_w, T_{wa} = temperature of aggregate, cement, added mixing water and free water on aggregate respectively ($^{\circ}\text{C}$);

$W_a, W_c, W_w, W_{wa}, W_1$ = mass of aggregate, cement, added mixing water, free water on aggregate and ice respectively (kg); and

S = specific heat of cement and aggregate.

6.2.1 Worked out examples for the calculation of temperature of fresh concrete, when cold water or ice is added in place of mixing water at higher temperature, are given in Appendix B.

6.3 In practice the specific heat of cement and aggregate shall be taken as 0.22 and $T_{wa} = T_a$.

6.4 Apart from assessing the temperature of concrete mix by the formula given in 6.2, the temperature of concrete should also be ascertained from a sample of the design mix. For this purpose a suitable metal-clad thermometer may be used by embedding it in concrete.

7. PRODUCTION AND DELIVERY

7.1 Temperatures of aggregates, water, and cement shall be maintained at the lowest practical levels so that the temperature of the concrete is below 40°C at the time of placement.

7.2 Mixing time shall be held to the minimum which will ensure adequate quality and uniformity, because the concrete is warmed from the work of mixing, from the air, and from the sun. The effect of mixer surface exposed to the hot sun should be minimized by painting and keeping the mixer drum yellow or white and spraying it with cool water.

7.3 Cement hydration, temperature, loss of workability, and loss of entrained air, increase with passage of time after mixing. Thus the period between mixing and delivery shall be kept to an absolute minimum. Attention shall be given to coordinating the delivery of concrete with the rate of placement to avoid delays in delivery.

8. PLACEMENT, PROTECTION AND CURING

8.1 Placement and Finishing — Forms, reinforcement, and subgrade shall be sprinkled with cool water just prior to placement of concrete. The area around the work shall be kept wet to the extent possible to cool the surrounding air and increase its humidity, thereby reducing temperature rise and evaporation from the concrete. When temperature conditions are critical, concrete placement may be restricted to the evenings or night when temperatures are lower and evaporation is less.

8.1.1 Speed of placement and finishing helps to minimize problems in hot weather concreting. Delays contribute to loss of workability and lead to use of additional mixing water to offset such loss. Ample personnel shall be employed to handle and place concrete immediately on delivery. On flat work, all steps in finishing shall be carried out promptly. Delays in finishing air-entrained concrete pavement in hot weather may lead to formation of a rubbery surface which is impossible to finish without leaving ridges that impair the riding qualities of pavement.

8.1.2 Concrete shall be placed in layers thin enough and in areas small enough so that the time interval between consecutive placements is reduced and vibration or other working of the concrete will ensure complete union of adjacent portions. If cold joints tend to form or if surfaces set and dry too rapidly, or if plastic shrinkage cracks tend to appear, the concrete shall be kept moist by means of fog sprays, wet burlap, cotton mats, or other means. Fog sprays applied shortly after placement and before finishing, have been found to be particularly effective in preventing plastic shrinkage cracks when other means have failed.

8.1.3 All placement procedures shall be directed to keep the concrete as cool as practicable and to ensure its setting and hardening under temperature conditions which are reasonably uniform and, under moisture conditions, which will minimize drying. Concrete, whether delivered by a truck or otherwise, shall reach the forms at a temperature not higher than 40°C, and whatever is practicable shall be done to minimize temperature increase during placing, consolidation, finishing, and curing operations.

8.2 Protection and Curing — Since hot weather leads to rapid drying of concrete, protection and curing are far more critical than during cold weather. Particular attention shall be paid to having all surfaces protected from drying. Immediately after consolidation and surface finish, concrete shall be protected from evaporation of moisture, without letting ingress of external water, by means of wet (not dripping) gunny bags, hessian cloth, etc. Once the concrete has attained some degree of hardening sufficient to withstand surface damage (approximately 12 hours after mixing), moist curing shall commence. The actual duration of curing shall depend upon the mix proportions, size of the member as well as the environmental conditions; however in any case it shall not be less than 10 days. Continuous

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curing is important, because volume changes due to alternate wetting and drying promote the development of surface cracking.

8.2.1 Reliance shall not be placed on the protection afforded by forms for curing in hot weather. If possible, water shall be applied to formed surfaces while forms are still in place and unformed surfaces shall be kept moist by wet curing. The covering material shall be kept soaked by spraying. Steeply sloping and vertical formed surfaces shall be kept completely and continuously moist prior to and during form removal by applying water to top surfaces so that it will pass down between the form and the concrete.

8.2.2 On exposed unformed concrete surfaces, such as pavement slabs, wind is an important factor in the drying rate of concrete. For example, other conditions being equal, a gentle wind of 15 km/h will cause four or more times as much evaporation from a flat surface as still air. Hence wind breakers shall be provided as far as possible.

8.2.3 On hardened concrete and on flat surfaces in particular, curing water shall not be much cooler than the concrete because of the possibilities of thermal stresses and resultant cracking. At the termination of curing with water, an effort shall be made to reduce the rate of drying by avoiding air circulation. This can be accomplished by delay in removal of wet covers until they are dry.

9. INSPECTION AND TEMPERATURE RECORDS

9.1 Competent inspection personnel shall be available to anticipate the need for requirements during hot weather concreting, such as spraying of forms and subgrade; the need for ice as a portion of the mixing water, providing sunshades, wind screens etc, and minimizing delays in placement and curing.

9.2 The supervisor shall record at frequent intervals air temperature, general weather condition (calm, windy, clear, cloudy), and relative humidity. The record shall include frequent checks on temperatures of concrete as delivered and after placing in the forms, and the protection and curing time as provided.

9.3 All such data shall be gathered with the work in progress so that conditions surrounding the construction of any part of the structure can be determined if necessary at a later date. A copy of all these observations shall be included in the permanent records of the job.

10. CONCRETE TESTING

10.1 Due to the small size of the test specimen in relation to most structural components, test specimens are likely to reach high temperatures and

dry more rapidly than the concrete in place, with correspondingly increased detrimental effects. For those reasons, extra care shall be exercised in hot weather to maintain temperature and moisture conditions for strength test specimens as required in standard test methods.

10.2 Proper temperature shall be maintained by avoiding exposure to the sun and by utilizing the cooling effect of evaporating water, either from damp burlap or wet sand covering the specimen.

10.3 Specimens used as the basis for acceptance of concrete as delivered to the structure shall be transferred at the age of one day to a location (usually the laboratory) where they will receive continuous standard moist curing until test.

10.4 Specimens cured on the job shall never be substituted for laboratory cured specimens as a check of the proportioning and mixing of the concrete. The results of tests of job-cured specimens properly interpreted, may be used to obtain information helpful in judging when to strip forms, put the structure in service, etc. Moulded specimens used for these purposes shall be cured at the same place and as nearly as possible under the same conditions as those around the structure.

10.5 It is sometimes desirable to conduct tests, such as workability, air content and moisture content of materials if sprinkled with water, more frequently than for normal conditions. Additional tests, such as temperature of materials and the fresh concrete, initial and final setting time, and temperature and relative humidity at the forms may also be conducted.

APPENDIX A

(Clause 3.1)

EFFECTS OF HOT WEATHER ON CONCRETE PROPERTIES

A-1. EFFECTS ON COMPRESSIVE STRENGTH

A-1.1 The desirable properties of concrete, for example, strength; impermeability; dimensional stability; and resistance to weathering, wear and chemical attack can be adversely affected by combinations of high air temperature, low relative humidity and high wind velocity. Concretes mixed, placed and cured at elevated temperatures normally develop higher early strength than concretes produced and cured at normal temperatures; but at 28 days or later the strengths are lower. This is illustrated in Fig. 3. Further reduction in strength can occur if sufficient water curing is absent or there is considerable delay in the commencement of moist curing. Tests have shown that laboratory test specimens moulded and cured at 23°C,

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60 percent relative humidity and 38°C, 25 percent relative humidity produced strength of only 73 and 62 percent, respectively of that obtained for standard specimens moist cured at 23°C for 28 days.

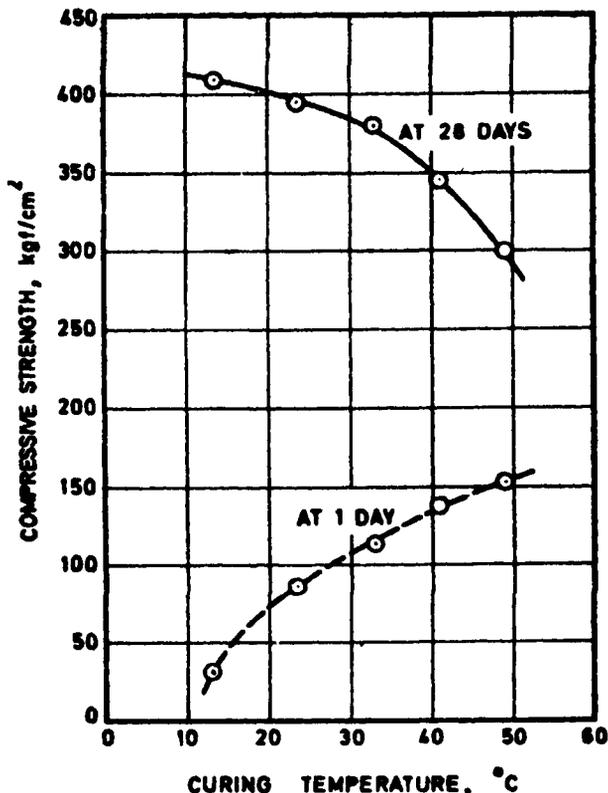


FIG. 3 EFFECT OF CURING TEMPERATURES ON 1-DAY AND 28-DAY COMPRESSIVE STRENGTH OF CONCRETE

A-2. EFFECTS ON WORKABILITY AND WATER DEMAND

A-2.1 For maintaining the same workability, the quantity of water in the concrete mix has to be increased as the concrete temperature increases. If the amount of water remains unchanged, then conversely, there will be loss of workability of concrete as the temperature increases. Figure 4 (dotted line) illustrates the effects of increasing concrete temperature on the resulting workability of concrete when the amount of net mixing'water is held constant. It indicates that an increase of 11°C in temperature may be

expected to decrease the slump by 25 mm. Figure 4 (solid line) also illustrates changes in water requirement that may be necessary to produce a 25 mm change in slump at various temperature levels. As the temperature increases from 5°C to 27°C, only 2.25 to 2.5 percent additional water will be required to effect a 25 mm change in slump, while 4.5 percent would be required when the temperature reaches 49°C. The actual water content in a mix, in order to attain a given workability will thus depend on the actual mix proportions, the workability desired as well as the temperature. Figure 5 illustrates the water required to attain 75 mm slump, in case of a typical concrete (maximum size of aggregate — 40 mm) at various temperatures.

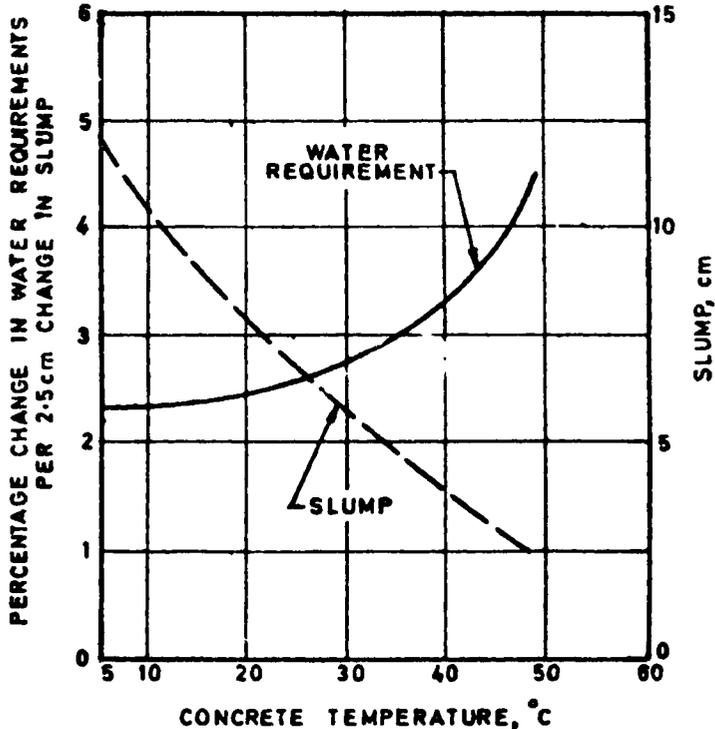


FIG. 4 EFFECT OF CONCRETE TEMPERATURE ON SLUMP AND ON WATER REQUIRED TO CHANGE SLUMP

A-3. EFFECTS ON SHRINKAGE

A-3.1 In the hot weather, whenever the rate of evaporation of water from the concrete mix is greater than the rate at which water rises to the surface of freshly placed concrete (bleeding), plastic shrinkage cracking will usually

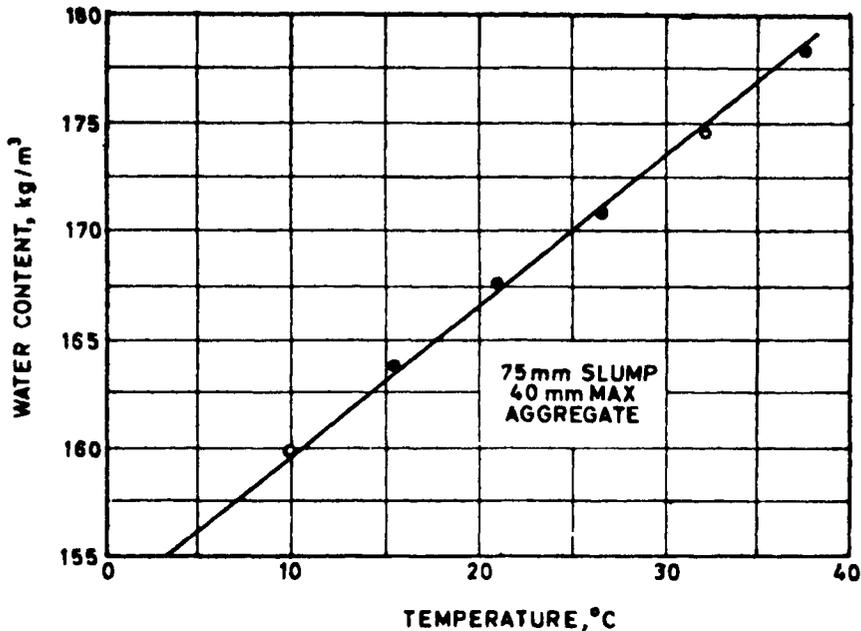
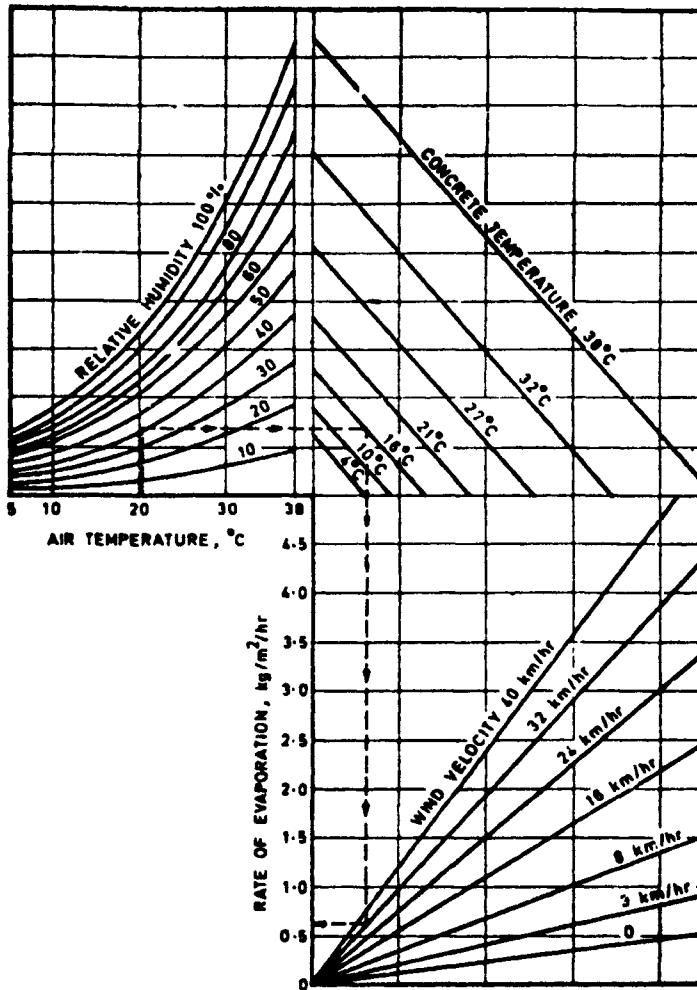


FIG. 5 EFFECT OF TEMPERATURE ON WATER REQUIREMENT OF CONCRETE

occur. High concrete temperature, high air temperature, high wind velocity and low relative humidity, or combinations thereof, cause rapid evaporation which significantly increases the likelihood of occurrence of plastic shrinkage cracking. A graphic method of estimating the loss of surface moisture for various concrete and air temperatures, relative humidity and wind velocity is given in Fig. 6. Following the four steps listed in the figure, whenever the rate of evaporation is estimated to be approaching 1.0 kg/m²/hr, precautions against plastic shrinkage cracking should be taken, as contained in 7 and 8 of the standard.

A-3.1.1 Drying shrinkage increases with the increase in water content in the mix and lowering of relative humidity. Increase in the concreting temperature increases water demand which may lead to increased drying shrinkage. Figure 7 shows the relationship between drying shrinkage and unit water content, for various amounts of cement in the mix. It shows that shrinkage is a direct function of the unit water content of the fresh concrete and cement content (or water-cement ratio) has only a secondary importance. Subsequent cooling from high temperatures, at which the concrete hardens, increases the cracking tendency of concrete.



NOTE — To use this chart :

- a) Enter with air temperature, move up to relative humidity
- b) Move right to concrete temperature
- c) Move down to wind velocity
- d) Move left to read approximate rate of evaporation

FIG. 6 EFFECT OF CONCRETE AND AIR TEMPERATURES, RELATIVE HUMIDITY, AND WIND VELOCITY ON THE RATE OF EVAPORATION OF SURFACE MOISTURE FROM CONCRETE

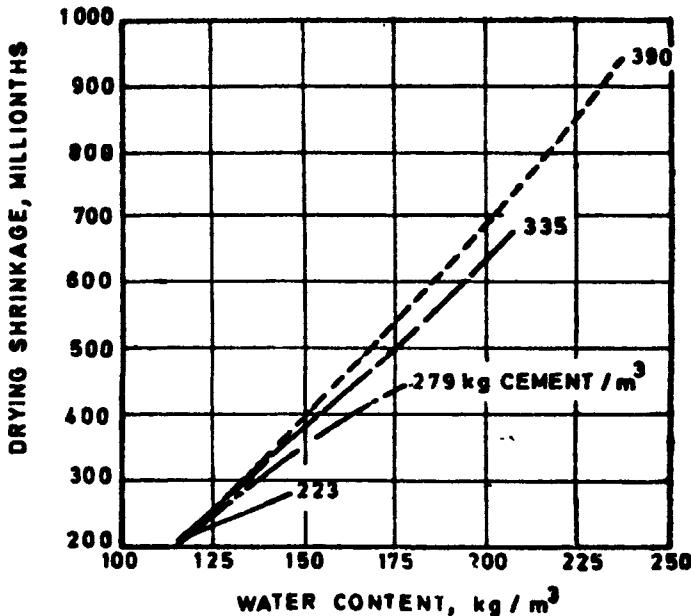


FIG. 7 THE INTER-RELATION OF SHRINKAGE, CEMENT CONTENT AND WATER CONTENT

APPENDIX B

(Clause 6.2.1)

SOLVED EXAMPLES OF CALCULATION OF TEMPERATURE OF CONCRETE AS PLACED, BY USING FORMULAE

B-1. COLD WATER AS MIXING WATER (WITHOUT ICE)

B-1.1 Consider a concrete mix having the following ingredients (per m³), and the initial temperature shown against each:

Cement	336 kg at 35°C
Water	170 kg at 30°C
Aggregates	1 850 kg at 45°C

It is assumed that the aggregates are dry, that is, $W_{wa} = 0$

The temperature (°C) of fresh concrete as mixed with these ingredients will be:

$$T = \frac{0.22 (45 \times 1850 + 35 \times 336) + 30 \times 170}{0.22 (1850 + 336) + 170}$$

$$= 39.9^{\circ}\text{C}$$

Suppose, the mixing water is added at 5°C, then the temperature of concrete (°C) as mixed will be:

$$T = \frac{0.22 (45 \times 1850 + 35 \times 336) + 5 \times 170}{0.22 (1850 + 336) + 170}$$

$$= 33.4^{\circ}\text{C}$$

Hence, reduction in concrete temperature is:

$$(39.9 - 33.4)^{\circ}\text{C} = 6.5^{\circ}\text{C}$$

B-2. WITH ICE ADDED TO THE MIXING WATER

B-2.1 In the example under B-1, suppose 50 percent of the mixing water (that is, 85 kg) is replaced by ice.

Then the temperature of fresh concrete as mixed is given by:

$$T = \frac{0.22 (45 \times 1850 + 35 \times 336) + (170 - 85) \times 30 - 79.6 \times 85}{0.22 (1850 + 336) + 85 + 85}$$

$$= 25.6^{\circ}\text{C}$$

Hence reduction in concrete temperature is:

$$(39.9 - 25.6)^{\circ}\text{C} = 14.3^{\circ}\text{C}$$

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