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CODE OF PRACTICE
FOR
CURING OF CEMENT CONCRETE PAVEMENTS

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Mathura Road, New Delhi-110044

Published by
THE INDIAN ROADS CONGRESS
Jamnagar House, Shahjahan Road,
New Delhi-110 011
1983

Price Rs 24
(plus packing and postage)

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1. INTRODUCTION

1.1. The purpose of adequate curing of cement concrete after its placement and finishing is to maintain satisfactory hygro-thermal conditions for continued and progressive hydration of cement. The importance of maintaining satisfactory moisture condition is evident from the fact that hydration of cement can take place only if the capillary pores remain saturated. It is also necessary to supplement the mixing water to account for the water needed to fill the gel pores formed as a result of hydration of cement. Optimum temperature conditions are important in view of the fact that at lower temperatures, the rate of hydration of cement is slow, whereas if the initial temperature is higher, the long term strength of concrete may be lowered.

1.2. Fresh concrete exposed to the atmosphere may lose water due to evaporation. In case of pavement concrete, the chances of rapid evaporation of water are more because of the relatively greater surface-to-volume ratio. It is, therefore, necessary to prevent such evaporation of water from fresh concrete by proper curing.

1.3. In the absence of proper curing, the concrete may exhibit excessive shrinkage cracks and will not have adequate strength, durability and resistance to abrasion, even if the materials and techniques used in making, placing and compaction of concrete are satisfactory.

1.4. In view of these considerations, it is necessary to ensure proper curing of concrete by maintaining favourable moisture and temperature conditions for freshly laid and finished concrete for some stipulated period before it is put to service, to assure proper hydration of cement and proper hardening of concrete.

1.5. This Code of Practice was approved by the Cement Concrete Road Surfacing Committee (personnel given below) in their meeting held at Patna on the 28th December, 1980.

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This was then processed by the Specifications & Standards Committee in their meeting held at *New Delhi* on the *11th October* 1982, and later approved by the Executive Committee and the Council in their meetings held on *13th & 24th December 1982* respectively.

2. REQUIREMENT

2.1. Preservation of moisture content of the paving concrete may be accomplished by any of the several methods or by a combination of two or more methods. The surface of the concrete may be kept wet with water, or loss of moisture may be prevented or restricted by the application of impervious coatings, membranes, or coverings.

2.2. Curing of concrete may be achieved in a wide range of temperatures. The rate at which hydration of the cement occurs varies with the temperature of the concrete, proceeding slowly at low temperatures, and rapidly at high temperatures. Concrete will cure at any low temperature above freezing, but it is necessary that sufficient time and moisture be provided for it to obtain required strength, and that it is protected from freezing.

Curing at higher temperatures in excess of 40°C may not be desirable particularly when combined with high wind velocity and/or low humidity. There is some evidence, however, that curing temperatures higher than about 30°C may somewhat affect the long-term service life of a pavement. For air temperature 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/hr., instructions contained in IRC:61-1976 "Tentative Guidelines for Construction of Cement Concrete Pavements in Hot Weather" may be followed.

2.3. The setting and hardening of concrete is indicative of the early progress of hydration of cement. Mechanical disturbance of concrete during this process, when the concrete has little ability to take stress, results in the failure to form the integral solid intended in the design of the pavement. Premature stressing, vibration or shock of the concrete is therefore to be meticulously avoided.

2.4. The minimum period required for the concrete to attain the strength desired for safe use varies with the design strength of the pavement, type of cement used, the temperature at which the concrete is cured and the availability of moisture for hydration of cement through curing. The period of curing of concrete pavements under normal and other conditions is stipulated in IRC : 15-1981 "Standard Specifications and Code of Practice for the Construction of Concrete Roads".

2.5. The most conventional method of curing in this country is to use damp hessian cloth, burlap or gunny bags (jute mats) for the initial 24 hours followed by ponding with water. Water used for curing shall not contain salt in injurious amounts. Generally, any potable water can be used. In case of doubt, the water shall be tested to conform to the requirements of curing water stipulated in IS:456-1978. In areas where water is not easily available and is costly or where construction is on slope so that ponding is not practicable, membrane curing using liquid or solid membrane may be adopted. Liquid membranes have, however, hardly ever been used in this country and are not generally available.

3. CONVENTIONAL METHOD OF CURING

3.1. Curing procedure for concrete pavement involves two stages: initial curing and final curing.

3.2. Initial Curing

3.2.1. On completion of the final finishing operation in pavement construction, the surface needs to be protected as early as possible against the effects of hot dry weather and/or strong drying winds. This process may be termed as initial curing and comprises the covering of pavement surface by damp hessian cloth, burlap or gunny bags as soon as it can take their weight without impression.

3.2.2. When the air temperature and drying conditions are very critical, additional precautions such as covering the concrete-in-place with tarpaulins mounted on travelling stands or similar arrangements during hottest hours (11.00 AM to 5.00 PM) of the 24 hours subsequent to laying shall be adopted as stipulated in IRC:61.

3.2.3. The hessian cloth or burlap is available in rolls about 1 m in width and of standard, medium and superior quality, and shall be laid across the pavement. An overlap of about 150 mm shall be provided at each joint of the strips. The overlapping in the case of gunny bags may be about 75-100 mm. The matting shall extend at least 500 mm beyond the edges of the slab.

3.2.4. The matting shall be so placed that the entire surface and both the edges of the slab are completely covered. The matting shall be placed as soon as the concrete has sufficiently set to prevent marring of the surface. Prior to their being placed, the covering shall be thoroughly wetted with water and placed with the wettest side down. The matting shall be so placed and weighed down as to cause them to remain in intimate contact with the surface covered. They shall be maintained fully wet and in position for 24 hours after the concrete has been placed, or at least until the concrete is sufficiently hard to be walked upon without suffering any damage. To maintain the matting wet, water shall be gently sprayed so as to avoid damage to the fresh concrete. If it becomes necessary to remove the matting for any reason, the concrete slab shall not be kept exposed for a period of more than half an hour.

3.2.5. Worn matting or matting with holes shall not be permitted. Matting reclaimed from previous use shall be thoroughly washed prior to use for curing purposes.

3.2.6. The mattings shall be placed from suitable wooden bridges (see IRC: 43 "Recommended Practice for Tools, Equipment

and Appliances for Concrete Pavement Construction"). Walking on freshly laid concrete to facilitate placement of matting shall not be permitted.

3.3. Final Curing

3.3.1. The final curing follows immediately after the initial curing. It is generally done by ponding of water after the hessian cloth or other matting used for initial curing is removed. The matting shall be removed in parts so that the surface is not left exposed for more than one-half of an hour, before steps are complete for final curing.

3.3.2. The exposed edges of the slab shall first be banked with a substantial berm of local soil (about 200 mm base, 100 mm height and 150 mm top). Upon the slab shall then be laid a system of transverse and longitudinal dykes of clay about 50 mm high and 150 mm wide, covered with local soil (preferably sandy soil) free from stones so as to provide roughly trapezoidal bunds of about 150 mm base, 100 mm height and 100 mm top. The rest of the slab shall then be covered with sufficient local soil (preferably sandy soil) so as to produce a blanket of earth not less than 40 mm in depth after wetting.

3.3.3. The earth covering shall be thoroughly wetted by pouring water lightly so that either the soil does not get displaced exposing the concrete or the bunds do not get damaged. If the earth covering becomes displaced during the curing period, it shall be replaced to the original level and re-saturated. The ponds shall be provided with water whenever the need arises, keeping in mind that at no stage the soil shall be allowed to dry out till the 14th day after the initial curing has been started.

3.3.4. In the morning of the 15th day, the soil shall be thoroughly wetted down and allowed to remain in place (generally till the 28th day) until the concrete has attained the required strength and permission is given to open the pavement to traffic.

3.3.5. Once permission to open the pavement to traffic has been granted by the Engineer-in-Charge the soil covering with dykes, bunds and berms shall be removed. Any material falling into the joints shall be raked out completely and the pavement swept thoroughly clean with water.

3.4. Curing of Airfield Pavements

3.4.1. In case of airfield pavement, the procedure for initial

curing (para 3.2.) will remain the same. While the procedure mentioned in para 3.3. for final curing can be followed, it may be rather costly because the width (runway 50 m, and taxitracks 25 m) involved is very large and the carriage and placement of clay/soil will entail large labour force and considerable time.

3.4.2. In such a case, an alternative method consisting of ponds of size about 1.5 m × 1.5 m × 5 cm with bunds of roughly equilateral triangular cross-section (base and height about 50 mm each) made of 1:12 to 1:15 cement-sand mortar may be adopted. The bunds may be made by pressing the mortar with trowel against a wooden strip having a face of 1.5 m × 5.0 cm.

3.4.3. While the bunds are being made, the pavement shall be kept wet by sprinkling water gently with rose cans. After about 6-8 hours of making the bunds, water is poured slowly into the pond to a depth of 20-30 mm. The ponds shall not be allowed to dry during the stipulated period of curing but in no case less than the 14th day from the start of the initial curing. After the permission to open the airfield to traffic has been granted by the Engineer-in-Charge, the bunds shall be removed by light chiselling. Any material getting into the joints shall be removed by raking and the pavement thoroughly swept clean with water.

4. MEMBRANE CURING

4.1. In areas where water is not easily available and is costly or where the pavement is in slope so that curing by ponding of water is not feasible, pavement may be cured by membranes. The membranes are of two types:

(a) Solid membranes, and

(b) Liquid membranes.

While liquid membranes are not generally available and have hardly ever been used in the country, solid membranes have been used in desert region and in ghat sections. In case of solid membrane curing, it is desirable to use wet matting as described in para 3.2. for initial curing and adopt solid membrane for final curing. Where, however, water is extremely scarce, complete curing may be done with solid membrane as in the case of liquid membrane.

4.2. Solid Membrane Curing

4.2.1. As solid membrane, polyethylene (or plastic as commonly known) sheets or bituminous waterproof papers may be used. While the plastic sheets shall be transparent and of at least 400 gauge, the bituminised waterproof papers may be multi-ply paper bonded together with bitumen. Heavy duty papers should besides be reinforced with fibre mesh of cotton, jute or hessian.

4.2.2. Where no wet matting is adopted for initial curing, the membrane shall be applied within $\frac{1}{2}$ to 1 hour of final finishing, taking the same precautions to prevent any damage to the broomed surface or sides of the freshly laid concrete as described in para 3.2. Where membrane is used for final curing only, it shall be laid after removing the wet matting in accordance with para 3.3.1. In this case, water shall be sprinkled lightly with rose cans before the membrane is laid.

4.2.3. The procedure to be adopted when solid membrane is used for curing consists of spreading the membrane of suitable width (1-2 m) and length 500 mm more than the pavement width. The ends shall be tucked with compacted local soil to prevent fllapping or removal of the membrane under wind pressure. At each transverse joint of the membrane, an overlap of about 300 mm shall be provided. While on the overlapped portion slightly compacted bunds (approximate cross-section 100 mm $\times$ 100 mm) of local soil shall be provided, wooden battens (about 3 m $\times$ 5 cm $\times$ 5 cm) shall be placed over the sheet. Such battens shall be placed at 3 m intervals. In case a sheet is found to be damaged subsequently, water shall be sprinkled over the pavement under the damaged sheet followed by covering the portion with an additional piece of membrane and a heap of soil thereupon or on the sides of the piece depending on the size patched. A practical observational method of finding out whether any damage has occurred to the sheet or not, is to look for the presence of water drops underneath the membrane. If water drops are present, it may be considered that the membrane is intact.

4.2.4. Membrane curing shall be continued upto the 28th day from the start of the initial curing. After the permission has been received from the Engineer-in-Charge to open the pavement to traffic, the battens, bunds and the membrane shall be removed. Any material getting into the joints shall be removed by raking and the pavement thoroughly swept clean preferably with water.

4.3. Liquid Membrane Curing

4.3.1. The liquid membrane shall consist of a practically colourless, impervious liquid of a type approved by the Engineer-in-Charge. The bituminous membranes such as emulsions, whilst being efficient in preventing loss of moisutre have the following objections against their use: (a) the unsightly appearance of the resultant concrete surface and (b) excessive heat absorption due to dark colour leading to high temperature stresses and surface cracking of concrete pavement. Besides, the stability of such emulsions is likely to be affected through their breakdown at low temperature and under continuous storage. The use of any liquid membrane which would impart a slippery surface to the pavement shall not be permitted.

4.3.2. Among the light coloured liquid membranes, silicones wax emulsions 25-50 per cent diluted, linseed oil, resinous solutions, sodium silicate solution (diluted with 20 per cent water to attain paint consistency), etc. have been known to be in use abroad. Some of these like resinous solutions are prohibitive in cost.

4.3.3. The liquid membrane shall be applied under light pressure with a spray-nozzle in such a manner as to cover the entire surface with a uniform film, and shall be of such a character that it hardens within 30 minutes after application. The amount of liquid applied shall be ample to seal the surface of the pavement thoroughly. The liquid shall be applied after the finishing of the surface and before the cement has set (preferably within 1 hour of finishing) or, if the pavement is first covered with hessian cloth, burlap or the like for initial curing, it may be applied upon their removal.

4.3.4. The impervious coating used shall be such that, when applied to the surface of test slabs made of cement sand mortar, it shall retain at least 90 per cent of the mixing water when exposed for 72 hours to temperatures between 35 and 38°C, at a relative humidity of 30 to 35 per cent. To check this the supplier shall be required to provide the results of type test made with the product by a recognised and reputed laboratory.

4.3.5. The mortar test slab used in the type test shall be composed of one part cement, 1.71 parts fine aggregate and 0.346 parts of water, by weight. The slab shall be cast in a non-absorbent watertight mould, and shall remain in the mould throughout the test. The slab shall be approximately 400 mm long by 400 mm

wide by 50 mm deep. The coating shall be applied to the exposed surface of the slab within 2 hours of the time the slab is cast.

4.3.6. Materials for use as impervious coatings will be approved by the Engineer-in-Charge on the basis of test outlined above. The rate of application of such coatings will be prescribed by the Engineer-in-Charge on the basis of the same tests.

4.3.7. Curing period shall be the same as stated in para 4.2.4. Special care has to be taken to thoroughly clean the surface cured with such membranes to prevent a slippery surface leading to traffic accident, even though the coatings will get worn off soon under traffic. While hardened sodium silicate may be removed by water jet, wax and other oily materials may need sand blasting.

5. CONCRETING AT HIGH TEMPERATURE

5.1. The air-temperature alone above 40°C, or a combination of air temperature above 35°C with relative humidity below 25per cent and/or wind velocity higher than 10 km/hour, should be considered as constituting conditions necessitating special precautions suggested in IRC : 61. Brief details are given in paras 5.2. and 5.3.

5.2. Under hot weather conditions, the finished concrete pavement shall be covered with wet hessian cloth, burlap or gunny bags as early as possible. Alternately, concrete may be done towards the evening or in extreme cases even at night.

5.3. The concrete-in-place shall be covered with tarpaulins mounted on travelling stands or similar arrangements during noon hours (11.00 AM to 5.00 PM) of the 24 hours subsequent to laying. There shall be sufficient supply of matting 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. The total curing period should not be less than 28 days. Solid membrane curing shall not be permitted. However, where water is scarce, liquid membranes may be used.

6. CONCRETING AT COLD TEMPERATURES

6.1. Ambient Temperature Below 4°C

6.1.1. Except by specific written authorisation from the Engineer-in-Charge, no concreting shall be done when a descending

air temperature in the shade and away from any artificial heat drops below 4°C, nor shall concreting be resumed until an ascending air temperature in the shade and away from the artificial heat reaches 4°C.

6.1.2. When written authorisation is granted to permit concreting at temperatures below those specified above, various steps, heating equipment and arrangements, addition of accelerators etc. as stipulated in IRC : 15 shall be strictly followed. At the time of placement between forms, the concrete temperature shall not be less than 10°C (under no circumstances less than 5°C) and not more than 32°C.

6.1.3. When concrete is being placed in cold weather and the air temperature is expected to fall below 4°C, the air surrounding the concrete shall be maintained at a temperature of 10°C for at least 3 days or not less than 5°C for a period of not less than 5 days, by using suitable insulating material of adequate thickness alone, or in conjunction with steam/warm air circulation, depending on the severity of conditions.

6.1.4. During placement of concrete, tarpaulin or other readily removable coverings should closely follow the finishing operations so that only a few metres of the finished slab are exposed to the outside air at any one time, and that too, for the briefest possible period.

6.1.5. Where steam or warm air is provided, the covering shall be so arranged as to ensure its free circulation on top and sides of the pavement. For this purpose, low height wooden bridges required for surface finishing or initial curing operations may be used to hold the covering. If tarpaulin is used as covering, the bridges may be placed at about 2 m spacing. If available, tarpaulin covering fixed on wooden or metal frame may be preferable. Light mattings of 3.5 cm saw dust, straw or other similar materials may be provided in addition over the covering for heat insulation. Steam would be more desirable than warm air. In the case of the latter, occasional sprinkling of warm water (temperature coresponding to that stipulated in para 6.1.3.) would be required to keep the pavement surface wet. Steam or warm air could be circulated under the enclosure through a suitable tubing system. The same system may also be utilised to spray warm water intermittently in case of warm air circulation. While steam production would require a regular or makeshift boiler at the site, warm air could be generated by forcing air, by means of a blower of appropriate capacity, through a furnace. Any available fuel e.g. coal, oil or

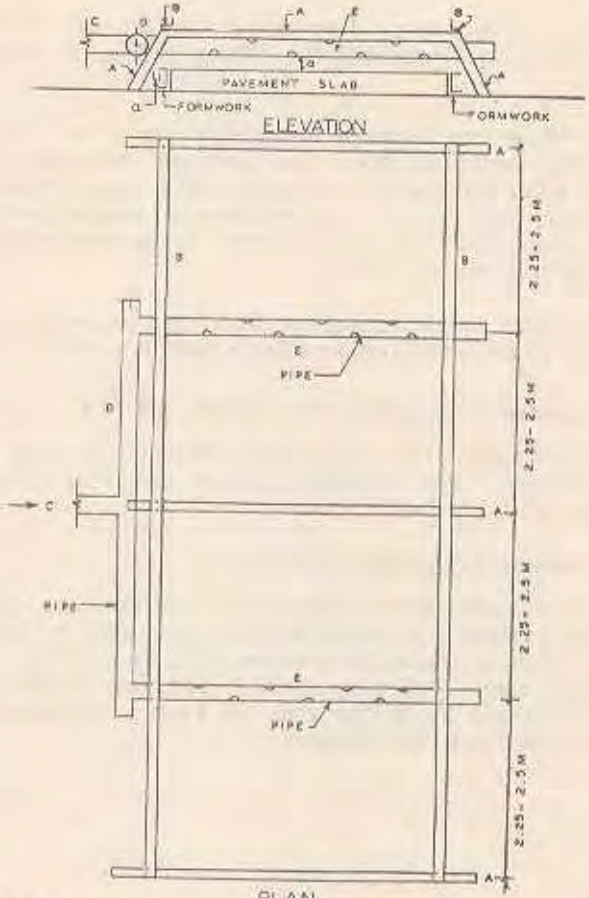

FIG. 1. TYPICAL DESIGN OF FRAME AND TUBING SYSTEM FOR HOT AIR/STEAM CURING ENCLOSURE FOR PAVEMENT SLABS IN COLD WEATHER

Legend

A — Trapezoidal frame stands, made of angle iron or wood, spacing 4.5-5 m.
B — Angle iron or wooden member for fixing the frame stands in position.
C — Steam/hot air/water inlet pipe.
D — Distributor pipe.
E — Perforated discharge pipes for steam/hot air/water, spacing 4.5-5 m.

Notes : 1. The covering of tarpaulins or other material over the frames to form enclosure for hot air/steam not shown.

2. The steam/hot air distribution system may be secured in position by fixing to the members B and/or by supporting from below at the ends of the pipe E.

3. Minimum clearance 'a' to be not less than 7.5 cm.

electricity may be used to produce heat in the furnace. A typical design of a trapezoidal frame with the tubing system is shown in Fig. 1.

6.1.6. Where conditions do not justify steam or warm air treatment, the insulating layer for covering concrete may be composed of water-proof paper, overlaid with a layer of saw dust or straw, and finally with a second layer of water-proof paper. Saw dust or straw, 10-30 cm thick, is likely to protect concrete in air temperatures as low as −4°C.

6.1.7. Under no circumstances shall the concreting operations continue when the air temperature is less than −7°C.

6.2. Ambient Temperature Between 4°C and 14°C

For this condition, the stipulations contained in para 6.1.6. shall be followed. The thickness of the insulating layer may, however, be reduced to 5—10 cm.

6.3. Ambient Temperature Above 14°C

For ambient temperature above 14°C, but less than 35-40°C, normal curing procedure indicated in para 3 or 4 may be adopted. In case of 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/hr, the stipulations contained in para 5 shall be followed.