IS 7861-2 (1981): Code of practice for extreme weather concreting, Part 2: Recommended practice for cold weather concreting [CED 2: Cement and Concrete]

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Indian Standard

CODE OF PRACTICE FOR EXTREME WEATHER CONCRETING

PART II RECOMMENDED PRACTICE FOR COLD WEATHER CONCRETING

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CODE OF PRACTICE FOR EXTREME WEATHER CONCRETING

PART II RECOMMENDED PRACTICE FOR COLD WEATHER CONCRETING

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AMENDMENT NO. 1 JUNE 1991
TO
IS 7861 (Part 2) : 1981 CODE OF PRACTICE FOR EXTREME WEATHER CONCRETING

PART 2 RECOMMENDED PRACTICE FOR COLD WEATHER CONCRETING

(*Page* 11, *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* 11, *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 $T_a = T_w$.'

(CED 2)

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Indian Standard

CODE OF PRACTICE FOR EXTREME WEATHER CONCRETING

PART II RECOMMENDED PRACTICE FOR COLD WEATHER CONCRETING

0. FOREWORD

0.1 This Indian Standard (Part II) was adopted by the Indian Standards Institution on 30 January 1981, after the draft finalized by the Cement and Concrete Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 In order to meet the need for recommended practices for extreme weather concreting, the Sectional Committee decided to evolve Indian Standards on the subject. Accordingly, IS : 7861 (Part I)-1975 was brought out to cover recommended practice for hot weather concreting. This standard covers recommended practice for cold weather concreting.

0.3 The present demand on the building and civil engineering structures makes it imperative that work be continued throughout the winter months irrespective of cold weather. In India certain areas are subjected to severe cold weather for a long period. They include Northern, North-East and North-West Zones, etc, of the country. Winter concreting techniques should be followed to carry out continuous construction in these areas.

0.4 The production of concrete in cold weather introduces special and peculiar problems which do not arise while concreting at normal temperatures. Quite apart from the problems associated with setting and hardening of cement concrete, severe damage may occur if concrete which is still in the plastic state is exposed to low temperature, thus causing ice lenses to form and expansion to occur within the pore structure. Hence it is essential to keep the temperature of the concrete above a minimum value before it is placed in the formwork. After placing, concrete may be kept above a certain temperature with the help of proper insulating methods before the protection is removed. During periods of low ambient temperature, special techniques are to be adopted to cure the concrete while it is in the formwork or after its removal.

0.5 The objects of this recommended code are to identify the problems and to recommend cold weather concreting practices which will eliminate to a large extent the adverse effects likely to be experienced in the absence of such practice. Adoption of these recommended practices may result in concrete possessing improved characteristics in the freshly mixed and hardened state.

0.6 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 or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places ratained in the rounded off value should be the same as that of the specified value in this standard.

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1. SCOPE

1.1 This code deals with the procedure and precautions to be observed while concreting in cold weather so as to minimize the detrimental effects of cold weather on concreting in general types of construction, such as buildings, bridges, highways, pavements and other similar structures.

NOTE—All requirements of IS : 456-1978† and IS : 1343-1980‡ 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 by IS : 4815-1968§ and IS : 6461 (Parts I to XII)‖.

2.1 Cold Weather Concreting — Any operation of concreting done at about 5°C atmospheric temperature or below.

2.2 Prehardening Period — The prescribed time for which the temperature of freshly placed concrete is required to be maintained above the freezing point.

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*Rules for rounding off numerical values (*revised*).

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

‡Code of practice for prestressed concrete (*first revision*).

§Definitions and terminology relating to hydraulic cement.

‖Glossary of terms relating to cement concrete:

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 concete
Part XII-1973 Miscellaneous

3. EFFECTS OF COLD WEATHER ON CONCRETE

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

a) *Delayed Setting* — When the temperature is falling to about 5°C or below, the development of concrete strength is retarded compared with the strength development at normal temperatures. The hardening period necessary before the removal of forms is thus increased and the experience from concreting at normal temperature cannot be used directly.

b) *Freezing of Concrete at Early Ages* — When concrete is exposed to freezing temperature, there is the risk of concrete suffering irreparable loss of strength and other qualities, that is, permeability may increase and the durability may be impaired.

c) *Repeated Freezing and Thawing of Concrete* — If concrete is exposed to repeated freezing and thawing after final set and during the hardening period, the final qualities of the concrete may also be impaired.

d) *Stresses Due to Temperature Differentials* — It is a general experience that large temperature differentials within the concrete member may promote cracking and have a harmful effect on the durability. Such differentials are likely to occur in cold weather at the time of removal of form insulations.

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

3.2 The harmful effects of cold weather on concrete and concreting may be minimized by a number of practical procedures outlined in 4 to 8. The degree to which their application is justified depends on circumstances and shall be determined appropriately.

3.3 The severity of the weather determines the precautions to be taken. For this purpose cold weather can be divided into three categories:

a) When the temperature is below 5°C but does not fall below freezing point,

b) When frost occurs at night only and is not very severe, and

c) When there is severe frost day and night.

Table 1 generally summarizes the precautions to be taken in each case.

4. TEMPERATURE CONTROL OF CONCRETE INGREDIENTS

4.1 The most direct approach to keeping concrete temperature up 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 cold weather, all available means shall be used for maintaining these materials at as high a temperature as practicable.

TABLE 1 PRECAUTIONARY MEASURES

(*Clause* 3.3)

Conditions	Precautions to be Taken
a) At low temperature	1) Keep formwork in position longer, or use rapid hardening cement; 2) Cover the top of the concrete with insulating material; 3) Insulate steel formwork; and 4) Make sure that concrete is delivered to the point of placing at not less than 5°C.
b) When there is frost at night	Take all the precautions given at (a) and the following: 1) Insulate all formwork, 2) Make sure that concrete is not placed against a frozen sub-grade or against reinforcement or forms covered with snow or ice, and 3) Place concrete quickly and insulate.
c) When there is severe frost day and night	Take all the precautions given at (a) and (b) and the following: 1) Heat the water and, if necessary, the aggregate; and 2) Make sure that concrete is delivered to the point of placing at not less than 10°C, place quickly and insulate; or make sure concrete is delivered to the point of placing at not less than 5°C, place quickly and provide continuous heating to the concrete.

4.2 Aggregates — Heating of aggregates shall be such that frozen lumps, ice and snow are eliminated and at the same time over-heating is avoided. At no point shall the aggregate temperature exceed 100°C; the average temperature of aggregate for an individual batch shall not exceed 65°C. The heating of aggregates to temperatures higher than 15°C is rarely necessary with mixing water at 60°C.

4.2.1 If the coarse aggregate is dry and free of frost and ice lumps, adequate temperatures of fresh concerte can be obtained by increasing the temperature of only the sand, which will seldom have to be higher than about 40°C, if mixing water is at 60°C.

4.2.2 Steam in embedded pipes is recommended for heating aggregate, but for small jobs aggregates may be heated with the help of steel drums embedded in heaped aggregates and filled with fire. When aggregates in stockpiles are heated by steam pipes, exposed surfaces of aggregate shall be covered with tarpaulins as much as practicable to maintain uniform distribution of heat and to prevent formation of frozen crusts.

4.3 Water — Mixing water shall be heated under such a control and in sufficient quantity as to avoid appreciable fluctuations in temperature from batch to batch. The required temperature of mixing water to produce specified concrete is shown in Fig. 1. To avoid possibility of flash set when either aggregate or water is heated to a temperature in excess of 40°C, water and aggregate shall be mixed together in the mixer first in such a way that the high temperature of one or other is reduced before cement is added. The heated water shall come into direct contact with aggregate first and not cement.

4.3.1 Water having temperature up to the boiling point may be used provided the aggregate is cold enough to reduce the temperature of the mixing water and aggregate to appreciably below 40°C. In fact this temperature shall not normally exceed 25°C.

4.3.2 If loss of effectiveness of air entraining admixtures is noticed due to hot water, the admixture may be added to the batch only after water temperature has been reduced.

4.4 Cement — During winter concreting, it is preferable to use rapid-hardening Portland cement (*see* IS : 8041-1978*).

5. PROPORTIONING OF CONCRETE MIX MATERIALS AND CONCRETE MIX DESIGN

5.1 In general, for the winter conditions prevailing in India satisfactory concreting can be achieved mainly by conserving the heat of hydration of cement with insulations and insulated formworks. Wherever damage to hardened concrete by alternate freezing and thawing during service is anticipated, air entrainment is necessary. The type and quantity of cement used in the concrete mix affect, the rate of development of compressive strength and rate of increase in temperature of concrete. Additional quantity of ordinary Portland cement, rapid-hardening Portland cement or use of accelerating admixtures, when used with proper precautions, helps in development of the required strength in a shorter period. This often results in saving due to shorter duration of protection, faster re-use of forms, earlier removal of shores and less labour in finishing the work. Use of cement which gives earlier and higher heat of hydration is preferable. The cement content in the mix shall preferably be not less than 300 kg/m³.

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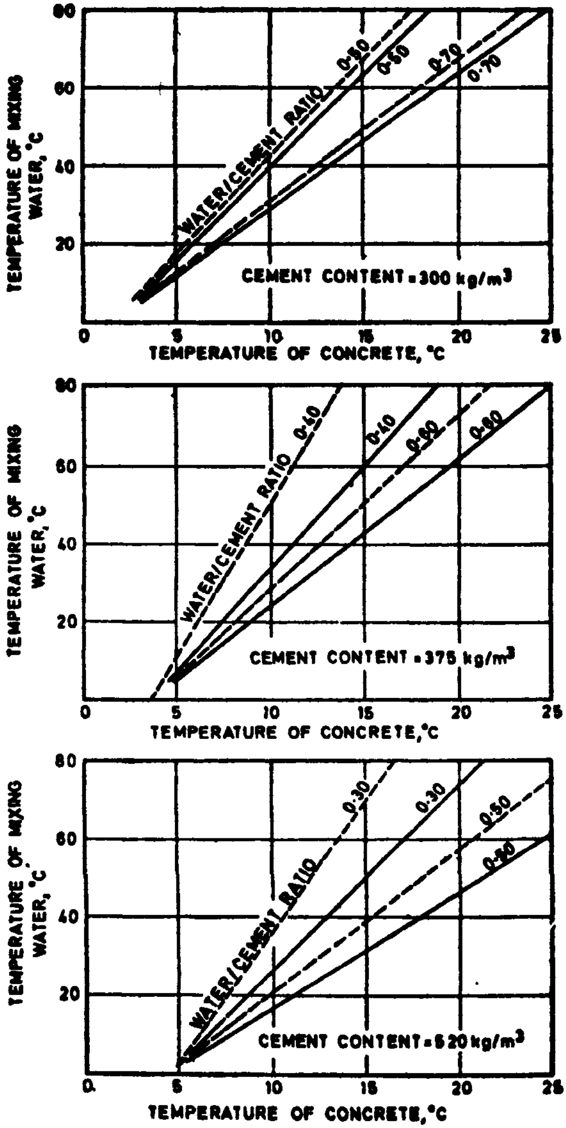
*Specification for rapid hardening Portland cement (*first revision*).



Moisture content of aggregate:
Damp (4% in fine, 1% in coarse) ————
Wet (8% in fine, 2% in coarse) - - - - - -
Temperature of aggregate and contained moisture = 1°C
Temperature of cement = 5°C

Fig. 1 Required Temperature of Mixing Water to Produce Heated Concrete

5.1.1 Air-entraining admixtures and accelerators, when proposed to be used, shall conform to the requirements of IS : 9103-1979* and shall be used only after proper evaluation with the cement and aggregates proposed to be used in the works. If a combination of different admixtures is used, preliminary tests shall be carried out with such combination prior to use in the actual construction.

5.2 Calcium Chloride as an Accelerator

5.2.1 In cold weather concrete construction jobs, calcium chloride may be used as an accelerating admixture. However, there are conditions under which it should not be used and such applications as given in **5.2.1.1** to **5.2.1.4** shall be carefully noted. While calcium chloride is used as an accelerator in concrete, the limit of total chloride in the concrete shall be as stipulated in IS : 456-1978†. It shall however not be used in prestressed concrete because of its potential danger in augmenting stress corrosion. Where sulphate resisting concrete is required, calcium chloride shall not be used.

5.2.1.1 In reinforced concrete works, the threat of corrosion is higher when chlorides are used as admixtures, especially under any or a combination of the following conditions:

a) When there are cracks in the concrete,

b) When there are areas exposed to alternate wetting and drying,

c) When the concrete cover is small, and

d) When the concrete is permeable.

5.2.1.2 The presence of chlorides has been associated with corrosion of galvanised steel, when this material is used for permanent forms or for embedded parts and its use is not recommended in such construction.

5.2.1.3 Recent studies have indicated that galvanic corrosion of metal is intensified by addition of calcium chloride to concrete.

5.2.1.4 Calcium chloride increases the risk of alkali aggregate reaction, unless controlled by the use of low alkali cement or by addition of pozzolanas.

5.2.2 Tests have indicated that increase in strength resulting from the use of calcium chloride usually can be maximum in 1 to 3 days; the relative increase in flexural strength in concrete is not as high as increase in compressive strength, and decrease in flexural strength may occur at 28 days or later ages.

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*Specification for admixtures for concrete.

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

5.2.3 There are insufficient data on the use of calcium chloride with Portland slag cement or other blended cements to justify any recommendations concerning the use of chlorides with such cements.

5.2.4 As calcium chloride precipitates most air-entraining agents and some water retaining agents when mixed in the same solution, it is important that these be kept in separate solutions and introduced separately into the mixer.

5.2.5 When calcium chloride is used, the doses shall be dissolved in a portion of mixing water before batching, since undissolved lumps may, later on, disfigure concrete surfaces.

5.2.6 While making solution of calcium chloride, add calcium chloride to water and not water to calcium chloride, as it is an exothermic reaction and may cause accident.

5.2.7 Calcium chloride, or other chemicals in the mix, if used in permissible amounts, will not lower the freezing point of concrete to any significant degree. The use of harmful materials to protect the concrete from freezing shall not be permitted.

5.3 Air-Entraining Agents— This type of admixture, in proper amounts, increases the resistance of hardened concrete to freezing and thawing and normally at the same time improves the workability of fresh concrete. The compressive strength of air-entrained concrete at 28 days shall not be less than 90 percent of a reference mix without air entrainment. A small increase in shrinkage may occur.

5.3.1 For prestressed concrete, air-entraining agents shall be permitted only if they do not contain chlorides.

6. TEMPERATURE OF CONCRETE AS PLACED

6.1 In cold weather, the temperature of concrete at the time of placement goes below the optimum placement temperature. When placing concrete at or near freezing temperature, precautions shall be taken to ensure that concrete at the time of placing has a temperature of at least 5°C and that the temperature of concrete after having been placed and compacted is maintained above 2°C until it has hardened thoroughly.

6.2 The temperature of concrete at the time of leaving the mixer or batching plant may be calculated from the following formula, when the temperatures of all constituents are known; the actual drop in 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:

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

where

T = temperature of the fresh concrete (°C);

T_a, T_c, T_w and T_{wa} = temperature of the aggregates, cement, added mixing water, and free water (moisture) in the aggregates respectively (°C);

W_a, W_c, W_w and W_{wa} = masses of the aggregates, cement, mixing water and free moisture in the aggregates respectively (kg); and

S = specific heat of cement and aggregate.

6.2.1 A worked out example for the calculation of temperature, when mixing water at a higher temperature is used, is given in Appendix B.

6.3 In practice the specific heat of cement and aggregate shall be taken as 0·22 and $T_a = T_{wa}$.

6.4 In cold weather, the ingredients that go to make concrete shall be heated to the extent necessary to maintain the temperature of concrete (*see* **6.2**) at the time of placing not less then 5°C.

6.5 Apart from assessing the temperature of concrete mix by the formula given in **6.2**, the temperature of concrete shall 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 Preparation for concreting in cold weather may be completed well in advance of setting in of severe conditions. Wind breakers shall be erected to shield the mixing and batching plants; tarpaulin, plastic sheet and other covering and insulating materials may be made available on the site and the steam generating plant or other necessary equipment shall be installed and checked for correct functioning.

7.2 Suitable protecting clothing shall be available to the site staff and the operators shall be carefully instructed in procedures for concreting during cold weather.

7.3 The concrete shall be delivered to the point of placing at not less than 5°C. It is necessary to place the concrete quickly and cover the top of the concrete with an insulating material.

8. PLACEMENT, PROTECTION AND CURING

8.1 Placement — Before any concrete is placed, all ice, snow and frost shall be completely removed and the temperature of all surfaces to be in contact with new concrete shall be raised as close to the temperature of fresh concrete to be placed thereon as practicable. No concrete shall be placed on a frozen subgrade or on one that contains frozen materials. Where concrete is to be placed over permanently frozen ground, subgrade material may be thawed deep enough to ensure that it will not freeze back up to the concrete or it may be covered with a sufficient depth of dry granular material.

8.1.1 Arrangements for covering and insulating of newly placed concrete shall be made in advance of placement and shall be adequate to maintain in all parts of concrete, the temperature and moisture conditions that are referred to herein for winter curing temperature and methods.

8.2 Protection — During cold weather, all concrete surfaces shall be covered as soon as the concrete has been placed in order to keep the heat in and to help prevent freezing. Clean straw blankets, about 50 mm thick, sacking, tarpaulins, expanded polystyrene, plastic sheeting and waterproof paper can all be used in conjuction with air gap as an insulation. If possible insulating material shall be placed against any formwork before concreting and the same can be used as protection after the formwork has been stripped.

8.2.1 Recommendations for protection are given in Table 2 for concrete walls and floor slabs above ground, and in Table 3 for concrete slabs laid on ground at a temperature of 4·4°C, the concrete being placed at 10°C in each instance. The requirements are calculated for blanket type insulation with a conductivity of 360·6W/m.°C/m^2 for a thermal gradient of 0·22°C per cm and the values given are for still air conditions. The equivalent thicknesses of various insulating materials that may be used are given in Table 4.

8.2.2 For cement contents intermediate between those given in Tables 2 and 3, allowable air temperatures may be linearly interpolated.

8.2.3 Heated enclosures are commonly used for protecting concrete when air temperatures are near or below freezing. Enclosures may be heated by steam, steam pipes, and other types of heaters. Enclosures may be made of wood, canvas, fibre insulation board, plywood, etc.

8.2.4 During placement of unformed concrete, tarpaulins or other readily movable coverings supported on framework shall follow closely the placing of concrete, so that only a small area of finished slab is exposed to outside air at any time.

TABLE 2 INSULATION FOR WALLS AND SLABS ABOVE GROUND

(*Clauses* 8.2.1 *and* 8.2.2)

Wall Thickness	Minimum Air Temperature Allowable for Thickness of Blanket Insulation, °C			
mm	12 mm	25 mm	37 mm	50 mm
Cement Content = 300 kg/m³				
150	7·2	1·7	− 5·6	−10
300	1·7	− 9·4	−21	−32
450	−2·8	−19	−36	−54
600	−5·0	−23	−46	—
900	−7·8	−29	—	—
1 200	−8·3	−31	—	—
1 500	−8·9	−32	—	—
Cement Content = 400 kg/m³				
150	6·7	0	− 8·9	−14
300	0	−13	−27	−41
450	− 6·1	−26	−46	−67
600	− 7·8	−30	—	—
900	−11	−34	—	—
1 200	−12	−38	—	—
1 500	−12	−40	—	—

TABLE 3 INSULATION FOR GROUND SLABS

(*Clauses* 8.2.1 *and* 8.2.2)

Slab Thickness	Minimum Air Temperature Allowable for Thickness of Blanket Insulation, °C			
mm	12 mm	25 mm	37 mm	50 mm
Cement Content = 300 kg/m³				
200	5·6	0	− 6·1	−12
300	0	−12	−25	−37
450	− 8·3	−31	−53	−75
600	−16	−48	—	—
750	−24	—	—	—
900	−33	—	—	—
Cement Content = 400 kg/m³				
100	10	10	89	89
200	3·9	− 4·4	−13	−21
300	− 2·8	−18	−35	−51
450	−12	−40	−68	−95
600	−22	−61	—	—
750	−32	—	—	—
900	−42	—	—	—

TABLE 4 EQUIVALENT THICKNESS OF INSULATING MATERIALS

(*Clause* 8.2.1)

Insulating Materials	Equivalent Thickness
	mm
25 mm loose fill insulation of fibrous type	25
25 mm insulating board	20
25 mm sawdust	15
25 mm timber	8
25 mm damp sand	0·6

Such tarpaulins shall be used so that hot air can be circulated freely on the slab. Layers of insulating materials placed directly on the concrete are also effective in protecting the concrete.

8.3 Curing — During periods of freezing or near-freezing conditions, water curing is not necessary, as loss of moisture from the concrete by evaporation is greatly reduced in cold air conditions.

8.3.1 For concrete cast in insulated formwork it is only necessary to cover the member completely in order to retain sufficient water for the hydration of the cement. On removal of the formwork and insulation, the member shall be immediately covered with plastic sheet or tarpaulins, properly lapped and made wind-tight. On no account should such concrete, just released from insulated formwork, be saturated with cold water. When protective measures are to be discontinued, the surface temperature of the concrete shall be gradually adjusted to the air temperature.

8.3.2 Low pressure wet steam provides the best means of both heating the enclosures and moist curing the concrete. Early curing with liquid membrane-forming compounds may be followed on concrete surface with heated enclosures. It is better to cure first with exhaust steam during the initial period of protection and than apply a curing compound after the protection is removed and the air temperature is above freezing.

8.4 Removal of Forms — In cold weather, curing (though important) it not urgent and protection offered by forms other than of steel is often of greater importance.

With suitable insulations, the forms, including those of steel, in many cases will provide adequate protections without supplementary heating. Therefore, it is often advantageous not to remove forms until the end of the minimum period of protection or even later. Table 5 gives recommended minimum times for stripping formwork to normal structural concrete. The time limit indicated for removal of formwork to the sides of beams, columns and walls shall, in no case, be less than the prehardening period (*see* Table 6). If these forms are not immediately required elsewhere, it is advantageous to leave them in position, as this will accelerate the hardening process and shorten the time for striking load-bearing formwork. The time limits indicated in Table 5 are for general guidance only. When cubes have been stored and cured under actual site conditions (*see* **10.4**), they can be used to confirm whether concrete has attained the necessary strength to allow the safe removal of forms as per **10.3** of IS : 456-1978*.

TABLE 5 RECOMMENDED MINIMUM TIME LIMITS FOR STRIPPING FORMWORK TO NORMAL STRUCTURAL CONCRETE, WHEN THE MEMBER IS CARRYING ONLY ITS OWN WEIGHT

		Beam Sides, Walls and Columns	Slabs (Props Left Under)	Beam Soffits (Props Left Under)	Removal of Props to Slabs	Removal of Props to Beams
		Days	Days	Days	Days	Days
Ordinary Portland cement concrete	Cold weather air temperature about 3°C	5	7	14	14	28
	Normal weather air temperature about 16°C	1	3½	7	7	14
Rapid hardening Portland cement concrete	Cold weather air temperature about 3°C	3	4	8	8	16
	Normal weather air temperature about 16°C	1	2	4	4	8

9. INSPECTION, TEMPERATURE AND HUMIDITY RECORDS

9.1 During cold weather inspection personnel shall keep a record of the date, time, outside air temperature, temperature of concrete at the time of placing and general weather (calm, windy, clear, cloudy, etc). The record shall include temperature at several points within the enclosure and on the concrete surface, corners and edges in sufficient number to show the highest and the lowest temperatures of the concrete.

9.2 Thermometers shall be inserted in those parts of the concrete where maximum stresses will appear at the removal of forms.

*Code of practice for plain and reinforced concrete (*third revision*).

9.3 To control the hardening process it is necessary to measure the temperature of concrete at placing, at the time of applying the protection and three times each day until resistance to freezing has been obtained.

9.4 Table 6 gives the minimum prehardening periods that is, the time taken by different grades of concrete to reach the frost safety level, the concrete being made with ordinary Portland cement without any accelerator. The periods given in Table 6 start from the time when the concrete first stiffens.

9.4.1 For most medium strength structural grade concretes a reduction in the minimum prehardening period of 25 percent on those indicated in Table 6 can be taken when using rapid-hardening Portland cement. When using an accelerator in approved dosage, the minimum prehardening period can be reduced by 25 percent. However, whatever the measures taken to accelerate the hardening, the minimum prehardening period shall not be less than the following:

Curing temperature, °C	20	15	10	5
Minimum prehardening period, hours	12	16	24	36

TABLE 6 MINIMUM PREHARDENING PERIODS

(*Clauses* 8.4, 9.4, 9.4.1, *and* A-2.1)

Grade of Concrete	Requisite Prehardening Period at Stated Curing Temperature of Concrete in Hours			
	20°C	15°C	10°C	5°C
M 20	24	32	46	71
M 25	22	30	42	65
M 30	20	27	38	59
M 40	17	23	33	50

10. CONCRETE TESTING

10.1 Concreting in winter time requires that the quality control of concrete is carried out with great care. The test results shall be used for fixing the time of removal of insulations, forms, etc, or be the basis for further precautions at the building site.

In addition to the regular quality control, special emphasis shall be placed on:

a) Determination of the suitability of concrete making materials for winter concreting and control of the properties of fresh concrete,

b) Records of air temperature and measurements of concrete temperature at placing and during concreting, and

c) Control of strength development in the structure by testing similarly cured specimens.

10.2 Concrete Constituents and Fresh Concrete — The testing of the properties of the concrete constituents shall be carried out in accordance with IS : 1199-1959*. Of special importance is knowledge on the reactivity of the cement and control of the setting time of the cement. In addition, it is important to ensure that water cement ratio does not exceed the designed values. When air-entraining agents are used, the air content shall also be controlled.

10.3 Control Specimens — Under normal concreting conditions, test specimens are cast and cured in a standard way to indicate the potential strength properties of the concrete mix. For winter concreting, it is recommended that before the job is started preliminary tests are carried out in the laboratory of the selected concrete mix, cured at 5°C.

10.4 In addition to cubes as per **10.3** under winter concreting conditions it is necessary to cast a number of specimens the curing conditions of which are arranged in such a way that they are exposed to the same temperature and humidity conditions as the actual structure and preferably similar to those of the most exposed parts. These specimens are tested before stripping takes place to ensure that the indications of strength development obtained by temperature measurements are infact obtained.

10.5 In order to prevent drying out of the specimen, it is necessary that similarly cured specimens are kept in the moulds until testing takes place.

10.6 The specimens shall not be tested in frozen state.

APPENDIX A

(*Clause* 3.1)

EFFECTS OF COLD WEATHER ON CONCRETE PROPERTIES

A-1. EFFECTS ON COMPRESSIVE STRENGTH

A-1.1 Concretes mixed, placed and cured at temperatures lower than the normal develop strength at a slower rate. Effects of temperature of concrete on the development of compressive strength during the first 28 days can be expressed as in Fig. 2 from which it can be seen that the

*Methods of sampling and analysis of concrete.

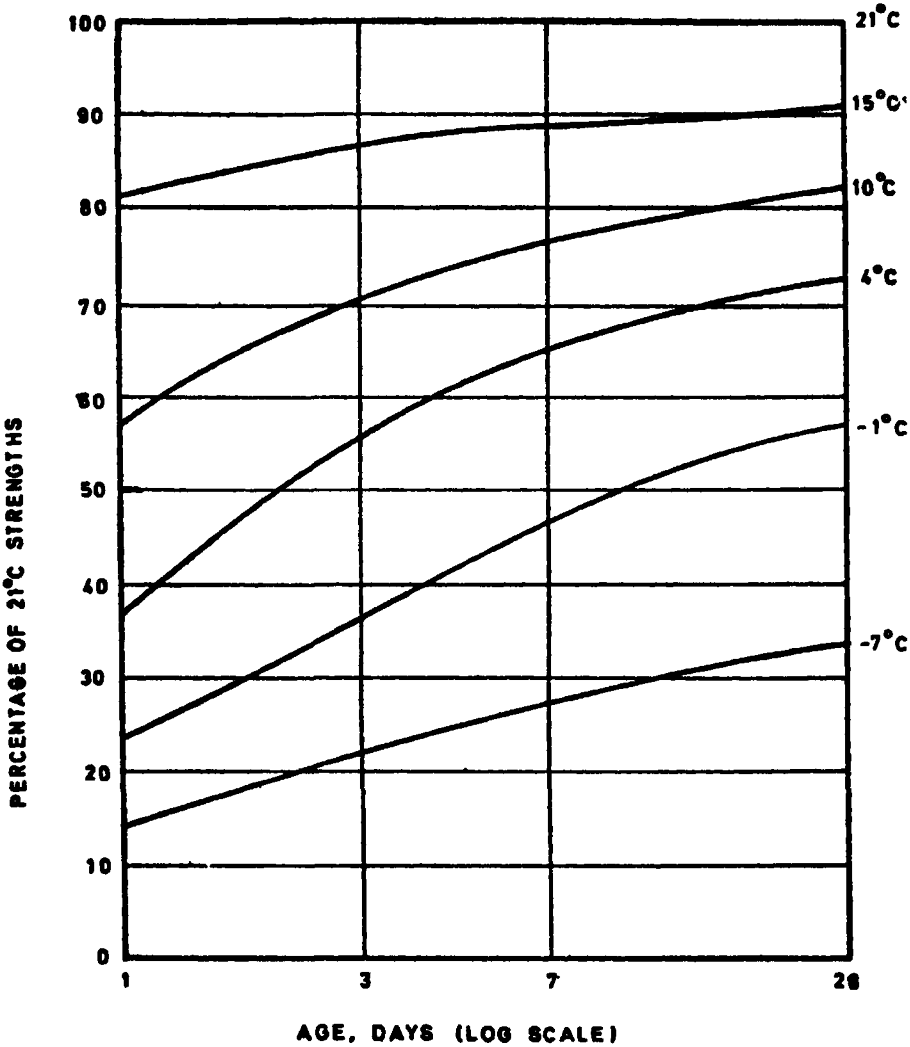

FIG. 2 EFFECT OF LOW TEMPERATURE ON COMPRESSIVE STRENGTH OF CONCRETE

strength could be lowered by 40 to 60 percent, even at temperature 5 to 10°C. However, this slower development of initial strength does not necessarily impair the long term strength and adequately protected concrete in winter would have the long term strength not significantly lower than at normal temperatures.

A-2. EFFECTS OF FREEZING OF FRESH CONCRETE

A-2.1 Freshly placed concrete is vulnerable to freezing temperatures so much so that if water in fresh concrete is allowed to be frozen, irreparable damage to the quality of concrete and permanent lowering of compressive strength can occur. Water, upon freezing, increases in volume by 9 percent, which in the case of ordinary concrete may mean an expansion of up to 2 percent. If concrete, while still plastic is allowed to freeze, the expansion of water could render the concrete useless and such damage would be obvious once the formwork is removed. Concrete which has stiffened, but not attained sufficient maturity to withstand such disruptive forces, can be damaged upon freezing in that the bond between the aggregates and the cement paste is weakened. This results in lowering of the compressive strength by 30 to 50 percent even for one cycle of freezing; the extent of damage depending upon the maturity attained (*see* Fig. 3).

In order to safeguard against such damage by early freezing, fresh concrete is required to be protected and its temperature maintained above freezing till such time that it attains sufficient strength to withstand the disruptive forces. The length of such prehardening time is specified either in terms of the period it attains certain compressive strength varying from 2 to 7 N/mm² or in terms of days the actual period depending upon the cement content, water-cement ratio and the degree of saturation. The minimum prehardening periods specified in Table 6 refer to the time required for the concrete to attain a minimum compressive strength of 2 N/mm² and is longer, the lower the grade of concrete.

A-3. EFFECT OF FREEZING AND THAWING CYCLES ON HARDENED CONCRETE

A-3.1 Similar disruptive effects of freezing of pore water make hardened concrete vulnerable to repeated cycles of freezing and thawing, even beyond the minimum prehardening period. Damages due to freezing and thawing is usually measured in terms of lowering of dynamic modulus of elasticity of concrete. Using the data on loss of dynamic modulus of elasticity with the number of freezing and thawing cycles on the one hand and the relationship between compressive strength and dynamic modulus of plasticity on the other, a typical relation between the loss of compressive

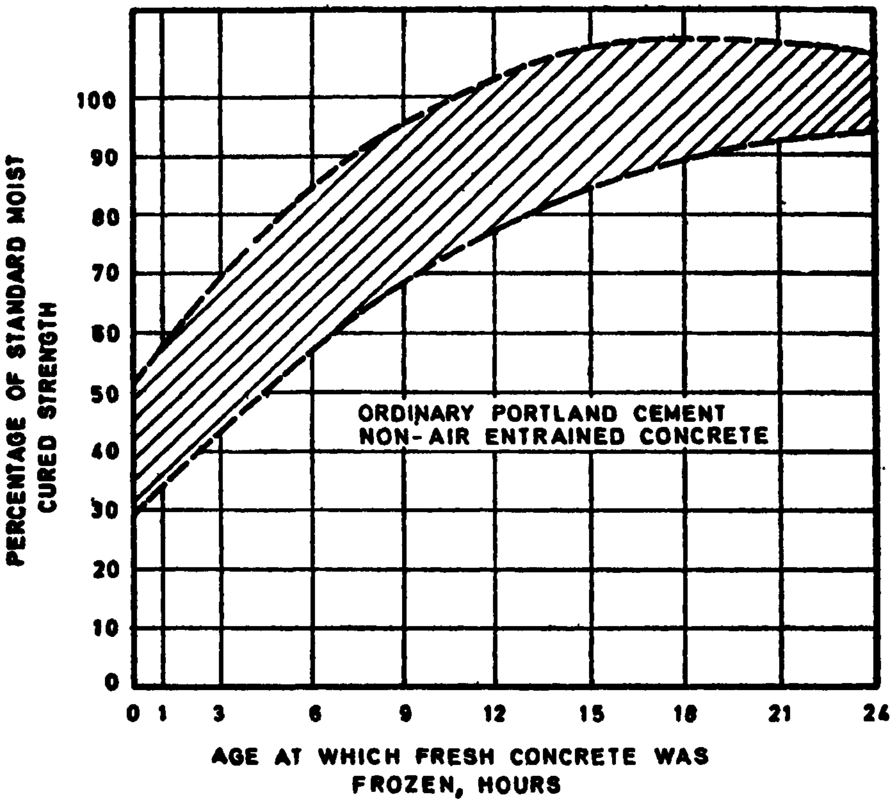

FIG. 3 EFFECT OF EARLY FREEZING OF CONCRETE

strength or the dynamic modulus of elasticity of concrete and the number of freezing and thawing cycles is given in Fig. 4. Entrainment of discrete air bubbles in the pore system of the concrete, by means of air-entraining admixtures, is the best remedy. Such voids do not contain water from the capillary pores due to surface tension effects, but under freezing conditions they behave as expansion chambers to accommodate the ice formed. Properly air-entrained concrete is satisfactory even in severe winter conditions provided other precautions in mixing, placing and curing have been taken.

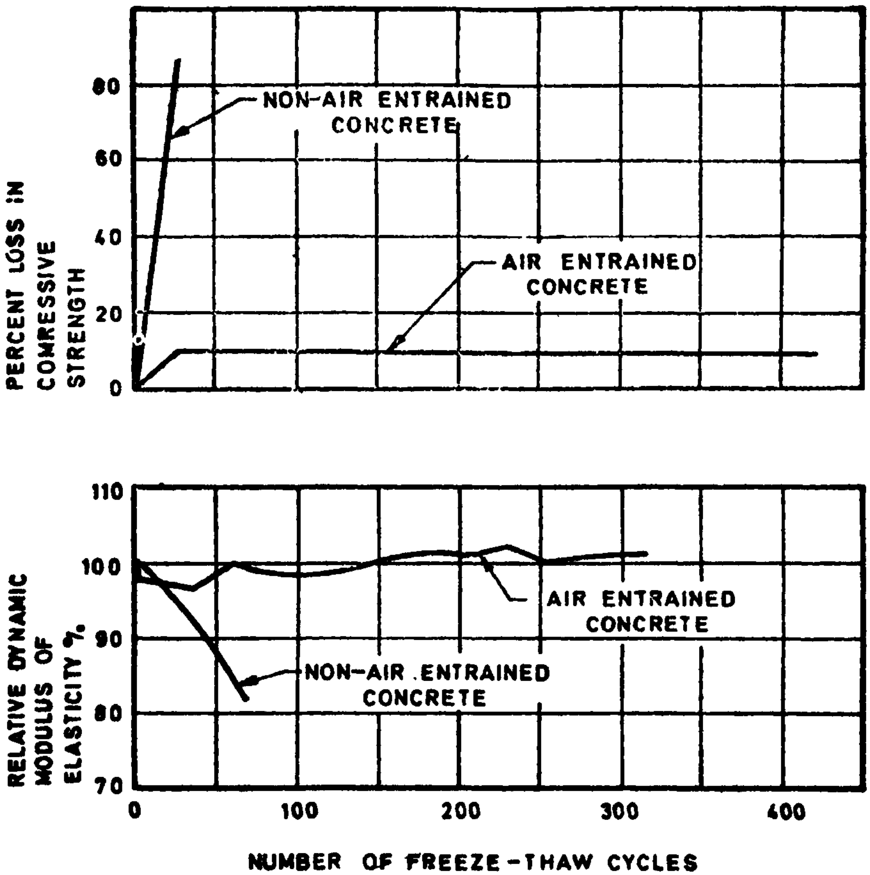

FIG. 4 EFFECTS OF REPEATED FREEZING AND THAWING ON HARDENED CONCRETE

APPENDIX B

(*Clause* 6.2.1)

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

B-1. Consider a concrete mix having the following ingredients (per m^3) and the initial temperature shown against each:

Cement	300 kg at 5°C
Water	210 kg at 60°C
Aggregates	1 779 kg at 1°C

The total aggregate contains coarse and fine fractions in the ratio of 2 : 1.

Moisture content of the aggregate—damp (4 percent in fine, 1 percent in coarse)

$W_{wa} = 35{\cdot}58$ kg

$T_{wa} = 1$°C

The temperature of fresh concrete as mixed with these ingredients will be:

$$T = \frac{0{\cdot}22\,(1\,779 \times 1 + 300 \times 5) + 210 \times 60 + 35{\cdot}58 \times 1}{0{\cdot}22\,(1\,779 + 300) + 210 + 35{\cdot}58}$$

$= 19$°C

(*Continued from page* 2)

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