TENTATIVE GUIDELINES
FOR
CONSTRUCTION OF CEMENT CONCRETE PAVEMENTS IN HOT WEATHER

Published by

The Indian Roads Congress
Jamnagar House, Shahjahan Road
New Delhi-110011
1976

Price Rs 40/-
(Plus Packing & Postage)

TENTATIVE GUIDELINES FOR THE CONSTRUCTION OF CEMENT CONCRETE PAVEMENTS IN HOT WEATHER

1. INTRODUCTION

1.1. These guidelines were approved by the Cement Concrete Road Surfacing Committee (personnel given below) in their meeting held at New Delhi on the 26th November, 1974.

K.K. Nambiar	*—Convenor*
Dr. R.K. Ghosh	*—Member-Secretary*

MEMBERS

D.C. Chaturvedi	K.C. Mital
Dr. M.P. Dhir	N.L. Patel
Brig. Gobindar Singh	P.S. Sandhawalia
C.L.N. Iyengar	A.R. Satyanarayana Rao
P.J. Jagus	S.B.P. Sinha
M.D. Kale	N. Sivaguru
Brig. R.K. Kalra	Dr. H.C. Visvesvaraya
Dr. S.K. Khanna	Director General (Road Development)
	C.V. Padmanabhan (co-opted)

These were processed by the Specifications & Standards Committee in their meeting held on the 12th and 13th December, 1975 and approved by the Executive Committee and the Council in their meetings held on the 22nd December, 1975 and 3rd January, 1976 respectively.

1.2. General

1.2.1. In tropical countries, such as ours, air temperatures may rise upto 40-50°C during summer months. Such high temperatures combined with high wind velocity and/or low humidity unduly accelerate the setting of concrete. The time available for transportation of concrete to the site, its placement, compaction and finishing becomes thereby limited, thus affecting adversely the properties and durability of hardened concrete. The early setting in hot weather poses an even bigger problem when concreting is done manually.

1.2.2. The procedures recommended for adoption in case of hot weather concreting are indicated in these guidelines. These are intended to ensure that the adverse effects of hot weather concreting are limited to the minimum. The guidelines are meant to supplement IRC: 15-1970—"Standard Specifications and Code of Practice for the Construction of Concrete Roads", and should be used in conjunction therewith.

2. SCOPE

2.1. It is difficult to define hot weather in terms of temperature alone as any single or a combination of the factors viz., high air temperature, low relative humidity and high wind velocity are likely to cause the problems associated with hot weather.

2.2. An appreciably high air temperature combined with a comparatively low relative humidity will be the most critical condition especially when in addition the wind velocity is also high. When air temperatures are identical, a dry windy day is likely to be more severe than a calm humid day. As a rough guideline, air temperature alone above 40°C, or a combination of air temperature above 35°C with relative humidity below 25 per cent and/or wind velocity higher than 10 km/hour as should constitute conditions necessitating precautions suggested in the guidelines.

3. THE PROBLEMS ASSOCIATED WITH HOT WEATHER CONCRETING

3.1. It is known that a concrete mixed, placed and cured at relatively higher temperatures develops higher early strength than that produced at normal temperatures, but at 28 days or later the strengths are generally lower than of concrete cured at 272±2°C. Tests have shown that insufficient curing, especially in combination with higher temperatures of placing, impairs hydration of cement and reduces the strength. High concrete temperatures combined with high air temperature, high wind velocity and low humidity enhance the rate of evaporation at the surface. This rate is much higher than that at which water rises to the surface of green concrete resulting in plastic shrinkage cracks. If the rate of evaporation is expected to be above 1 kg/m^2 per hour, precautions against plastic shrinkage cracking are necessary. Plastic shrinkage cracks may be the nucleus for other types of damage due to water penetrating through them. In the corner regions (where tensile flexural stresses are developed at the top under wheel load), they may increase tensile stresses at the root of these cracks thus transforming them to deep structural cracks in course of time. A ready-to-use chart for calculation of rate of evaporation of surface moisture of concrete from air temperature and humidity, concrete temperature and wind velocity is given in Fig. 1.

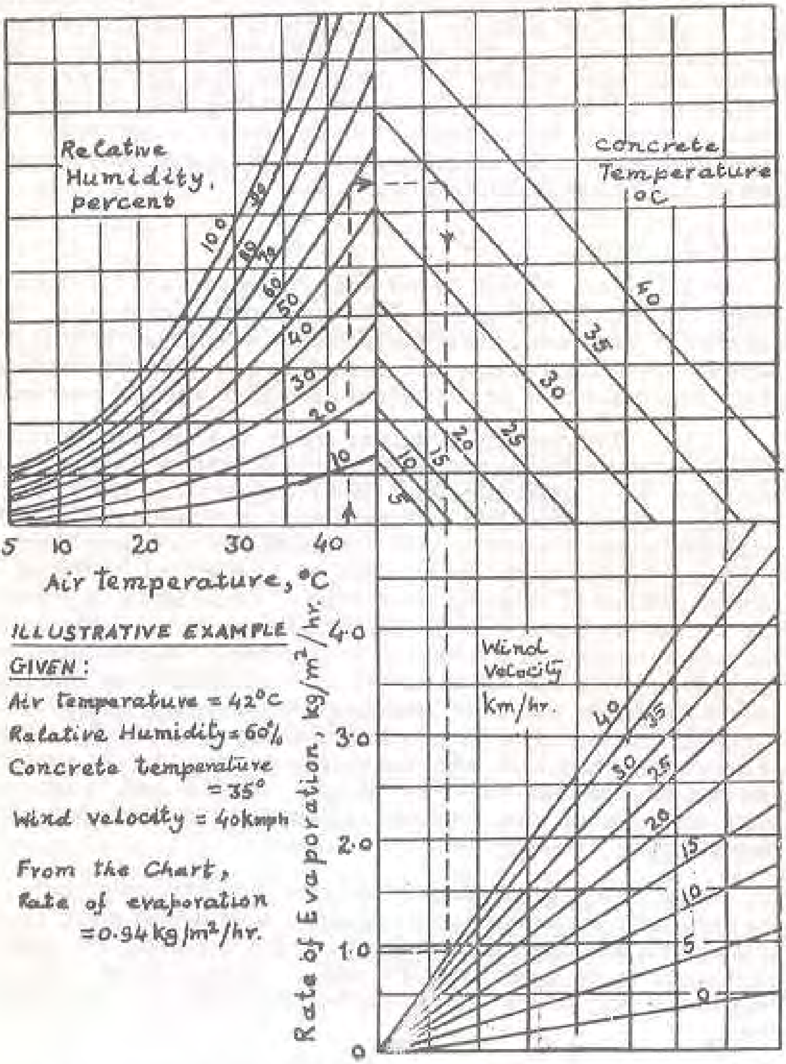

Fig. 1. Chart for calculation of rate of evaporation of surface moisture of concrete from air temperature and relative humidity, concrete temperature and wind velocity (enter the chart on the temperature scale and proceed as shown by dotted line, till the rate of evaporation scale is reached)

4. REMEDIAL MEASURES AGAINST ADVERSE EFFECTS OF HOT WEATHER CONCRETING-CONCRETE MATERIALS

4.1. A good quality concrete, which is strong, impermeable and durable against abrasion, chemical attack and adverse effects of weather, can only be achieved with suitable choice of materials, proper mix proportioning and satisfactory exercise of necessary controls at all stages of manufacture, placing and curing. The initial concreting temperature and subsequent temperature and humidity conditions during placement, finishing and curing operations influence significantly the end product.

4.2. Water

4.2.1. Even though water forms only 1/6 to 1/8 the total weight of concrete, the role it plays is of much significance. The quantity of water used, the temperature of water, the thermal properties of concrete, the rate of evaporation and bleeding are some of the major factors to be considered during hot weather placement.

4.2.2. The quantity of mixing water in a unit of concrete is decided primarily by the workability desired, besides the role of the maximum size of aggregate. Any need for higher workability means a higher water demand. In hot weather, if the temperature of the materials including water is not controlled, the resultant concrete will be of higher temperature. Due to accelerated hydration of cement and loss of water by evaporation, the concrete is prone to lose workability fast and in an effort to maintain the consistency, the unit water content will have to be increased. Merely increasing the water content without increasing the cement content will cause an increase in the w/c ratio, resulting in decreased strength and durability. It is known that the loss in slump could be of the order of 2.5 cm for every 11°C increase in the temperature of concrete and this could necessitate an addition of about 3 and 4½ per cent more water when the concrete temperature is 30°C and 50°C respectively.

4.2.3. Drying shrinkage of concrete is directly proportional to the unit water content and in a restrained mass it may mean avoidable distress due to tensile cracking. In hot weather, the rate of bleeding of water would be high and if there is scope for rapid evaporation by strong winds, plastic shrinkage cracking could result.

4.2.4. The specific heat of water being 4 to 5 times higher than the other component materials of concrete, the overall temperature of concrete is significantly affected by this one factor—the temperature of water. The use of cold mixing water (chilled water) has been found to effect a moderate reduction in the temperature of concrete. Therefore efforts should be made to obtain cold water and maintain it cool; trucks and tanks storing cold water and pipes carrying water must be insulated, and painted white or white-washed on the outer side. Pipes burried deeply will also be helpful in keeping water cool and this procedure may be adopted wherever practicable.

4.2.5. Ice may be used as a part of mixing water; the latent heat of ice (79.6 cal/gm) will assist in bringing about a further drop in temperature of concrete. Crushed or flake ice is normally added directly to the mixer and the mixing shall be continued until complete melting of the ice is ensured. Flake or solid ice remaining behind in the consolidated concrete may leave voids. The quantity of ice added should be taken into account in the total mixing water requirement.

4.3. **Cement**

The effect of higher temperature on cement is that the rate of hydration of cement is increased thus reducing the setting time considerably. Rapid stiffening results in increased water demand for equal mix consistency with consequent reduction in strength (unless the cement content is correspondingly increased) and increased plastic shrinkage. Use of rapid hardening cement should, therefore, be avoided in case of hot weather concreting.

4.4. **Aggregates**

High aggregate temperatures result in loss of moisture therefrom. Since total water demand by concrete corresponds to saturated surface dry condition of aggregates, additional quantity of water is required to be added to compensate for the loss of moisture in aggregates. High aggregate temperatures will also increase the temperature of the resultant concrete in the same way as high water and cement temperatures do leading to quicker rate of cement hydration and rapid evaporation of water from the concrete. Since aggregates constitute the largest part of concrete, the effect of increased aggregate temperature on the resultant concrete is also the maximum. Aggregates should, therefore, always be stacked under shade.

4.5. **Admixtures**

4.5.1. To off-set the accelerated setting of concrete in hot weather and to reduce the increased water demand, judicious use may be made of set-retarding and water-reducing admixtures. However, as some of the admixtures can cause undesirable secondary effects such as reduction in ultimate strength of concrete, or increase in bleeding, etc., it is recommended that only such admixtures should be used in respect of which adequate prior experience or test data are available.

4.5.2. Set-retarding admixtures include calcium ligno-sulphonate, various carbohydrates, other calcium salts, sulphates of zinc, aluminium, copper and iron. These are generally used in quantities equivalent to 0.05 to 0.5 per cent by weight of cement. Of the various carbohydrates, use of sugar has been reported to be very promising as a set-retarding and water-reducing agent. The retarding admixtures may conveniently be added to the mixing water. Addition of 0.05 per cent sugar has been found to retard the setting time of concrete by about 2 hours in outdoor hot weather condition of 44°C temperatures. For the same water-cement ratio, workability and strength are also improved. For equal strength, the sugar admixed concrete could enable a leaner mix to be used, resulting in about 4 per cent saving in cement. The dosage of sugar is very important and overdosing may lead to harmful effects. Adequate care should, therefore, be exercised in measuring the quantity of sugar to be added.

5. REMEDIAL MEASURES AGAINST ADVERSE EFFECTS OF HOT WEATHER CONCRETING: PRODUCTION, PLACEMENT AND CURING OF CONCRETE

5.1. The control of concrete temperature is best done at the time of mixing. For concretes of conventional mix proportions, a reduction of concrete temperature of 0.5°C requires reducing the cement temperature by about 4°C, the water temperature by 2°C or the aggregate temperature by 1°C. Since the largest constituent in concrete is aggregate, reduction in aggregate temperature will bring about the maximum reduction in concrete temperature. Hence efforts should be made to keep the aggregates as cool as possible. This can be done by stacking them under shade and/or by sprinkling water on aggregate stockpiles, or by inundating with water. Relationships to calculate the temperature of freshly mixed concrete from the temperatures and weights of the different ingredients are available, which can be used wherever needed. The relationships are given in *Appendix* for guidance.

5.2. Batching and mixing times should be kept to the minimum feasible for uniform mixing with adequate number of units and proper management of personnel and sequence of operations.

The mixer could be painted white on the outer side to inhibit absorption of heat from sun and air. The mixer drum and blades should be checked frequently, as the hardened materials getting stuck to the inside faces are likely to reduce the efficiency of the mixer. There should be sufficient number of wheel barrows (or taslas) so that very little time is utilised in transport. The location of the batching and mixing units should be such that the lead is kept to the minimum. To keep up the speed of construction, several work heads may be simultaneously operated.

5.3. The formwork should be covered with earth from outside which could be kept wet continuously. The concrete should be placed, as far as possible, in its final position without the need for much rehandling. Breakdowns or delays slowing the progress of work are likely to seriously affect the quality of concrete. Sufficient number of screed and needle vibrators with stand-by units and adequate manpower including mechanics should be readily available. The working condition of the equipments should be frequently checked and maintained in very good order and all necessary spares also should be kept handy. Breakdowns of vibrators may be safeguarded against in view of the early stiffening of the mix. Ample supply of water for mixing, dampening of sub-base, curing etc., should be readily available. The location of joints including construction joints should be planned well in advance and all the materials including joint filler, dowel bars, tie bars, bulk head, etc., should be in place quite in advance so that placement of concrete is not delayed at any stage.

5.4. Sometimes when the air temperatures and drying conditions are very critical (i.e., when rate of evaporation approaches 2.5 $kg/m^2/hour$), concrete placed during morning hours may attain an undesirably high temperature around noon. During subsequent cooling, very high thermal stresses may be induced. In such cases, it will be advisable to cover the concrete with wet gunny bags or hessian cloth as early as possible. Alternatively, concreting may be done towards the evening or in extreme cases even at night.

5.5. The placing, compacting and finishing operations should be specially speeded up and at the same time the operations should be so coordinated that concrete is not placed faster than it can be properly compacted and finished with the available equipment and manpower. The stipulations regarding thicknesses of individual layers in case of two layer construction as specified in IRC: 15-1970 should be strictly followed.

5.6. The concrete in place shall be covered with tarpaulins mounted on travelling stands or similar arrangements during noon

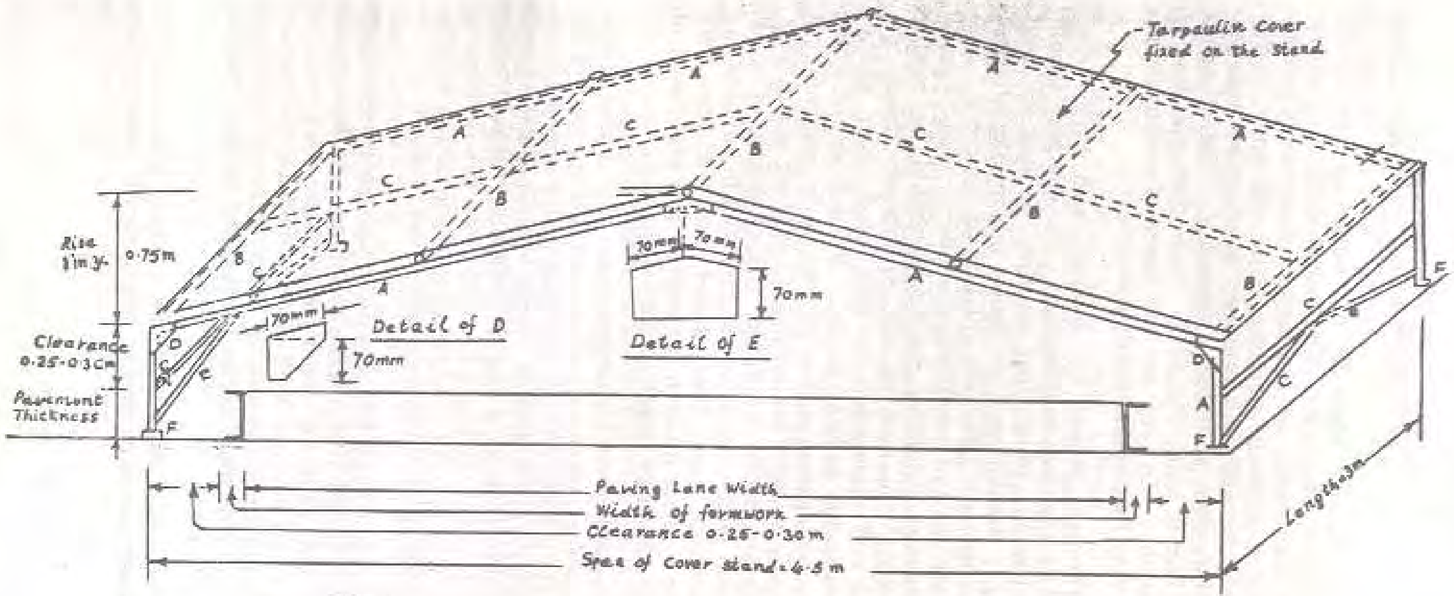

Fig. 2. A typical cover stand for sheltering freshly laid concrete pavement in hot weather

SCHEDULE OF MEMBERS

A : M.S. Angle, 40×40×5 mm
B : M.S. Tubing, 22 mm O.D. 12 SWG thickness
C : M.S. Angle : 25×25×3 mm
D : M.S. Plate, 5 mm thick
E : M.S. Plate, 5 mm thick
F : M.S. Plate 6 mm thick/wheel and Castor arrangement

hours (11.00 a.m. to 5.00 p.m.) of the 24 hours subsequent to laying. A typical sketch of cover is shown in Fig. 2. For an average daily output of 30 m length with semi-mechanised construction, a minimum of 10 such cover stands would be required per work head. There should be sufficient supply of wet hessian cloth for initial curing which will have to be started much earlier than in the case of concreting in normal weather. Subsequent curing by ponding should be thorough and therefore regular supply of water be ensured. The total curing period should not be less than 28 days. Membrane curing with plastic type membrane shall not be permitted. However, where water is scarce, liquid membranes, such as sodium silicate or silicones may be used provided a uniform layer is applied. This may, however, result in slight less in strength *vis-a-vis* water curing.

5.7. The quality control tests, as per IRC: SPL. 11-1973: "Handbook of Quality Control for Construction of Roads and Runways", should be conducted on samples of concrete as quickly as possible, so that they correspond to the actual condition. Greater care is necessary in this case since smaller quantities collected as samples are more prone to the hazards of hot weather than the concrete in-situ itself. Proper care should be taken in the protection and curing of specimens for strength test. Apart from the usual control steps, frequent checks should be made on air temperature, concrete temperature, wind velocity and relative humidity. The general weather conditions such as clear sky or cloudy etc., should also be recorded. The appearance of the concrete at each stage, the time interval between each stage, the time of start of curing, the special protective measures taken at each stage etc., should all be recorded while the work is in progress so as to be useful at a later date in assessing the quality of concrete at a particular location.

Appendix

ESTIMATION OF TEMPERATURE OF FRESHLY MIXED CONCRETE FROM THE TEMPERATURES AND PROPORTIONS OF THE MIX INGREDIENTS

The temperature of freshly mixed concrete can be estimated from the temperatures and proportions of the mix ingredients, using the formulae given below :

Case I. Without the addition of Ice

$$t = \frac{W_a . t_a . S_a + W_c . t_c . S_c + W_w\, t_w\, S_w}{W_a\, S_a + W_c\, S_c + W_w\, S_w} \quad \ldots (1)$$

with t = temperature of freshly mixed concrete (°C)

t_a, t_c, t_w = temperature of aggregate, cement and mixing water respectively (°C)

S_a, S_c, S_w = specific heats of aggregate, cement and water respectively (cal/gm°C).

W_a, W_c, W_w = weight of aggregate, cement, and water respectively (kg)

As $S_a = S_c$ = 0.22, and $S_w = 1$, the formula reduces to :

$$t = \frac{0.22\,(W_a t_a + W_c t_c) + W_w\, t_w}{0.22\,(W_a + W_c) + W_w} \quad \ldots (2)$$

Note: In case the aggregates contain some free water, its temperature will be the same as that of the aggregate. Moreover, the water added at the mixer will be adjusted in this case to allow for the free water in the aggregate, such that :

$$W_w = W_{wm} + W_{wa} \quad \ldots (3)$$

with W_{wm} = water added at the mixer (temperature W_w)

W_{wa} = free water present in the aggregate (temperature W_a)

$$t = \frac{0.22\,(W_a t_a + W_c t_c) + W_{wm}\, t_w + W_{wa} t_a}{0.22\,(W_a + W_c) + (W_{wm} + W_{wa})} \quad \ldots (4)$$

Case II With the addition of Ice.

If part of water added at the mixer is replaced with ice, the formula (4) modifies to :

$$t = \frac{0.22\,(W_a t_a + W_c t_c) + (W_{wm} - W_i)\, t_w + W_{wa} t_a - 79.6 W_i}{0.22\,(W_a + W_c) + (W_{wm} - W_i) + W_{wa} + W_i}$$

with W_i = weight of ice added at the mixer (kg)

and W_{wm} = weight of water + ice added at the mixer (kg).