STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR CONSTRUCTION OF CONCRETE ROADS

(Third Revision)

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STANDARD SPECIFICATIONS
AND
CODE OF PRACTICE
FOR
CONSTRUCTION OF
CONCRETE ROADS

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STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR CONSTRUCTION OF CONCRETE ROADS

1. INTRODUCTION

The Standard Specifications and Code of Practice for Construction of Concrete Roads was first published in July, 1965 and the 2nd edition was brought out in December, 1970. Since then, the technology for road construction has undergone considerable changes. Therefore, a need was felt to update the standard. The draft revision was prepared by Dr. L.R. Kadiyali, Convenor and Shri M.C. Venkatesha, Member - Secretary of the Rigid Pavement Committee. The draft was considered by the Rigid Pavement Committee in its meeting held on 25th October, 1999 (personnel given below) for placing before the HSS Committee:

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The Highways Specifications and Standards (HSS) Committee in its meeting held on 21st December, 1999 considered the draft revision of IRC:15 subject to certain modifications in light of the comments made by the members and authorised the Convenor, Rigid Pavement Committee to modify the same for sending the document to Convenor, HSS Committee for approval. The Convenor, HSS Committee approved the modified draft for being placed before the Executive Committee and the Council of IRC. The Executive Committee in its meeting held on 2nd May, 2000 approved the 3rd revision of IRC:15 for being placed before the Council. The Council in its 159th meeting held at Pune on the 26th May, 2000 approved and authorised the Convenor, Rigid Pavement Committee to modify the document in light of comments including written comments made by the Members. Subsequently, the Convenor, Rigid Pavement Committee has forwarded the modified draft which was approved by the Convenor, HSS Committee on 14th February, 2002.

2. SCOPE

2.1. The Code of Practice is intended to indicate what is considered to be good practice for the construction of cement concrete road pavements, including preparation of the subgrade and sub-base underneath these pavements. It covers the requirements of fully mechanised construction as well as partly mechanised and partly labour-oriented techniques.

2.2. The Code deals with various aspects of cement concrete road construction, like, materials, equipment, proportioning, measurement, handling of materials, and mixing.

subgrade and sub-base preparation, formwork, joints, reinforcement, of concrete placing, finishing, curing, etc. For greater elucidation of certain aspects, such as, properties and tests for concrete, arrangement of joints, reinforcement, load transfer devices, tie bars, and concreting under cold weather supplementary notes have been added to this Code, vide paras N. 1 to N. 6 ***(Appendices-A&B)***. Provisions of this Code shall apply unless required to be modified by special circumstances to take into account unusual conditions of traffic, subgrade, etc.

2.3. Some of the aspects of cement concrete roads are dealt with in greater detail in separate standards of IRC. Reference to these standards is drawn in the text where relevant.

3. MATERIALS

3.1. Cement

Any of the following types of cement capable of achieving the design strength may be used with prior approval of the Engineer, but the preference should be to use the 43 Grade:

(i) Ordinary Portland Cement, 33 Grade, IS:269
(ii) Ordinary Portland Cement, 43 Grade, IS:8112

If the soil around has soluble salts, like, sulphates in excess of 0.5 per cent, the cement used shall be sulphate resistant and shall conform to IS:12330.

Portland Blast Furnace Slag Cement conforming to IS:455 and Portland Pozzolana Cement conforming to IS:1489 may also be used.

Guidance may be taken from IS:SP:23 Handbook for Concrete Mixes for ascertaining the minimum 7 days strength of cement required to match with the design concrete strength. In this context, IRC:44 may also be referred. Cement for large sized projects may preferably be obtained in bulk form. For small sized projects, cement in bags may be used. If cement in paper bags are proposed to be used, there shall be bag-splitters with the facility to separate pieces of paper bags and dispose them suitably. No paper pieces shall enter the concrete mix. Bulk cement shall be stored in vertical or horizontal silos. The cement shall be subjected to acceptance tests just prior to its use.

3.2. Admixtures

Admixtures conforming to IS:6925 and IS:9103 may be used to improve workability of the concrete or extension of setting time, on satisfactory evidence that they will not have any adverse effect on the properties of concrete with respect to strength, volume change, durability and have no deleterious effect on steel bars. Satisfactory performance of the admixtures should be proved both on the laboratory concrete trial mixes and in trial paving works. If air entraining admixture is used, the total quantity of air in air-entrained concrete as a percentage of the volume of the mix shall be 5±1.5 per cent for 25 mm nominal size aggregate. In freezing weather, use of air entraining agent is recommended to counter the freezing and thawing effect. Besides it helps in improving the workability of the mix and to reduce the bleeding effect.

3.3. Aggregates

3.3.1. Aggregates for pavement concrete shall be natural material complying with IS:383 but with a Los Angeles Abrasion Value not more than 35 per cent. The limits of deleterious materials shall not exceed the requirements set out in IS:383.

The aggregates shall be free from chert, flint, chalcedony or silica in a form that can react with the alkalies in the cement. In addition, the total chlorides content expressed as chloride ion

content shall not exceed 0.06 per cent by weight and the total sulphate content expressed as sulphuric anhydride (SO_3) shall not exceed 0.25 per cent by weight.

3.3.2. **Coarse aggregate:** Coarse aggregate shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone or crushed gravel and shall be devoid of pieces of disintegrated stone, soft, flaky, elongated, very angular or splintery pieces. The maximum size of coarse aggregate shall not exceed 25 mm for pavement concrete. Continuously graded or gap graded aggregates may be used, depending on the grading of the fine aggregate. No aggregate which has water absorption more than 2 per cent shall be used in the concrete mix. The aggregates shall be tested for soundness in accordance with IS:2386 (Part V). After 5 cycles of testing, the loss shall not be more than 12 per cent if sodium sulphate solution is used or 18 per cent if magnesium sulphate solution is used.

If the aggregates are not free from dirt, the same may be washed and drained for at least 72 hours before batching. In such situation, the absorbed moisture content shall be carefully monitored for controlling Water/Cement ratio.

Stone crushing technology has improved the world over where besides jaw type of primary crushers, use of cones, impactors/hammers, etc. is made at secondary and tertiary stages to produce cubical shaped aggregates. Lately crushing involving aggregate to aggregate impact is also exploited in the crushing industry thus saving the wear and tear of the moving parts.

3.3.3. **Fine aggregate:** The fine aggregate shall consist of clean natural sand or crushed stone sand or a combination of the two and shall conform to IS:383. Fine aggregate shall be free from soft particles, clay, shale, loam, cemented particles, mica and organic and other foreign matter. The fine aggregate shall not contain substances more than the following:

Clay lumps	4.0 per cent
Coal and lignite	1.0 per cent
Material passing IS sieve No.75 micron	4.0 per cent*

* **Cautionary Note :** Although IS:383 permits the fines passing 75 microns upto 15 per cent, this provision should be used with caution only when crushed stone dust is used as fine aggregate and when the mix produced in the Laboratory and the field is satisfactory in all respects and complies with the requirement of Specification.

3.3.4. **Water:** Water used for mixing and curing of concrete shall be clean and free from injurious amount of oil, salt, acid, vegetable matter or other substances harmful to the finished concrete. It shall meet the requirements stipulated in IS:456. Potable water is generally considered satisfactory for mixing and curing.

3.3.5. **Steel:** These shall conform to the requirements of IS:432, IS:1139 and IS:1786 as relevant. The dowel bars shall conform to Grade S 240 and tie bars to Grade S 425 of IS. If steel mesh is used, it shall conform to IS:1566. The steel shall be coated with epoxy paint for protection against corrosion.

3.3.6. **Temperature reinforcement:** The steel bars used as temperature reinforcement whenever shall be either deformed or cold twisted and shall preferably be welded. Where spot welding is not possible these bars can be tied with binding wires to form the mesh. The size and spacing of bars depends on the design considerations, material properties and climatic condition of the region, but in any case the weight of the mesh shall not be less than 3.14 kg/sqm. The steel mesh may be placed in the upper half of the slab between say 5 cm below the top surface to sufficiently above the dowel bars such as not to cause any interference to their movement.

3.3.7. **Premoulded joint filler:** Joint filler board for expansion joints which are proposed for use only at some abutting structures, like, bridges and culverts shall be of 20-25 mm thickness within a tolerance of ± 1.5 mm and of a compressible synthetic material and having compressibility more than 25 per cent as per IS:1838. It shall be 25 mm less in depth than the thickness of the slab within a tolerance of ± 3 mm and provided to the full width between the side forms. It shall be in suitable lengths which shall not be less than one lane width. Holes to accommodate dowel bars shall be accurately bored or punched out to give a sliding fit on the dowel bars.

3.3.8. **Joint sealing:** The joint sealing compound shall be of hot poured, elastomeric type or cold type chemical based polysulphide or single chemical based silicone type having flexibility, durability and resistance to age hardening. If the sealant is of hot poured type, it shall be rubberised bitumen and shall conform to AASHTO M282 or ASTM:D 3406 and cold applied sealant shall be in accordance with BS : 5212 (Part 2) and IS:11433.

The brief description of these Specifications are given in ***Appendix-C***.

4. PROPORTIONING OF CONCRETE

4.1. Proportioning on the Basis of Strength

4.1.1. As the stresses induced in concrete pavements are mainly flexural, it is desirable that their design is based on the flexural strength of concrete. The mix shall be so designed in the laboratory as to ensure the minimum flexural strength in the field with the desired tolerance level as per IS:516-96. To achieve the desired minimum strength in the field, the mix in the laboratory shall be designed for somewhat higher strength, making due allowance for the type and extent of quality control feasible in the field. To achieve the desired minimum flexural strength 'S'', which is known as characteristic strength, the mix design strength is designed for a target strength 'S', which is always higher making due allowance for the type and extent of quality control feasible in the field.

The formula relating characteristic strength 'S' to target strength 'S' is in the form of :

$$S = S' + J_a \sigma$$

Where,

S' = Characteristic flexural strength at 28 days

S = Target average flexural strength at 28 days

J_a = Tolerance factor for the desired confidence level, known as the standard normal variate

σ = Standard deviation of field samples. If it is not known, it may be estimated from the knowledge of type of control, viz., very good, good or fair.

The values of standard normal variate for different values of tolerance are given in Table 1.

TABLE 1. VALUES OF STANDARD VARIATE FOR DIFFERENT VALUES OF TOLERANCE (IS:19262)

Accepted results of low results (tolerance)	Standard Normal Variate, J_a
1 in 15	1.50
1 in 20	1.65
1 in 40	1.96
1 in 100	2.33

Where there are no facilities for testing beam samples for determining flexural strength, the mix designs may be carried

out using equivalent compressive strength values. The following formula may be used for relating flexural strength with compressive strength :

$$F_c = 7.63\, F_f + 2.58$$

Where,

F_c = 28 days compressive strength, MPa

F_f = 28 days flexural strength, MPa

For computing target compressive strength from the characteristic compressive strength, the expected standard deviations are given in Table 2. The exact values of standard deviation should, however, be worked out soon after data of 30 samples are available and they should be used for subsequent quality control work.

TABLE 2. EXPECTED VALUES OF STANDARD DEVIATION OF COMPRESSIVE STRENGTH

Grade of Concrete	Standard Deviation for different degrees of control, MPa (Compressive Strength)		
	Very good	Good	Fair
M 30	5.0	6.0	7.0
M 35	5.3	6.3	7.3
M 40	5.6	6.6	7.6
M 45	6.0	7.0	8.0
M 50	6.4	7.4	8.4

4.1.2. The paving quality concrete mix should preferably be designed in the laboratory and controlled in the field on the basis of its flexural strength. Where this is not possible, correlation between flexural and compressive strengths should first be established on the basis of actual tests on additional samples of beams and cubes made for the purpose at the time of designing the mix in the laboratory. Quality control is exercised on the basis of flexural strength.

4.1.3. For design of cement concrete mixes, guidance may be had from IRC:44 "Tentative Guidelines for Cement Concrete Mix Design for Road Pavements", IRC:59 "Tentative Guidelines for Design of Gap Graded Cement Concrete Mixes for Road Pavements" or IS:10262 and IS:SP:23 "Handbook on Concrete Mixes".

4.1.4. The minimum cement content for the mix corresponding to 4.5 MPa flexural strength in the field at 28 days shall not, however, be less than 350 kg per cum of concrete. If this minimum cement content is not sufficient to produce in the field concrete of the strength specified in the design, it shall be increased as necessary. The cement content shall, however, not exceed 425 kg per cum of concrete.

4.2. Approximate Proportions

The approximate proportions by weight (or by volume, only in unavoidable cases) necessary to produce concrete satisfying the above conditions using aggregates from the sources designated may be furnished in the tender documents, for guidance only, it being expressly understood that this information is only for the convenience of the bidder.

4.3. Field Mix

After the award of the contract, the proportions, i.e., the field mix, determined by the laboratory for the particular aggregates approved by the Engineer shall govern. These proportions will be corrected and adjusted by the Engineer to compensate for moisture content in the aggregates or fluctuations in the grading of coarse and fine aggregates at the time of use. Any change in the source of materials or mix proportions found necessary during the work shall be assessed by making laboratory trial mixes. Normally contractor must make efforts to get the mix proportion approved at least one month in advance of commencing paving operation.

Where fine aggregate is permitted to be measured volumetrically, due allowance should be made for its bulking.

4.4. Water Content and Workability

The water content shall be the minimum required to provide the agreed workability for full compaction of the concrete to the required density which should be established through laboratory and field trials of the mix. The maximum water cement ratio shall be 0.50. The water content per batch of concrete should be maintained constantly except for suitable allowances to be made for free moisture and absorption by aggregates during construction. Adjustments for workability shall be made by variations in the ratio of the coarse to fine aggregate or improving upon their grading without change in cement content or water-cement ratio. Any such change will warrant retesting of samples to assess the changes in the strength. The slump of concrete mix for pavements compacted by vibration using paving trains should be in the range of 30±15 mm and that in manual construction using needle vibrators for compaction, the slump shall not be more than 40 mm.

On account of long distances over which concrete needs to be carried in road projects, the concrete mix is generally designed using liquid plasticiser which have slight retardation effect. The plasticisers conforming to IS:9103-1999 are generally desirable for road works. The quantity of admixtures shall be determined by trials.

The laboratory mix designs should satisfy the requirement of workability when mix is produced through batching plant. Generally, further refinement of the mix becomes necessary in all project sites which may involve retesting of samples. Therefore, sufficient time should be allowed for developing a satisfactory mix design.

4.5. Supplementary Notes on Concrete

More information about the desirable properties of paving quality concrete is given in Supplementary Notes, para N.1 (*Appendix-A*).

5. TOOLS, EQUIPMENT AND APPLIANCES

5.1. General

All tools, equipment and appliances necessary for proper preparation of subgrade, laying of sub-base and batching, mixing, placing, finishing and curing of concrete shall be at the project site in good working condition, and shall have been inspected by the Engineer-in-Charge before the paving operations are permitted to start. Throughout the construction of the project, the construction agency shall maintain all necessary tools, equipment and appliances in first class working condition to ensure proper execution of the work. Arrangements shall also be made for requisite number of stand-by units in the event of break-downs during construction.

5.2. List of Tools, Equipment and Appliances

5.2.1. A list of tools, equipment and appliances required for the different phases of concrete road construction is given below:

List of Tools and Equipment for Semi-Mechanised Type of Construction

(a) Subgrade and Sub-base Compaction:

(i) Compaction equipment (three-wheeled steel roller or tandem roller, pneumatic roller, vibratory roller or sheep-foot roller)
(ii) Watering devices (water lorries, bhisties/water carriers or watering cans)

(b) Preparation of Sub-base for Concreting and Formwork:

(i) Scratch templates or strike boards
(ii) Bulk-heads
(iii) Pick axes, shovels and spades
(iv) Formwork and iron stakes

(c) Concrete Manufacture:

(i) Shovels and spades
(ii) Sieving screens
(iii) Weigh batcher
(iv) Aggregate measuring boxes (only where volume batching of aggregates is permitted as a special case)
(v) Water pump
(vi) Water measures
(vii) Concrete mixer

(d) Transportation, Laying and Compaction of Concrete:

(i) Wheel barrows/iron pans
(ii) Wooden bridges
(iii) Spades
(iv) Concrete vibrators (both internal and vibrating screeds)
(v) Wooden hand tampers

(e) Finishing Operations : Surface and Joints:

(i) Wooden bridges
(ii) Floats (longitudinal and long-handled wooden floats)
(iii) Templates
(iv) Three-metre long straight edges including one master straight edge
(v) Graduated wedge gauges
(vi) Mild steel sections and blocks for making joint grooves
(vii) Edging tools including double-edging tools
(viii) Canvas belts
(ix) Long handled brooms
(x) Diamond cutter (when making saw-cut joints)
(xi) Scabbler (for grinding local high spots)
(xii) Levelling instrument

(f) Curing:

(i) Hessian cloth/burlap or polyethylene sheeting
(ii) Watering devices (for ponding operation)
(iii) Liquid curing compound with spraying arrangement

(g) Cleaning and Sealing of Joints:

(i) Iron raker
(ii) Coir brush
(iii) Cycle pump/pneumatic air blower/air compressor
(iv) Kerosene stove
(v) Thermometer
(vi) Transferring pot
(vii) Double jacketed melter
(viii) Painter's brush
(ix) Pouring kettle
(x) Scraper
(xi) Sand paper/Sand blasting equipment
(xii) Plywood planks to keep on both sides of the joint groove.

Specifications for different tools, equipment and appliances are given in IRC:43 "Recommended Practice for Tools, Equipment and Appliances for Concrete Pavement Construction". This document also gives a list of other small tools, equipment and appliances; minimum balanced set of tools, equipment and appliances; their routine maintenance and upkeep; and details of field laboratory equipment.

List of Tools and Plants for Fully Mechanised Concrete Road Construction

(a) Subgrade Compaction Equipment:

(i) Three-wheeled static roller, vibratory roller (10 to 12 tonnes), sheep-foot roller, pneumatic tyred roller, plate compactor
(ii) Watering devices (water lorry, water sprinkler or bowser fitted with pump)
(iii) Motor grader

(b) Wet Mix Macadam Lower Sub-base:

(i) Pug-mill type wet mix macadam mixing plant
(ii) Dumpers
(iii) Paver finisher with electronic sensor (optional)
(iv) Motor grader
(v) Vibratory rollers of 10-12 tonnes weight
(vi) Levelling instrument

(c) Dry Lean Concrete Sub-base:

(i) Batching plant
(ii) Dumpers or tippers
(iii) Paver finisher with electronic sensor
(iv) Vibratory roller
(v) Pneumatic roller
(vi) Plate compactor
(vii) Liquid curing compound sprayer
(viii) Gunny bags/hessian/coir felt
(ix) Pneumatic roller
(x) Scabbler for correcting surface regularity
(xi) Levelling instrument

(d) Paving Concrete:

(i) Batching plant
(ii) Dumpers/tippers/transit mixers
(iii) Concrete paving train or paver and finisher assembly (slip-form or fixed-form)
(iv) Side forms for fixed form pavers
(v) Joint cutting machine (concrete saw)
(vi) Dowel bar inserter (DBI), if mechanical dowel insertion system is adopted
(vii) Dowel cradles/chairs, for manual dowel placement
(viii) Steel bulk-heads
(ix) Tie bar supporting assembly or tie bar inserter
(x) Guide-wires for slip-form pavers and stakes
(xi) Finishing and texturing equipment
(xii) Liquid curing compound sprayer

(xiii) Steel mobile bridges
(xiv) Portable pavement protection tents (minimum 150 m length) for hot season operation
(xv) Sealant application extruder with flexible hose and nozzle
(xvi) Scabbler
(xvii) Edging tool
(xviii) Levelling instrument
(xix) Slip-form kerb laying machine with electronic sensors.

6. PREPARATION OF SUBGRADE AND SUB-BASE

6.1. General

The cement concrete slabs shall be constructed on a layer of sub-base. The sub-bases suitable for such roads are discussed in Clause 6.2. Care shall be taken to construct subgrade below the sub-base complying the following requirements :

(i) No soft spots are present in the subgrade.
(ii) The subgrade shall be of coarse grained material.
(iii) When granular drainage layer is not provided below the sub-base, the top 150 mm of subgrade shall be having adequate drainage property and shall be extended upto full width of the road.
(iv) The camber and superelevation of subgrade shall be same as that of the concrete slabs. The camber shall be in the range of 1.5 to 2.0 per cent.
(v) If the k value of the subgrade tested under wet conditions is less than 6 kg/cm^3 cement concrete pavement should not be laid directly over the subgrade. A sub-base layer as per Clause 6.2 may then be provided.

6.2. The Sub-base

6.2.1. Sub-base provided under the concrete slabs can be a single layer or in two layers known as upper sub-base and

lower sub-base. The sub-base may be composed of granular material or stabilised soil or semi-rigid material as listed below:

(a) Granular material

(i) Layers of Water Bound Macadam (WBM) or Wet Mix Macadam.
(ii) Well-graded granular materials, like, natural gravel, crushed slag, crushed concrete, brick metal, laterite, kankar, etc. conforming to IRC:63.
(iii) Well-graded soil aggregate mixtures conforming to IRC:63.

(b) Stabilised soil

Local soil or moorum stabilised with lime or lime-fly ash or cement, as appropriate to give a minimum unconfined compressive strength of 1.7 MPa after 7 days moist curing in the laboratory. For guidance as regards design of mixes with lime or cement, reference may be made to IRC:50 and IRC:51 respectively. A correlation between CBR and 'k' value, the modulus of subgrade reaction, is given in Table 3.

TABLE 3. APPROXIMATE 'k'-VALUE CORRESPONDING TO CBR VALUES FOR HOMOGENEOUS SOIL SUBGRADES

CBR Value (%)	2	3	4	5	7	10	15	20	50	100
'k'-Value (kg/cm^3)	2.10	2.8	3.5	4.20	4.80	5.50	6.20	6.90	14.00	22.00

(c) Semi-rigid material:

(i) Lime-burnt clay puzzolana concrete. The lime-puzzolana mixture should conform to L.P. 40 or L.P. 20 of IS:4098-1967. The 28 days compressive strength of the concrete should be in the range of 40-60 kg/sqcm.
(ii) Lime-fly ash concrete conforming to IRC:60.
(iii) Dry Lean Concrete conforming to IRC:SP:49.

A dry lean concrete (DLC) sub-base is generally recommended for modern concrete pavements, particularly those with high intensity of traffic.

Table 4 gives the 'k' values of granular and cement treated sub-bases for three types of subgrade soils.

TABLE 4. 'k'-VALUES OVER GRANULAR AND CEMENT TREATED SUB-BASES

'k'-value of subgrade (kg/cm³)	Effective 'k' (kg/cm³) over untreated granular layer sub-base of thickness in cm			Effective 'k' (kg/cm³) over cement treated sub-base of thickness in cm		
	15	22.5	30	10	15	20
2.8	3.9	4.4	5.3	7.6	10.8	14.1
5.6	6.3	7.5	8.8	12.7	17.3	22.5
8.4	9.2	10.2	11.9	-	-	-

Table 5 gives 'k' values of dry lean concrete (DLC) sub-base of 100 mm and 150 mm thickness. The thickness and the type of sub-base should be selected depending upon the 'k'-value of the subgrade as given in Tables 4 and 5 and be constructed in accordance with the respective Specifications.

TABLE 5. 'k'-VALUES OVER DRY LEAN CONCRETE SUB-BASE

'k'-value of Subgrade kg/cm³	2.1	2.8	4.2	4.8	5.5	6.2
Effective 'k' over 100 mm DLC kg/cm³	5.6	9.7	16.6	20.8	27.8	38.9
Effective 'k' over 150 mm DLC kg/cm³	9.7	13.8	20.8	27.7	41.7	—

6.2.2. Thickness of sub-base should be minimum 15 cm when the material used is of any of the types listed in clause 6.2.1(a) and (b). This may, however, be reduced to 10 cm for semi-rigid materials in clause 6.2.1(c). The sub-base should be constructed in accordance with the respective specification and the surface finished to the required lines, levels and cross-section. The surface finish of the sub-base shall be smooth.

6.2.3. Where the subgrade consists of heavy clay (L.L.>50), such as, black cotton soil, the sub-base should be laid over a 22.5 cm thick blanket course consisting of non-plastic granular material, like, local sand, gravel, kankar, etc. or local soil stabilised with lime.

6.2.4. In water-logged areas and where the sub-grade soil is impregnated with deleterious salts, such as, sodium sulphate, etc. in injurious amounts, a capillary cut-off should be provided before constructing the sub-base, vide details given in clause 6.3. Injurious amount of sulphate concentration (as sulphur trioxide) is that limit where it is more than 0.2 per cent in subgrade soil and more than 0.3 per cent in ground water.

Cement used in both sub-base and pavement quality concrete in such situations should be sulphate-resistant.

6.2.5. The sub-base or blanket course, as the case may be, shall be laid over a properly compacted subgrade to give uniform support.

6.2.6. The sub-base shall be in a moist condition at the time the concrete is placed. There shall, however, be no pools of water or soft patches formed on the sub-base surface. In case where a sand layer is placed between the sub-base and pavement concrete, a layer of water-proof paper shall be laid over the sand layer. No moistening of the sub-base shall be done in this case.

6.3. **Capillary Cut-off**

6.3.1. As a result of migration of water by capillarity from the high water table, the soil immediately below the pavement gets more and more wet and this leads to gradual loss in its bearing value besides unequal support. Several measures, such as, depressing the sub-soil water table by drainage measures, raising of the embankment and provision of a capillary cut-off are available for mitigating this deficiency and should be investigated for arriving at the optimum solution. However, where deleterious salts in excess of the safe limits are present in the subgrade soil, a capillary cut-off should be provided in addition to other measures.

6.3.2. The capillary cut-off may be a layer of coarse or fine sand, graded gravel, bituminised material, or an impermeable membrane. Layer thicknesses recommended for different situations are given in Table 6.

TABLE 6. RECOMMENDED THICKNESS OF GRADED GRAVEL LAYER FOR CAPILLARY CUT-OFF

Sl. No.	Situation	Minimum Thickness of layer (cm)		
		Coarse sand	Fine sand	Graded gravel
1.	Subgrade 0.6-1.0 m above HFL	15	35	15
2.	Subgrade 0.6-1.0 m above HFL, the subgrade soil being sandy in nature (PI<5; sand content not less than 50 per cent)	10	30	10

Whenever sand is used as cut-off layer, the layer shall not be provided at the edges but should be replaced with suitable filter of graded granular material with or without non-woven geotextile material for preventing loss of fines.

6.3.3. Cut-off with bituminised or other materials may be provided in any of the following ways:

(i) **Bituminous impregnation using primer treatment**
Bituminous emulsion applied at the rate of 6-15 kg per 10 sqm.

(ii) **Heavy-duty tar felt**
Enveloping sides and bottom of the roadbed with heavy-duty tar felt.

(iii) **Bituminous stabilised soil**
Providing bituminous stabilised soil in a thickness of at least 4 cm.

(iv) **Geofilter layer**
Geofilter fabrics recommended to function as capillary cut-off.

Note: Experience on the successful use of the above capillary cut-offs is, however, limited.

6.3.4. For more details about mitigating the adverse effects of high water table, reference may be made to IRC:34 "Recommendations for Road Construction in Waterlogged Areas".

6.4. Weather Limitations

6.4.1. **Concreting in cold weather :** No concreting shall be allowed in normal circumstances when the concrete temperature is below 5°C and the temperature is descending. When the fresh concrete is likely to be subjected to freezing temperature in the nights, adequate measures are to be taken to protect the concrete from freezing by providing thick mat of hay, two to three layers of hessian, etc. The efficiency of this method should be checked by constructing trial sections. The details are given in N. 6 in ***Appendix-B***.

6.4.2. **Concreting in hot weather:** No concreting shall be done when the concrete temperature is above 30°C. To bring down the temperature of the concrete, chilled water or ice flakes can be made use of.

6.4.3. **Frost affected areas:** In frost affected areas, the sub-base may consist of any of the specifications given in clauses 6.2.1(a), (b) or (c) excepting that in the case of the clauses 6.2.1(b) and 6.2.1(c), the compressive strength of the stabilised or semi-rigid material cured in wet condition shall be at least 1.7 MPa at 7 days in the laboratory. For moderate conditions, such as, those prevailing in areas at an altitude of 3,000 m and below, the thickness of frost affected depth will be about 45 cm. For protection against frost, the balance between the frost depth (45 cm) and total pavement thickness should be made up with non-frost susceptible material.

For extreme conditions, such as, those prevailing in areas above an altitude of 3,000 m, the foundation may be designed individually for every location after determining the depth of frost.

The suggested criteria for the selection of non-frost susceptible materials are as follows:

(i) Graded gravel: Not more than 8 per cent passing 75 micron sieve. Plasticity index not more than 6. Liquid limit not more than 25.

(ii) Poorly graded sands, generally 100 per cent passing 4.75 mm sieve: Max. 10 per cent passing 75 micron sieve.

(iii) Fine uniform sand, generally 100 per cent passing 425 micron sieve: Max. 18 per cent passing 75 micron sieve.

6.5. Existing Pavement

6.5.1. When concrete pavement is laid over an existing bituminous pavement which is known as white-topping, it shall be ensured that the existing road extends over the required width and has a minimum thickness of 150 mm. Where the general unevenness of the surface varies within 25 mm, it can be provided with an overlay of dense bituminous macadam (DBM) with the help of a paver operating with electronic sensor to achieve the desired level, grade and alignment. The thickness of DBM shall be decided on basis of undulations present on the existing road. Alternatively, the existing bituminous pavement can be milled to recycle the existing asphalt mix and paved as a sub-base after treating the material with fresh bitumen and aggregates as per standard practice.

Where the width of the existing pavement falls short of the width to be concreted and the condition of the surface is sound enough for receiving the paving concrete, the extra width may be made up by placing at least 150 mm depth of lean cement concrete or lime-puzzolana concrete or lime-fly ash concrete or lean cement concrete as per clause 6.2.1(c) in trenches of required width at the sides of the existing metalling after taking care to see that the bottom of such trenches is well compacted with 100 mm WBM or WMM layer. The soil below shall be watered and well compacted before placing WBM/WMM material by suitable tampers before placing of the new sub-base material. The correction to the unevenness of the surface and for camber shall follow the same lines as in the preceding paragraph.

6.6. Separation Membrane

A separation membrane shall be used between the concrete slab and the sub-base. Separation membrane shall be impermeable plastic sheeting 125 microns thick laid flat without creases. Before placing the separation membrane, the sub-base shall be swept clean of all the extraneous materials using air compressor. Where overlap of plastic sheet is necessary, the same shall be at least 300 mm and any damaged sheeting shall be replaced. The separation membrane may be stuck to the lower layer with patches of adhesives or appropriate tape or concrete nails with washer so that sheet does not move during placement of concrete.

7. FORMS

7.1. Steel Forms

All side forms shall be of mild steel unless use of wooden sections is specially permitted. The steel forms shall be mild steel channel sections of depth equal to the thickness of the pavement or a few millimetres less than the thickness of the pavement to match with the plus level tolerances specified for sub-base. In the latter case, the forms shall be levelled by using metal wedges or shims. The thickness of flange and web shall not be less than 6 mm and shall be capable of resisting all loads applied in the paving process. The length of form shall not be less than 3 m except in the case of installations along curves.

The sections shall have a length of at least 3 m except on curves of less than 45 m radius, where shorter sections may be used. When set to grade and staked in place, the maximum deviation of the top surface of any section from a straight line shall not exceed 2 mm in the vertical plane and 5 mm in the horizontal plane. The method of connection between sections shall be such that the joint formed shall be free from difference in level, play or movement in any direction. The use of bent, twisted or worn-out forms will not be permitted. At least three stake pockets for bracing pins of minimum 25 mm dia or stakes shall be provided for each 3 m of form and the bracing and support must be ample to prevent springing of the forms under the pressure of concrete or the weight or thrust of machinery operating on the forms.

The supply of forms shall be sufficient to permit their remaining in place for 12 hours after the concrete has been placed, or longer if necessary in the opinion of the Engineer-in-Charge.

7.2. Wooden Forms

Wooden forms may be used only when specifically permitted in the drawing with the exception that their use is herein approved for all curves having radii of less than 45 m. Wooden forms shall be dressed on one side. They shall have minimum base width of 100 mm for slab thickness upto 200 mm and a

minimum base width of 150 mm for slabs over 200 mm thick. Their depth shall be equal or slightly less than the thickness of the pavement but it would be made up by metal shims. These forms when used on straights shall have a minimum length of 3 m. Forms shall be held by stakes set at intervals not exceeding 2 m. Two stakes, one on each side, shall be placed at each joint. The forms shall be firmly nailed or secured to the side stakes, and securely braced at joints, where necessary, so that no movement will result from the pressure of the concrete or the impact of the tamper and during finishing work. Wooden forms shall be capped along the inside upper edge with 50 mm angle iron, well recessed and kept flush with the face of the wooden forms. The maximum deviation of the top surface of any section from a straight line shall not exceed the stipulations laid down in clause 7.1.

7.3. Setting of Forms

The forms shall be jointed neatly and shall be set with exactness to the required grade and alignment. Both before and after the forms are placed and set, the subgrade or sub-base under the forms shall be thoroughly tamped in an approved manner. Sufficient rigidity shall be obtained to support the forms in such a position that during the entire operation of compacting and finishing of concrete they shall not at any time deviate more than 3 mm from a straight edge 3 m in length. Forms which show a variation from the required rigidity or alignment and levels shown in the drawing, shall be reset or removed, as directed. The length and number of stakes shall be such as to maintain the forms at the correct line and grade. All forms shall be cleaned and oiled each time before they are used. Forms shall be set ahead of the actual placing of concrete for the entire day's work.

8. JOINTS

8.1. General

The location and type of joints shall be as shown in the drawings. Where semi-mechanised method of construction is used, the concrete along the face of all joints and around all tie bars and dowels shall be compacted with an internal vibrator inserted in the concrete and worked along the joint and around all tie bars and dowels to ensure a concrete free from honeycombing.

8.2. Types of Joints

There are 3 general types of joints. These are:

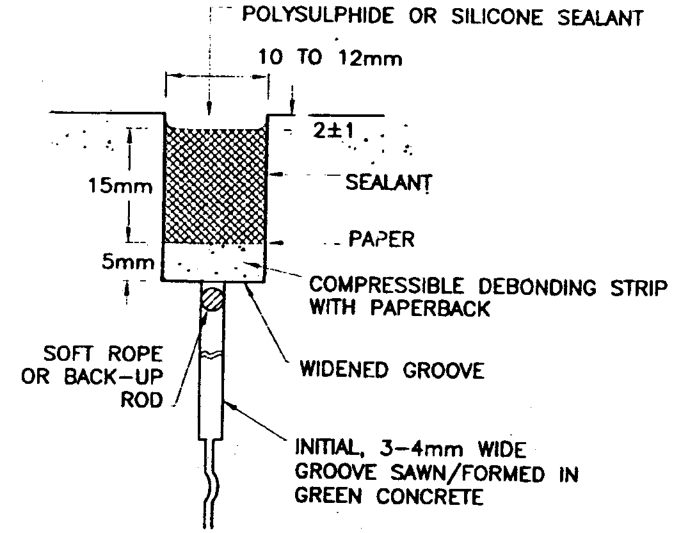
(i) **Expansion joint:** Such joint provides the space into which pavement can expand thus relieving compressive stresses due to expansion and inhibiting any tendency towards buckling of concrete slabs.

(ii) **Contraction joint:** Such joint relieves tensile stresses in the concrete and prevents formation of irregular cracks due to restraint in free contraction of concrete. Contraction joints also relieve stresses due to warping.

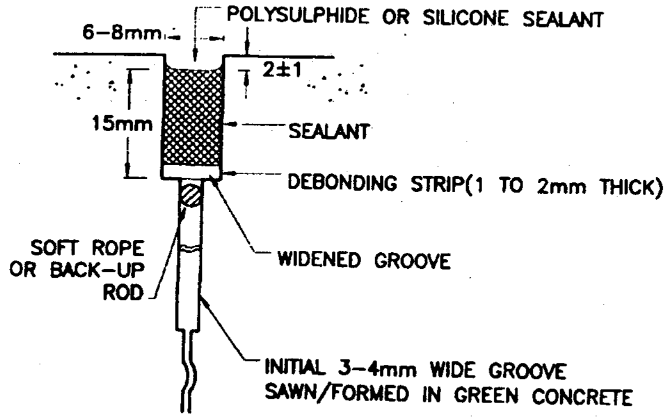
(iii) **Warping or Longitudinal joint**: Such joint relieves stresses due to warping. These are commonly used for longitudinal joints dividing the pavement into lanes.

In addition, construction joints are provided whenever construction operations require them. These are full depth joints and may belong to any of the above types.

All joints shall be carefully installed in accordance with the location and details given in the plans. The details of different types of joints are shown in Fig. 1.

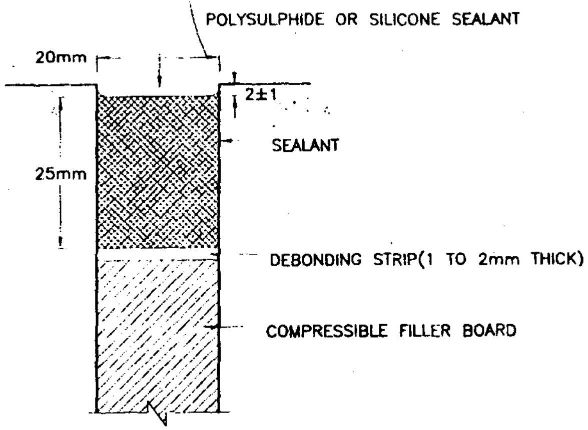


SEALING DETAILS OF CONSRACTION AND CONSTRUCTION JOINT GROOVE (DETAILS AT "A")

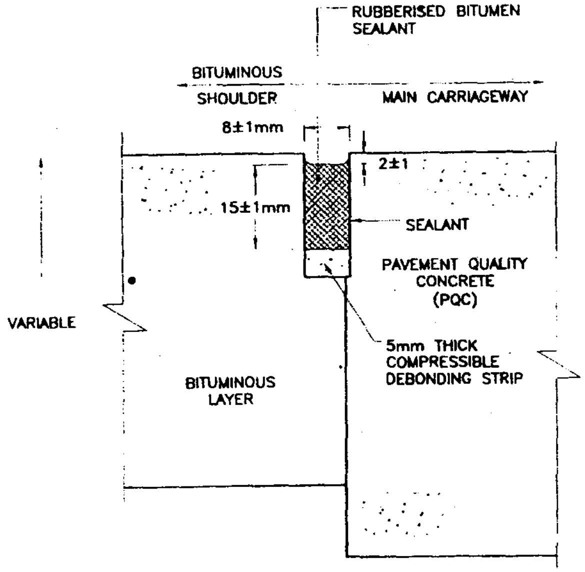


SEALING DETAILS OF LONGITUDINAL JOINT GROOVE (DETAILS AT "B")

Fig. 1. Details of Sealing Joint Grooves (Clause 8.2) (Contd.)



SEALING DETAILS OF EXPANSION JOINT GROOVE
(DETAILS AT "C")



SEALING DETAILS OF LONGITUDINAL JOINT
BETWEEN CEMENT CONCRETE SLABS AND
BITUMINOUS SHOULDER

Fig. 1. (Contd.) Details of Sealing Joint Grooves (Clause 8.2)

8.3. Transverse Joints

8.3.1. **General:** Transverse joints can be expansion, contraction or construction joints and shall be placed as indicated on the drawing. They shall make a right angle with the centre line of the pavement and surface of the sub-base/subgrade. Contraction and expansion joints shall be continuous from edge to edge of the pavement through all lanes constructed at the same or different times.

8.3.2. **Transverse expansion joints:** These shall extend over the entire width of the pavement. They shall be of the dimensions and spacing as shown on the drawing. They shall be provided only at bridge and culvert abutments.

Experience the world over has shown that there is no need to provide expansion joints at regular intervals but they are essential where cement concrete pavement is designed to abut with structures like bridges and culverts. It may be necessary to provide more number of expansion joints in succession in such locations to release the pressure.

Dowel bars conforming to Clause 8.3.6 and (see Supplementary Note N.4, Appendix-B) as per dimensions, location and spacing shown on the drawing are required at expansion joints to transfer wheel loads to the adjacent slab. For slabs of thickness less than 150 mm no dowel bars may be provided (IS:6509-1972). The premoulded synthetic expansion joint filler board, a compressible material shall be used to fill the gap between adjacent slabs at expansion joint. The height of the filler board shall be such that its top is 25 mm below the surface of the pavement. The dowel bars shall be held accurately in position during the placement, compaction and finishing of concrete at the expansion joint by dowel chair assembly. The accurate placing of dowels at the end of the day may be achieved by means of sufficiently strong bulkheads made of steel sections (as per IRC:43) with holes drilled along the centre line to accommodate the dowel bars in a mild steel section. The bulkhead shall be oiled or greased before placing in position to avoid bonding with concrete. The top and bottom edges of the bulkheads and mild steel section shall be shaped to correspond to camber of the pavements at the joint. If considered convenient, two-piece split bulkheads may also be used. When dowel bars are provided, bulkheads shall be designed such that they can hold the projecting ends of the dowel bars to maintain their alignment. A box section normally is adopted for such designs.

The bulkheads shall be securely staked in place at right angles to the centre line and surface of the pavement with sufficient stakes to hold them in the specified position. This may involve drilling of holes in sub-base to anchor the bulkhead with stakes.

Sealing grooves can be formed by placing wooden strips of 20-25 mm × 25 mm sections above the filler board. This can be pulled out when concrete sufficiently hardens. For easy removal of the wooden strip without damaging the edges, the sides of the strips may be shaped suitably.

Under no circumstances shall any concrete be left above the expansion joint filler or across the joint at any point. Any concrete spanning the ends of the joint next to the forms shall be carefully cut away after the forms are removed.

8.3.3. **Transverse contraction joints:** These shall be placed as shown on the drawing and shall be of the weakened plane of "dummy" groove type. They shall be constructed by forming in the surface of the slab, a slot not less than 3 mm wide

and having a depth equal to one-third to one-fourth the depth of the pavement at the thinnest part of its section. The groove is formed by a joint cutting saw. This groove is subsequently widened to seal with sealant. Alternatively in manual constructions and minor works, the slot may be formed in a manner approved by the Engineer-in-Charge, such as, by pushing into the concrete a flat bar or plastic strip or the web of a "T" bar using a suitable vibratory device, removing the bar subsequently, and keeping the slot open. It shall be ensured that no spalling of concrete occurs while removing the bar. Such manually formed grooves are found to affect the riding quality of the pavement.

8.3.4. **Transverse construction joints:** These shall be placed whenever placing of concrete is suspended for more than 30 minutes. Excepting in the case of emergency, construction shall always be suspended at the regular site of expansion or contraction joint. If the construction joint is located at the site of an expansion joint, regular expansion joint shall be provided; if at the site of a contraction joint or otherwise, the construction joint shall be of butt type with dowels. The joints should be placed only in the middle third of the specified contraction joint interval. Procedure of construction of butt type joint is given in clause 8.4. and details in ***Appendix-B***.

At all construction joints, bulkhead shall be used to retain the concrete and care shall be taken in striking off and finishing the surface to the top face of the bulkhead. When work is resumed, the surface of concrete laid subsequently, shall conform to the grade and cross-section of previously laid pavement, and a straight edge 3 m in length shall be used parallel to the centre line, to check any deviation in the surface of the two sections. Any deviation from the general surface in excess of 3 mm shall be corrected.

8.3.5. **General requirements of transverse joints:** Transverse joints shall be straight within the following tolerances along the intended line of joints which is the straight line transverse to the longitudinal axis of the carriageway at the position proposed by the Engineer, except at road junctions or roundabouts where the position shall be as described in the drawings:

(i) Deviations of the filler board in the case of expansion joints from the intended line of the joint shall not be greater than ± 10 mm.

(ii) The best fit straight line through the joint grooves as constructed shall not be more than 25 mm from the intended line of the joint.

(iii) Deviations of the joint groove from the best fit straight line of the joint shall not be greater than 10 mm.

(iv) Transverse joints on each side of the longitudinal joint shall be in line with each other and of the same type and width. Transverse joints shall have a sealing groove which shall be sealed.

8.3.6. **Dowel bars:** Dowel bars shall be mild steel rounds conforming to IS:432, IS:1139 and IS:1786 and Grade IS:240 and in accordance with details/dimensions as indicated in the drawing and free from oil, dirt, loose rust or scale. These shall be treated preferably by epoxy coating or any approved anti-corrosion treatment. They shall be straight, free of irregularities and burring restricting free movement in the concrete. The sliding ends shall be sawn or cropped cleanly with no protrusions outside the normal diameter of the bar. If the dia of the bars are not uniform, the bars shall be machined. The dowel bar shall be supported on cradles/ dowel chairs in pre-fabricated joint assemblies positioned prior to the construction of the slabs or mechanically inserted by a Dowel Bar Inserter (DBI) with vibration into the plastic concrete

by a method which ensures correct placement of the bars besides full re-compaction of the concrete around the dowel bars. The dowels used in contraction joints shall be provided with plastic sheath with closed end over 60 per cent of the length. The dowels also can be coated with polyethylene. The thickness of sheath or polyethylene coating shall not exceed 0.50 mm.

Design of dowel bars is discussed in IRC:58. Recommended dimensions of dowel bars in concrete pavements are given in Table 7.

TABLE 7. RECOMMENDED DIMENSIONS OF DOWEL BARS FOR RIGID PAVEMENTS

Slab thickness, cm	Dowel Bar Details		
	Diameter, mm	Length, mm	Spacing, mm
15	25	500	200
20	25	500	250
25	25	500	300
30	32	500	300
35	32	500	300

Unless shown otherwise on the drawings, dowel bars shall be positioned at mid depth of the slab within a tolerance of + 20 mm, and centred equally about intended lines of the joint within a tolerance of + 25 mm. They shall be aligned parallel to the finished surface of the slab and to the centre line of the carriageway and to each other within tolerances are given hereunder:

(1) For bars supported on cradles prior to the laying of the slab:

(a) All bars in a joint shall be within ± 3 mm per 300 mm length of bar.

(b) 2/3rd of the bars shall be within ± 2 mm per 300 mm length of bar.

(c) No bar shall differ in alignment from an adjoining bar by more than 3 mm per 300 mm length of bar in either the horizontal or vertical plane.

(d) Cradles supporting dowel bar shall not extend across the line of joint, i.e., no steel bar of the cradle assembly shall be continuous across the joint.

(2) For all bars inserted after laying of the slab:

(a) Twice the tolerance for alignment as indicated in (1) above.

Dowel bars, supported on cradles in assemblies, when subject to a load of 110 N applied at either end and in either the vertical or horizontal direction (upwards and downwards and both directions horizontally) shall conform to be within the following limits:

(i) Two-thirds of the number of bars of any assembly tested shall not deflect more than 2 mm per 300 mm length of bar

(ii) The remainder of the bars in that assembly shall not deflect more than 3 mm per 300 mm length of bar.

Dowel bars shall be covered by a thin plastic sheath for at least 60 per cent of the length from one end for dowel bars in contraction joints or half the length plus 50 mm for expansion joints. The sheath shall be tough, durable and of an average thickness not greater than 0.5 mm and shall have closed end. The sheathed bar shall comply with the following pull out test.

Four bars shall be taken at random from stock and without any special preparation shall be covered by sheaths as required in this Clause. The ends of the dowel bars which have been sheathed shall be cast centrally into concrete specimens

150x150x600 mm, made of the same mix proportions to be used in the pavement, but with a maximum nominal aggregate size of 20 mm and cured in accordance with IS:516. At 7 days a tensile load shall be applied to achieve a movement of the bar of at least 0.25 mm. The average bond stress to achieve this movement shall not be greater than 0.14 MPa.

For expansion joints, a closely fitting cap 100 mm long with closed end consisting of GI pipe of 3 mm thickness with closed ends shall be placed over the sheathed end of each dowel bar. An expansion space at least equal in length to the thickness of the joint filler board shall be formed between the end of the cap and the end of the dowel bar by using compressible sponge. To block the entry of cement slurry between dowel and cap it may be taped all round.

8.4. Longitudinal Joints

8.4.1. These joints known as warping joints can be formed by two different methods : (i) They can be of the plain butt type and shall be formed by placing the concrete against the face of the slab concreted earlier. The face of the slab concreted earlier, shall be painted with bitumen before placing of fresh concrete. (ii) When a pavement of width of more than one lane is laid, the longitudinal joint may be formed by a joint cutting machine. Longitudinal joint becomes necessary to relieve warping stresses when the pavement width exceeds 4.5 m.

8.4.2. **Tie bars:** Tie bars in longitudinal joints shall be plain mild steel bars conforming to IS:432 or deformed steel bars complying with IS:1786 and in accordance with the requirements given below. The bars shall be free from oil, dirt, loose rust and scale.

Tie bars projecting across the longitudinal joint shall be protected from corrosion for 75 mm on each side of the joint by a protective coating of bituminous paint with the approval of the Engineer. The coating shall be dry when the tie bars are used.

Tie bars in longitudinal joints shall be made up into rigid assemblies with adequate supports and fixings to remain firmly in position during the construction of the slab. Alternatively, tie bars at longitudinal joints may be mechanically or manually inserted into the plastic concrete from above by vibration using a method which ensures correct placement of the bars and recompaction of the concrete around the tie bars. When pavement is constructed in single lane width, tie rods are also inserted mechanically or manually from sides. During side insertion in fixed form paving they may be bent so that half length remains along the form. After removal of forms, bars shall be straightened so that they extend into the concrete placed on the other side of the concrete.

Tie bars shall be positioned to remain within the middle third of the slab depth as indicated in the drawings approximately parallel to the surface and approximately perpendicular to the line of the joint, with the centre of each bar on the intended line of the joints within a tolerance of + 50 mm, and with a minimum cover of 30 mm below the joint groove.

Table 8 gives typical sizes of tie rods used in concrete slabs.

8.5. Arrangement of Different Types of Joints

8.5.1. For details about arrangement of the different types of joints, see Supplementary Note, N. 2 *(Appendix-B)*.

TABLE 8. DETAILS OF TIE BARS FOR LONGITUDINAL JOINT OF TWO-LANE RIGID PAVEMENTS

Slab Thickness (cm)	Tie Bar Details				
	Diameter (d) (mm)	Max. Spacing (cm)		Minimum Length (cm)	
		Plain Bars	Deformed Bars	Plain Bars	Deformed Bars
15	8	33	53	44	48
	10	52	83	51	56
20	10	39	62	51	56
	12	56	90	58	64
25	12	45	72	58	64
	14	61	98	65	72
30	12	37	60	58	64
	16	66	106	72	80
35	12	32	51	58	64
	16	57	91	72	80

Note:

These calculations have been made for a slab configuration of 3.5 m x 5.0 m

The recommended details are based on the following values of different design parameters :

S = 1250 kg/sqm, B = 17.5 kg/sqm for plain bars and S = 2000 kg/sqm and B = 24.6 kg/sqm for deformed bars; and W = 24 kg/sqm per cm of slab thickness

Length of tie rod shown above has been increased by 20 cm to compensate for:

(a) For painted length of 10 cm in the middle of tie rod

(b) 5 cm to compensate for placement error laterally

8.5.2. **Anchor beam and terminal slab beam adjoining bridge structures :** Cement concrete slabs will expand during hot season and this will result in the building up of horizontal thrust on adjoining bridge structure. To contain this thrust RCC anchor beams are to be provided in the terminal slab. The terminal slab also needs to be provided with reinforcement to strengthen it. A typical arrangement of anchor beam and the terminal slab are shown in Fig. 2. In case of culverts, etc. where the concrete slabs are provided above the superstructure, there is no need to construct anchor beams and terminal slab. In case the concrete slab abuts with culvert structure, the construction of anchor beam and terminal slab will be necessary.

9. CONSTRUCTION

9.1. General

A systems approach may be adopted for construction of the pavement, and the Method Statement for carrying out the work, detailing all the activities including indication of time-cycle, equipment, personnel, etc. These shall be got approved from the Engineer before the commencement of the work. The above shall include the type, capacity and make of the batching and mixing plant besides the hauling arrangement and paving equipment. The capacity of crusher, batching plant the cement storage, silos and the paver shall be matching so that the rate of paving shall not be less than 60 m/hr and paving can progress without any stoppage. During planning stage, it should be noted that constructing multi-lane pavement is better than constructing single lane at a time from the point of view of riding quality. Therefore, the capacity of plants should be planned accordingly.

9.2. Storage and Handling of Cement

9.2.1. The requirement of cement being of a very high order, cement is normally stored in large capacity vertical silos. Cement is carted in bulk to feed the storage silos. In the case of small projects involving manual or semi-mechanised paving, cement in bags may be used.

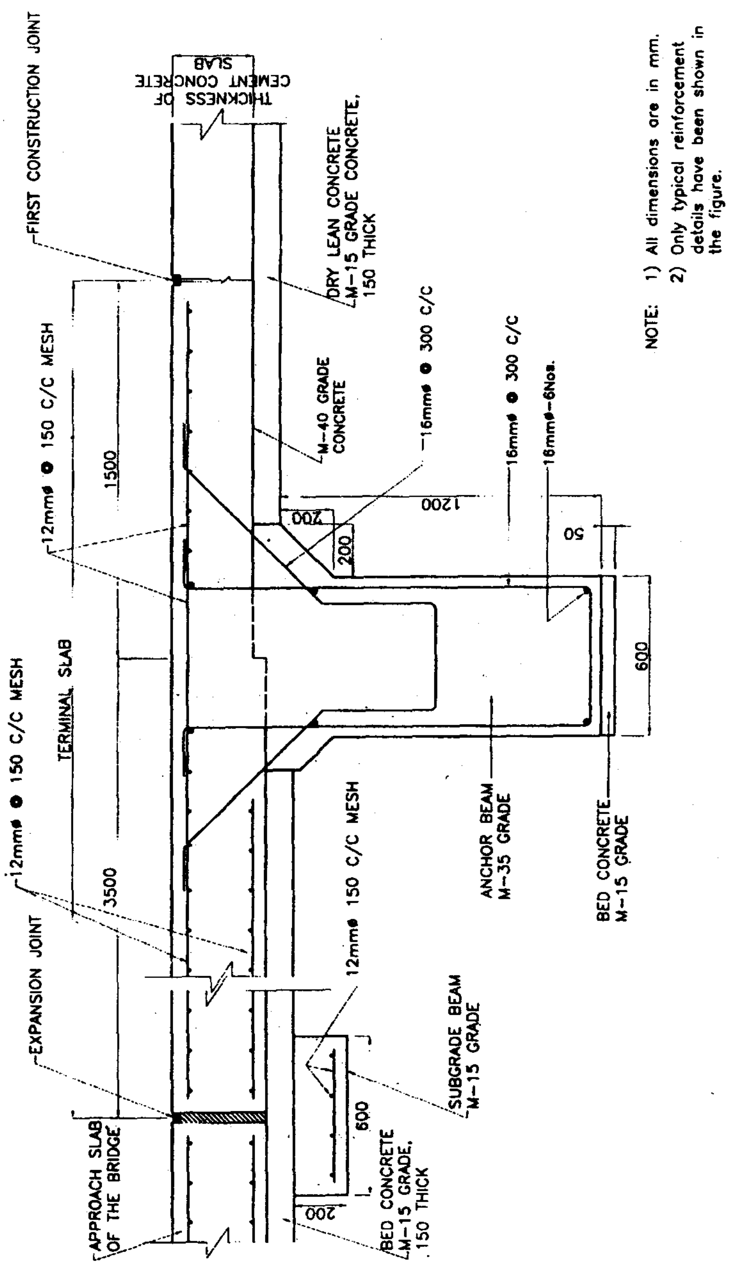


Fig. 2. Details of Anchor Beam and Terminals Slab (Clause 8.5.2)

9.2.2. Supply of cement should be co-ordinated with its consumption so that it is not stored right through the rainy season, when normally concreting is discontinued. Cement having lumps which have been caused due to improper storage or by pressure due to over-loading of bags shall not be considered for use unless these lumps can be easily powdered with pressure between fingers. Before such cement is used, representative sample containing the lumps in fair proportion also shall be taken and tested to fulfil the minimum requirements.

9.2.3. Owing to the slightly deliquescent nature of rapid hardening cement, special care should be taken in its storage and, in any case, it should not be stored for longer than three months.

9.3. Storage and Handling of Aggregates

9.3.1. The location and preparation of sites, minimum size of stack and the methods adopted for dumping and stacking to prevent segregation of coarse and fine material shall be subject to the approval of the Engineer. Aggregate stock piles may be made on ground that is denuded of vegetation, levelled, compacted with good quality soil sub-base material and well drained. Aggregates from different sources and/or of different gradings shall not be stacked together. Each separate size of coarse aggregate shall be stacked separately and separate wooden or steel partition shall be provided to avoid intermixing. The storing of aggregates upon the carriageway or shoulders shall not be permitted.

9.3.2. If aggregates are stored in conical stacks, segregation will be increased by the rolling of the coarser particles down the sides of the stacks. To avoid this, stacks should be built

up in approximately horizontal layers. Dry fine aggregate gets blown away easily; it may be helpful to moisten the layer on the surface.

9.3.3. Sufficient quantity of aggregates should be crushed in advance so that there is adequate supply of matching aggregates available in the site. Stock piling aggregates for use beyond 2-3 months should be done cautiously as it is likely to be contaminated with foreign matter.

9.3.4. The aggregates shall be handled form the stacks and fed into the mixer in such a manner as to secure the stipulated grading of the material. Aggregates that have become mixed with earth or other foreign material shall not be used. They shall be washed clean before use. The aggregates contaminated with fine dust, etc. are normally screened with a mobile screening plant before use.

9.4. Batching of Materials

9.4.1 All batching of materials shall be by weight. After determining the proportion of ingredients for the field mix, the fine aggregate and each separated size of coarse aggregate shall be proportioned by weight in an approved weigh-batching plant and placed into the hopper of the mixer along with the necessary quantity of cement. Cement shall be measured either by weight or by the bag as packed by the manufacturer. Where cement is measured by the bag, it would be necessary to sample-check the weight of the bags occasionally. All materials other than cement shall be calculated on the basis of one or more whole bags of cement taking the weight of cement as 1440 kg/cum. Water may be measured by volume. Where it is unavoidable, volume batching of aggregates may be permitted as a special case in small projects.

9.4.2. Batching plant and equipment for fully mechanised construction

(1) **General:** The batching plant shall include minimum four bins, weighing hoppers, and scales for the fine aggregate and for each size of coarse aggregate. If cement is used in bulk, a separate scale for cement shall be included. The weighing hoppers shall be properly sealed and vented to preclude dust during operation. Approved safety devices shall be provided and maintained for the protection of all personnel engaged in plant operation, inspection and testing. The batch plant shall be equipped with a suitable non-resettable batch counter which will correctly indicate the number of batches proportioned.

(2) **Bins and hoppers:** Bins with minimum four number of adequate separate compartments shall be provided in the batching plant.

(3) **Automatic weighing devices:** Batching plant shall be equipped to proportion aggregates and bulk cement by means of automatic weighing devices using load cells.

(4) **Mixers:** Mixers shall be pan type, reversible type or any other mixer capable of combining the aggregates, cement, water and admixtures into a thoroughly mixed and uniform mass within the specific mixing period, and of discharging the mixture, without segregation. Each stationary mixer shall be equipped with an approved timing device which will automatically lock the discharge lever when the drum has been charged and release it at the end of the mixing period. The device shall be equipped with a bell or other suitable warning device adjusted to give a clearly audible signal each time the lock is released. In case of failure of the timing device, the mixer may be used for the balance of the day while it is being repaired, provided that each batch is mixed 90 seconds or as per the manufacturer's recommendation. The mixer shall be equipped with a suitable non-resettable batch counter which shall correctly indicate the number of batches mixed.

The mixers shall be cleaned at suitable intervals. The pickup and throw-over blades in the drum or drums shall be repaired

or replaced when they are worn down 20 mm or more. The Contractor shall (1) have at the job site a copy of the manufacturer's design, showing dimensions and arrangements of blades in reference to original height and depth, or (2) provide permanent marks on blade to show points of 20 mm wear from new conditions. Drilled holes of 5 mm diameter near each end and at midpoint of each blade are recommended. Batching plant shall be calibrated in the beginning and thereafter at suitable interval not exceeding 1 month.

(5) The batching plant shall have facility for injecting at least two admixtures in the mixing pan.

(6) The discharging mechanism shall have appropriate chutes, downpipes, etc. so that the discharged mix will not get segregated.

(7) **Control cabin:** An air-conditioned centralised control cabin shall be provided for automatic operation of the equipment.

9.4.3. If batching by volume is permitted, as a special case, separate measuring boxes shall be provided for the different aggregates. The boxes shall be of strong construction provided with handles for convenient lifting and loading into the mixer. They shall be of such size that it should be possible to measure out the requisite and capable of being lifted by two men. Each box shall be provided with a straight edge of required length for striking off after filling. If so directed by the Engineer, improved facilities, such as, tipping boxes of accurate capacity working on run-out rails arranged for direct delivery into the hopper of the mixer shall be provided by the construction agency. In volume batching, suitable allowance shall be made for the bulking of fine aggregate due to the presence of water. For this purpose, the bulking shall be determined as per relevant Indian Standard Specification.

The location of the batching plant is an important issue to be looked into while planning the project. As there is a limitation on using the concrete mix after adding the water within a stipulated time, the mix cannot be carried beyond 10 km of lead. Therefore, the location of the batching plant in a road project has to be decided carefully.

9.5. Mixing

9.5.1. **General:** The mixing of concrete shall be done in a plant which will ensure a uniform distribution of materials throughout the mass so that the mix is uniform in colour and homogeneous. All concrete shall be mixed in quantities for immediate use.

The mixer shall be equipped with an approved water measuring device capable of accurate measurement of water required per batch. The mixer shall preferably be equipped with a mechanically operated pump for filling the mixer tank.

The mixer, if so specified, shall be equipped with an approved timing device which will automatically lock the discharge lever during the full time of mixing and release it at the end of the mixing period; the device shall also be equipped with a bell, adjusted to ring each time the lock is released. If the timing device gets broken or out of order, the mixer will be permitted to be used while the same is being repaired, provided an approved time-piece equipped with minute and second hands is provided. Each batch shall be mixed for at least one and a half minutes or as recommended by the plant manufacturer.

Spilling of the materials at either end of the mixer shall be corrected by reducing the size of the batch and in no case shall the volume of the mixed material per batch exceed the manufacturer's guaranteed capacity of the mixer. The type, size and number of mixers shall be so chosen as to provide the required output without overloading.

The mixing speed of the drum shall not be less than 15 revolutions per minute nor the peripheral speed of the drum greater than 60 m per minute.

The batch of cement, fine aggregate and coarse aggregate shall be fed into the mixer simultaneously with the water and admixtures being introduced either at the same time or after the dry materials.

The skip shall be so maintained and operated that each batch will be completely discharged into the mixing drum at the loading of the mixer. The mixer shall be cleaned at suitable intervals while in use.

9.5.2. **Time of mixing:** The mixing of each batch will continue generally not less than one and half minutes, after all the materials are discharged into the mixer or as recommended by the manufacturer of the plant and to the satisfaction of the Engineer.

9.5.3. **Retempering:** The retempering of concrete, i.e., remixing with or without additional cement, aggregate or water shall not be permitted.

9.6. Hauling and Placing of Concrete

9.6.1. Freshly mixed concrete from the central batching and mixing plant shall be transported to the paver site by means of trucks/tippers or transit mixers of sufficient capacity and approved design in sufficient numbers to ensure a constant supply of concrete. Tarpaulin covers shall be used for protection of concrete against the weather. The trucks/tippers shall be capable of maintaining the mixed concrete in a homogeneous state and discharging the same without segregation and loss of cement slurry. The feeding to the paver, when used, is to be regulated in such a way that the paving is done in an uninterrupted manner with a uniform speed throughout the days work. For semi-mechanised jobs, concrete can be transported in pans as head loads or in small wheel barrows.

9.6.2. **Placing of concrete:** Concrete mixed in central mixing plant shall be transported to the site without delay and the concrete which has been mixed too long before laying will be rejected and shall be removed from the site. The total time taken from the addition of the water to the mix, until the completion of the surface finishing and texturing shall not exceed 120 minutes when concrete temperature is less than 25°C and 100 minutes when the concrete temperature is between 25°C to 30°C. Trucks/ Tippers delivering concrete shall not run directly on plastic sheet nor shall they run on completed slabs until after 28 days of placing of concrete. Where semi-mechanised construction technique is adopted, concrete shall be deposited between the forms directly from head loads or wheel barrows. Where a certain amount of re-distribution is necessary, it shall be done with shovels and not with rakes. The concrete shall be compacted with needle vibrators and vibrating screeds in semi-mechanised construction where a paver finisher is not available. Use of vibrator near side forms is essential to eliminate honey combing. To effect adequate compaction, the concrete shall be placed with appropriate surcharge over the final slab thickness. The amount of surcharge will depend on the mode of placement of concrete and shall be determined by trial. In general, the required surcharge is about 20 per cent of the required slab thickness. Any portion of the batch of concrete that becomes segregated while depositing it on subgrade/sub-base shall be thoroughly mixed with the main body of the batch during the process of spreading. In case of unavoidable interruption, a full depth transverse joint shall be made at the point of stoppage of work provided the section on which the work has been suspended is about 2 to 3 m long.

In placing of concrete for two course construction, necessitated by either positioning of the reinforcement, a richer mix for the wearing surface, or when thickness of the concrete is beyond 20 cm, the bottom layer of concrete shall be struck off to the required levels by a vibrating screed working on the side forms. The vibrating unit mounted on it is similar to that of the screed used for compaction of the final surface of concrete. The time lag between laying of the two courses shall not exceed the initial setting time of cement. The use of retarder in the lower layer will be helpful.

9.7. Side Forms, Rails and Guidewires

9.7.1. **Side forms and rails:** All side forms shall be of mild steel of depth equal to the thickness of pavement minus the level tolerance stipulated for the lower layer. The forms can be placed on a series of steel packing plates or shims to take care of irregularity of sub-base. They shall be sufficiently robust with a minimum thickness of 6 mm and rigid to support the weight and pressure exerted by the paving equipment. Side forms for use with wheeled paving machines shall incorporate metal rails firmly fixed at a constant height below the top of the forms. The forms and rails shall be firmly secured in position by not less than 3 stakes/pins per 3 m length so as to prevent movement in any direction. Forms and rails shall be straight within a tolerance of 3 mm in 3 m and when in place shall not settle in excess of 1.5 mm in 3 m while paving is being done. Forms shall be cleaned and oiled immediately before each use. The forms shall be bedded on a continuous bed of lean cement mortar or concrete and set to the line and levels shown on the drawings within tolerances + 10 mm and + 2 mm respectively. The bedding shall not extend under the slab and there shall be no vertical step between adjacent forms of more than 2 mm. The forms shall be got inspected from the

Engineer for his approval before 12 hours before the construction of the slab and just prior to concreting and shall not be removed until at least 12 hours afterwards.

9.7.2. At all times, sufficient forms shall be used and set to the required alignment for at least 200 m length of pavement immediately in advance of the paving operations, or the anticipated length of pavement to be laid within the next 24 hrs whichever is more.

9.7.3. **Use of guidewires**

9.7.3.1. Where slip form paving is proposed, a guidewire shall be provided along both sides of the slab. Each guidewire shall be at a constant height above and parallel to the required edges of the slab as described in the contract/drawing within a vertical tolerance of ±2 mm. Additionally, one of the wires shall be kept at a constant horizontal distance from the required edge of the pavement as indicated in the contract/drawing within a lateral tolerance of ± 10 mm.

9.7.3.2. The guidewires shall be supported on stakes not more than 8 m apart by connectors capable of fine horizontal and vertical adjustment. The guidewire shall be tensioned on the stakes so that a 500 gram weight shall produce a deflection of not more than 20 mm when suspended at the mid point between any pair of stakes. The ends of the guidewires shall be anchored to fixing point or winch and not on the stakes.

9.7.3.3. The stakes shall be positioned and the connectors maintained at their correct height and alignment 12 hours on the day before concreting takes place until 12 hours after finishing of the concrete. The guidewire shall be checked and tensioned on the connectors at any section at least 2 hours before concreting that section.

9.7.3.4. The Engineer shall inspect and approve the line and level, the stakes and connectors which are ready for use in the length of road to be constructed at least 12 hours before the day of construction of slab. Any deficiencies noted by the Engineer shall be rectified. Engineer shall check the level before the commencement of work. Work shall not proceed until the Engineer has given his approval. It shall be ensured that the stakes and guidewires are not affected by the construction equipment when concreting is in progress. Arrangements should be readily available to correct it in case the string line is inadvertently disturbed.

9.8. **Placement of Steel**

9.8.1. In placing reinforcing steel, the initial layer of concrete shall be struck off to the entire width of the slabs and of sufficient length to permit sheet or mat of reinforcement to be laid full length without further manipulations of the reinforcement. Displacement of the reinforcement during concreting operations shall be prevented.

9.8.2. **Dowels:** Transverse joints shall be provided with dowels as explained in Clause 8.3.6 and of the dimension and at the spacing and location indicated on the drawing. They shall be firmly supported in place, accurately aligned parallel to the subgrade/sub-base, parallel to each other and parallel to the centre line of the pavement, by means of appropriate dowel supports.

9.8.3. **Tie bars:** Tie bars are provided in longitudinal joints of plain butt type to prevent opening of such joints shall be bonded to the adjacent slabs on both sides of the longitudinal joint. They are installed by providing appropriate (drilled) holes in the side forms depending on the size and spacing of bars. They are sometimes bent aside temporarily to avoid obstruction to construction traffic and straightened later at the time of laying of slab in the adjacent lane.

9.9. Fully Mechanised Construction

9.9.1. **Equipment:** The concrete shall be placed with an approved fixed form or slip form paver with independent units designed to (i) spread, (ii) consolidate from the mould, screed and float-finish, (iii) texture and cure the freshly placed concrete in one complete pass of the machine in such a manner that a minimum of hand finishing will be necessary and so as to provide a dense and homogeneous pavement in conformity with the plans and specifications. The paver shall be equipped with electronic sensors to pave the slab to the required thickness, camber and alignment in the case of slip form pavers.

Vibrators shall operate at a frequency and spacing recommended by the manufacturer. The variable vibration setting shall be provided in the machine.

The placement of dowels can be done by either using Dowel Bar Inserter (DBI) or by prefixing the dowels on steel chairs on the sub-base. The DBI is normally fitted in the paver finisher. The progress of work is better when a DBI is employed.

9.9.2. Construction by fixed form paver

9.9.2.1. The fixed form paving train shall consist of separate powered machines which spread, compact and finish the concrete in a continuous operation.

9.9.2.2. The concrete shall be discharged without segregation into a hopper of the spreader which is equipped with means for controlling its rate of deposition on to the sub-base. The spreader shall be operated to strike off concrete upto a level

requiring a small amount of cutting down by the distributor of the spreader. The distributor of spreader shall strike off the concrete to the surcharge adequate to ensure that the vibratory compactor thoroughly compacts the layer. If necessary, poker vibrators shall be used adjacent to the side forms and edges of the previously constructed slab. The vibratory compactor shall be set to strike off the surface slightly high so that it is cut down to the required level by the oscillating beam. The machine shall be capable of being rapidly adjusted for changes in average and differential surcharge necessitated by changes in slab thickness or cross fall. The final finisher shall be able to finish the surface to the required level and smoothness as specified, care being taken to avoid bringing up of excessive mortar to the surface by over-working.

9.9.3. Construction by slip form paver

9.9.3.1. The slip form paving train shall consist of power machine which spreads, compacts and finishes the concrete in a continuous operation. The slip form paving machine shall compact the concrete by internal vibration and shape it between the side forms with either a conforming plate or by vibrating and oscillating finishing beams. The concrete shall be deposited without segregation in front of slip form paver across the whole width and to a height which at all times is in excess of the required surcharge. The deposited concrete shall be struck off to the necessary average and differential surcharge by means of the strike off plate or a screw auger device extending across the whole width of the slab. The equipment for striking off the concrete shall be capable of being rapidly adjusted for changes of the average and differential surcharge necessitated by change in slab thickness or cross fall.

9.9.3.2. The level of the conforming plate and finishing beams shall be controlled automatically from the guidewires installed as per Clause 9.7.3 by sensors attached at the four corners of the slip form paving machine. The alignment of the paver shall be controlled automatically from the guidewire by at least one set of sensors attached to the paver. The alignment and level of ancillary machines for finishing, texturing and curing of the concrete shall be automatically controlled relative to the guidewire or to the surface and edge of an adjoining hardened slab.

9.9.3.3. Slip form paving machines shall have vibrators of variable output, with a maximum energy output of not less than 2.5 KW per metre width of slab per 300 mm depth of slab for a laying speed upto 1.5 m per minute or pro-rata for higher speeds. The machines shall be of sufficient mass to provide adequate reaction during spreading and paving operations on the traction units to maintain forward movements during the placing of concrete in all situations.

9.9.3.4. If the edges of the slip formed slab slump to the extent that the surface of the top edge of the slab does not comply with the requirements then special measures approved by the Engineer shall be taken to support the edges to the required levels and work shall be stopped until such time as the Contractor can demonstrate his ability to slip form the edges to the required levels. The slumped edge shall have to be corrected by adding fresh concrete after roughening the surface.

9.9.3.5. The pace of construction of slabs shall desirably not be less than 1 m per minute (60 m per hour). The capacity of the batching plant should be sufficiently more than this requirement so that the paver remains in motion without stoppages for want of mix. This factor is essential for achieving better riding quality.

9.9.4. **Surface texture**

9.9.4.1. After the final finishing of the slab and before the application of the curing membrane, the surface of concrete slab shall be brush-textured in a direction at right angles to the longitudinal axis of the carriageway. The texturing can be done either by bristles or tynes as approved by the Engineer.

9.9.4.2. The brushed surface texture shall be applied evenly across the slab in one direction by the use of a wire brush not less than 450 mm wide but wider brushes of 3.0 m length are preferred. The brush shall be made of 32 gauge tape wires grouped together in tufts spaced at 10 mm centres. The tufts shall contain an average of 14 wires and initially be 100 mm long. The brush shall have two rows of tufts. The rows shall be 20 mm apart and the tufts in one row shall be opposite the centre of the gap between tufts in the other row. The brush shall be replaced when the shortest tuft wears down to 90 mm length.

9.9.4.3. The texture depth shall be determined by the sand patch test as described in Clause 9.9.4.8. This test shall be performed at least once for each day's paving and wherever the Engineer considers it necessary. The tests shall be done as under:

> Five individual measurements of the texture depth shall be taken at least 2 m apart anywhere along a diagonal line across a lane width between points 50 m apart along the pavement. No measurement shall be taken within 300 mm of the longitudinal edges of a concrete slab constructed in one pass.

9.9.4.4. Texture depths shall not be less than the minimum required when measurements are taken as given in Table 9 nor greater than a maximum average of 1.25 mm.

9.9.4.5. After the application of the brushed texture, the surface of the slab shall have a uniform appearance.

TABLE 9. TEXTURE DEPTH

Time of Test	Number of Measurements	Required Texture Depth (mm)	
		Specified Value	Tolerance
1. Between 24 hours and 7 days after the constn. of the slab or until the slab is first used by vehicles.		1.00	+ 0.25
2. Not later than 6 weeks before the road is opened to public traffic.	An average of 5 measurements	1.00	+ 0.25 - 0.35

9.9.4.6. Where the texture depth requirements are found to be deficient, the Contractor shall make good the texture across the full lane width over the length, directed by the Engineer, by retexturing the hardened concrete surface in an approved manner.

9.9.4.7. The edges of the concrete slabs shall be rounded after texturing using an arrising tool having a radius of 3 mm deligently without applying pressure to the surface to leave the pavement edges smooth and true to line.

9.9.4.8. **Measurement of texture depth-sand patch method :** The following apparatus shall be used:

(1) A cylindrical container of 25 ml internal capacity.

(2) A flat wooden disc 64 mm diameter with a hard rubber disc. 1.5 mm thick, struck to one face, the reverse face being provided with a handle.

(3) Dry natural sand with a rounded particle shape passing a 300 micron IS sieve and retained on a 150 micron IS sieve.

The surface to be measured shall be dried, any extraneous mortar and loose material removed and the surface swept clean using a wire brush both at right angles and parallel to the

carriageway. The cylindrical container shall be filled with the sand, tapping the base 3 times on the surface to ensure compaction, and striking off the sand level with the top of the cylinder. The sand shall be poured into a heap on the surface to be treated. The sand shall be spread over the pavement surface, working the disc with its face kept flat in a circular motion so that the sand is spread into a circular patch with the surface depressions filled with sand to the level of peaks.

The diameter of the patch shall be measured to the nearest 5 mm. The texture depth of concrete surface shall be calculated from 31000/(DxD) mm where D is the diameter of the patch in mm.

9.10. Semi-Mechanised and Labour-Oriented Construction Technique

9.10.1. **Background:** Use of very sophisticated paving machines and high capacity concrete batch mixer is not possible in small concrete road projects and also in remote hilly terrains. But with the use of such machineries and plants the end product is always of better quality. Without these advanced equipments concrete roads can be constructed using semi-mechanised and labour-oriented constructions but the resulting quality and surface may not be the same as achieved with mechanised constructions.

9.10.2. **Forms:** In large sized projects, it is common to use slip form paving technique where no side forms are necessary to retain the mould of green concrete slab. The fixed-forms made of steel channels or fabricated steel sections are generally made use of. Wooden forms, although, can be used, are liable to get damaged after each usage. Therefore, wooden forms are to be considered as a last resort.

9.10.3. **Plants, equipments and tools:** The requirement of concrete quantity in road construction being large which again is to be supplied continuously, the mixes are normally to be produced from mixers. The plants and equipments considered essential even in semi-mechanised and labour-oriented constructions are:

(i) A couple of tilting type drum mixers of at least 0.2 cum capacity. The number of mixers to be employed in a project shall be decided on the basis of the size of the project.

(ii) Vibrating screeds for tamping and compacting pavement surface. These are moved on the levelled fixed forms or side forms to achieve the required smoothness, grade and surface regularity.

(iii) A couple of needle vibrators.

(iv) Concrete saw-this is required for forming contraction joints in a continuously constructed lane.

(v) Hand held sprayer for applying liquid curing compound with at least 10-20 kg capacity container/tank.

(vi) Texturing brooms.

(vii) Straight edges of 3 m length.

(viii) Appropriate tools for sealing joints.

(ix) Fixed side forms measuring at least 100-150 m length.

(x) Stop-end and start-end made of steel or wooden sections. These gadgets are required for commencing and stopping paving activity.

9.10.4. **Hauling of mix:** Transporting of concrete mix from mixer to paving site with steel pans should be avoided. The mix tends to get segregated during such handling. It is desirable to use wheel-barrows or trolleys for carrying mix to the paving site. The workability of the mix can be controlled better with the use of wheel-barrows.

9.10.5. **Compaction:** Where semi-mechanised and labour-oriented technique is adopted, compaction of the pavement

shall be accomplished by a vibrating screed supplemented by internal vibrators. For slabs of thickness more than 125 mm, vibrating screeds may be supplemented by portable needle vibrators. The vibrating screed shall rest on side forms. It shall be lowered vertically on to the concrete surface, evenly spread to the appropriate level above the base to provide the required surcharge for compaction; allowed to remain in position for a few seconds until compaction is complete, then lifted vertically and lowered on to the adjacent strip of uncompacted concrete. The amplitude of vibration of the screed shall not be less than 1.5 mm and the speed of travel not more than 0.6 m per minute. The screed shall again be taken slowly over the surface, sliding with its axis slightly tilted away from the direction of sliding and the operation repeated until the required dense, close knit textured surface is obtained. Compaction of concrete slabs upto 12.5 cm thickness may be done by means of vibrating screed alone, while for thicknesses greater than 12.5 cm both internal vibrators, like, needle and vibrating screeds shall be used. Even in the case of slabs of lower thickness, internal vibrators may be used with advantage for compacting the slab corners and edges. The working of the vibrators shall be regularly checked and stand-by shall always be maintained for emergency use. Segregated particles of coarse aggregate which collect in front of the screed shall be discarded. Under no circumstances shall such segregated particles be carried forward and pushed on to the base in front of the mass. Compaction by screeding shall be carried on till the mortar in the mix just works up to the surface. Care shall be exercised and the operation of tamping so controlled as to prevent an excess of mortar and water from being worked on the top. Repeated operation other than to secure the necessary compaction and to eliminate voids shall be avoided. Immediately after the screening has been completed and before the concrete has hardened, i.e., while the concrete is still in the plastic stage, the surface shall be inspected for irregularities with a profile checking template and any needed correction made by adding or removing concrete followed by further compaction and finishing.

9.10.6. **Floating:** As soon as practicable after the concrete has been compacted, its surface shall be smoothened by means of a longitudinal float, operated from a foot-bridge. The longitudinal float shall be worked with a sawing motion, while held in a floating position parallel to the carriageway centre line and passed gradually from one side of the pavement to the other. Movements ahead along the centre line of the carriageway shall be in successive advances of not more than one half the length of the float.

9.10.7. **Straight edging:** After the longitudinal floating has been completed, the excess water has disappeared, but while the concrete is still plastic, the slab surface shall be tested for trueness with a 3 m straight edge. The straight edge shall be held in successive positions parallel to the road centre line in contact with the surface and the whole area gone over from one side of the slab to the other. Advance along the road shall be in successive stages of not more than one-half length of the straight edge. Any area of depression found shall be scooped to a depth of 4-5 cm, filled immediately with freshly mixed concrete, struck, compacted, and refinished. High areas shall be cut down and refinished. The straight edging and refloating shall continue until the entire surface is found to be free from observable departures from the straight edge and the slab has the required grade and camber.

The slab surface shall be retested for trueness, before the concrete begins to set, with the 3 m long master straight edge and the graduated wedge gauge.

The straight edge shall be placed on the surface in successive positions, parallel to the carriageway centre line. Irregularities shall be measured with the help of the wedge gauge moved transversely at various points until it touches both the straight edge and the concrete surface.

At any point tested, the concrete shall not show a departure greater than 3 mm from the true surface. If at any place the departure exceeds this value, not more than 3 passes of the vibrating screed shall be allowed and the surface tested again in the specified manner. If the irregularity still exceeds the limit aforesaid, the concrete shall be removed to a depth of 50 mm or upto the top surface of the reinforcement, if any. The area of concrete to be removed shall be demarcated by the length of the straight edge in the position of measurement across the full width of the slab. The concrete so removed shall not be re-used in the carriageway. Fresh concrete shall be placed, compacted and finished in the manner already described in these specifications and shall again be subject to test for accuracy of finish.

The foregoing procedure shall be adopted at each shifting of the straight edge and the whole area shall be gone over from one side of the slab to the other. The straight edge shall advance longitudinally in successive stages of not more than one-half the length of the straight edge.

Although, the concrete may be removed immediately following measurement of the irregularity and while it is still wet, this shall not mean any waiver from complying with the requirements of this clause, if for any reason the concrete to be removed has already hardened.

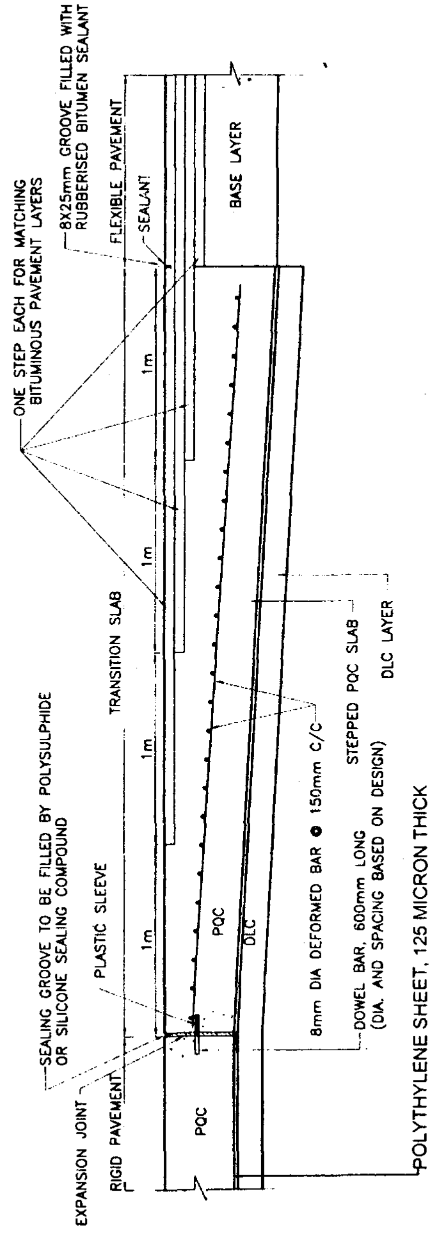
After straight edging of the surface, it shall be finished by belting and brooming.

9.10.8. **Texturing:** Just before the concrete becomes non-plastic, the surface shall be textured with an approved long handled steel or fibre broom conforming to the stipulations laid down in IRC:43. The broom shall be pulled gently over the surface of the pavement from edge to edge. Adjacent strokes shall be slightly overlapped. Brooming shall be perpendicular to the centre line of the pavement and so executed that the corrugations thus produced will be uniform in character and width, and about 1.5 mm deep. Brooming shall be completed before the concrete reaches such a stage that the surface is likely to be torn or unduly roughened by the operation. The broomed surface shall be free from porous or rough spots, irregularities, depressions and small pockets, such as may be caused by accidentally disturbing the particles of coarse aggregate embedded near the surface.

9.10.9. **Edging:** After belting and/or brooming have been completed, but before the concrete has taken its initial set, the edges of the slab shall be carefully finished with an edging or arrising tool of 3 mm radius and conforming to the requirements laid down in IRC:43 so as to leave the pavement edges smooth and true to line.

9.10.10. **Longitudinal joint with shoulder:** This is one of the critical areas which is generally not given proper treatment. The joint widens after the concrete slabs have shrunk and this wide joint allows water to seep to the lower layers. Whether the shoulder is rigid or flexible type, the joint should be treated with sealant after widening.

9.10.11. **Transition slabs:** At the interface of rigid and flexible pavement, at least 3 m long reinforced buried slab should be provided to give a long lasting joint at the interface. The details are shown in Fig. 3.



NOTES:
PQC: PAVEMENT QUALITY CONCRETE
DLC: DRY LEAN CONCRETE

Fig. 3. Typical Details of Transition Slab Between Rigid and Flexible Pavement (Clause 9.10.11)

9. 11. Curing of Concrete

9.11.1. Immediately after the finishing operations have been completed, the entire surface of the newly laid concrete shall be covered against rapid drying, and cured.

Curing can be done by one of the following two methods:

(i) By application of curing compound followed by spreading of wet hessian and moistening it regularly. In case of arid areas where water is extremely scarce, two applications of curing compound without moist curing by wet hessian may be allowed at the discretion of the Engineer.

(ii) For small works, curing can be done by manual methods using wet hessian which is kept moist during curing period. Curing shall be done for a minimum period of 7 days.

The water used for curing shall also be free from all injurious chemicals, like, chlorides and sulphate and shall meet the requirements of IS:456.

9.11.2. **Curing by application of curing compound:** Immediately after the surface texturing, the surface and sides of the slab shall be cured by the application of approved resin-based aluminised reflective curing compound or white pigmented curing compound which hardens into an impervious film or membrane with the help of a mechanical sprayer.

Curing compounds shall contain sufficient flake aluminium in finely divided dispersion to produce a complete coverage of the sprayed surface with a metallic finish. The compound shall become stable and impervious to evaporation of water from the surface of the concrete within 60 minutes of application and shall be of approved type. The curing compounds shall have a water retention efficiency index not less than 90 per cent in accordance with BS Specification No.7542.

The curing compound shall not react chemically with the concrete and the film or membrane shall not crack, peel or disintegrate within three weeks after application. Immediately prior to use, the curing compound shall be thoroughly agitated in its containers. The rate of spread shall be in accordance with the manufacturer's instructions checked during the construction of the trial length and subsequently whenever required by the Engineer. The mechanical sprayer shall incorporate an efficient mechanical device for continuous agitation and mixing of the compound during spraying. Arrangements should be made to spray the curing compound on the sides of the slab. In addition to spraying of curing compound, the fresh concrete surface shall be protected for at least 3 hours by covering the finished concrete pavement with tents during adverse weather conditions as directed by the Engineer. After two to three hours, the pavement shall be covered including sides by moist hessian (minimum of two layers) and the same shall then be kept damp for a minimum period of 7 days after which time the hessian may be removed. The hessian shall be kept continuously moist. All damaged/torn hessian shall be removed and replaced by new hessian on a regular basis.

9.11.3. **Curing by manual methods:** After completion of the finishing operations, the surface of the pavement shall be entirely covered with wet hessian cloth (minimum of two layers), burlap or jute mats. The coverings used shall be of such length (or width) that when laid will extend at least 500 mm beyond the edges of the slab, shall be so placed that the entire surface and both the edges of the slab are completely covered. They shall be placed as soon as the concrete has set sufficiently to prevent marring of the surface. Prior to their being placed, the coverings shall be thoroughly wetted with water and placed with the wettest side down. They shall be so weighed down as to cause them to remain in intimate contact with the surface covered. They shall be maintained fully wetted and in position for 24 hours after the concrete has been placed, or until the concrete is sufficiently hard to be walked upon without suffering any damage. To maintain the coverings wet, water shall be gently sprayed so as to avoid damage to the fresh concrete. If it becomes necessary to remove the coverings for cutting the joints, the concrete slab shall not be kept exposed for a period of more than half an hour.

Worn coverings or coverings with holes shall not be permitted. If the covering is furnished in strips, the strips shall be laid to overlap at least 150 mm.

Covering shall be placed from suitable wooden bridges (IRC:43). Walking on freshly laid concrete to facilitate placing coverings will not be permitted.

Upon the removal of the wet covering at the end of 24 hours, the slab shall be thoroughly wetted and then cured by ponding or sprinklers. Exposed edges of the slab shall be banked with a substantial berm of earth. Upon the slab shall then be laid a system of transverse and longitudinal dykes of clay about 50 mm high, covered with a blanket of sandy soil free from stones to prevent the drying up and cracking of clay. Before constructing clay dykes, the joints formed in concrete slabs shall be temporarily sealed with jute ropes, or synthetic back-up rods so that no foreign material, like, clay or sand enters the joint. The rest of the slab shall be covered with sufficient sandy soil so as to produce a blanket of earth not less than 40 mm depth after wetting. The earth covering shall be thoroughly wetted while it is being placed on the surface and against the sides of the slab and kept thoroughly saturated with water for 7 days and thoroughly wetted down during the morning of the 8th day and shall thereafter remain in place until the concrete has attained the required strength and permission is given to open the pavement to traffic. When such permission

is granted, the covering shall be removed and the pavement swept clean. If the earth covering becomes displaced during the curing period, it shall be replaced to the original depth and re-saturated.

9.12. Trial Length

9.12.1. The trial length shall be constructed at least one month in advance of the proposed start of concrete paving work. At least one month prior to the construction of the trial length, a detailed method statement shall be submitted giving description of the proposed materials, plant, equipments, like, paving train, batching plant, tippers, etc., proposed in the construction and got approved by the Engineer before their procurement. No trials of new materials, plant, equipment or construction methods, nor any development of them shall be permitted either during the construction of trial length or in any subsequent paving work, unless they form part of further approved trials. These trial lengths shall be constructed away from the carriageway but with at least a sub-base layer stipulated below it.

9.12.2. The trial length of slab shall be at least 60 m but not more than 300 m long for mechanised construction and at least 30 m long for hand guided methods.

9.12.3. The trial length shall be constructed in two parts over a period comprising at least part of two separate working days, with a minimum of 30 m constructed each day for mechanised construction and a minimum of 15 m on each day for hand guided construction. The trial length shall be constructed at a similar rate (speed, 1m/hr) to that which is proposed for the main work.

9.12.4. Transverse joints and longitudinal joints of each type that are proposed for dowel-jointed unreinforced concrete slabs in the main work shall be constructed and assessed in the trial length. If in the trial length the construction of expansion joint is not demonstrated, the first 2 expansion joints for mechanised paving in the main work, shall be considered as the trial length for these joints. Any deficiency in that work shall be reinstated at the cost of the Contractor.

9.12.5. The trial length shall comply with the Specification in all respects, with the following additions and exceptions:

9.12.5.1. **Surface levels and regularity**

(i) In checking for compliance with Clause 9.22.5, the levels shall be taken at intervals at the locations specified in this Clause along any line or lines parallel to the longitudinal centre line of the trial length.

(ii) The maximum number of permitted irregularities of pavement surface shall comply with the requirements of Clause 9.22.5. Shorter trial lengths shall be assessed pro-rata based on values for a 300 m length.

9.12.5.2. **Joints**

(i) Alignment of dowel bars shall be inspected in any two consecutive transverse joints in a trial length construction. If the position or alignment of the dowel bars at one of these joints does not comply with the requirements, if that joint remains the only one that does not comply after the next 3 consecutive joints of the same type have been inspected, then the method of placing dowels shall be deemed to be satisfactory. In order to check sufficient joints for dowel bar alignment without extending the trial length unduly, joints may be constructed at more frequent joint intervals than the normal spacing required in trial slabs.

(ii) If there are deficiencies in the first expansion joint that is constructed as a trial, the next expansion joint shall be a trial joint. Should this also be deficient, further trial of expansion joints shall be made as part of the trial length which shall not form part of the permanent works, unless agreed by the Engineer.

9.12.5.3. **Density:** Density shall be assessed as described in Clause 9.22.2 from at least 3 cores drilled from each part of the trial length.

9.12.5.4. **Position of tie bars:** Compliance for the position and alignment of tie bars shall be checked by drilling additional cores from the slab unless they can be determined from cores taken for density.

9.12.6. **Approval and acceptance**

9.12.6.1. Approval of the materials, plant, equipment and construction methods shall be given when a trial length complies with the Specification. Normal working shall not be proceeded with until the trial length has been approved and any earlier defective trial lengths have been removed, unless that can be remedied to the satisfaction of the Engineer.

9.12.6.2. When approval has been given, the materials, plant, equipment and construction methods shall not thereafter be changed, except for normal adjustments and maintenance of plant, without the approval of the Engineer. Any changes in materials, plant, equipment and construction methods shall require the laying of a further trial length to demonstrate that the changes will not adversely affect the permanent works.

9.12.6.3. Trial lengths which do not comply with the requirements, with the exception of areas which are deficient only in surface texture and which can be remedied shall be removed immediately upon notification of deficiencies by the Engineer and a further trial length shall be constructed.

9.12.6.4. Construction of trial sections is considered obligatory on the part of the Contractor and the entire cost of construction, dismantling and transportation of debris is to be borne by the Contractor.

9.12.7. **Dowel bars**

9.12.7.1. Compliance for the position and alignment of dowel bars at construction and expansion joints shall be checked by measurements relative to the side forms or guidewires.

9.12.7.2. When the slab has been constructed, the position and alignment of dowel bars and any filler board shall be measured after carefully exposing them in the plastic concrete across the whole width of the slab. When the joint is an expansion joint, the top of the filler board shall first be exposed sufficiently in the plastic concrete to permit measurement of any lateral or vertical displacement of the board. During the course of normal working, these measurements shall be carried out in the pavement section at the end of day's work by extending slab length by 2 m. After sawing the transverse joint groove, the extended 2 m slab shall be removed carefully soon after concrete has set in order to expose dowels over half the length. These dowels can be tested for tolerances. This should be carried out at every 2 km of pavement construction.

9.12.7.3. If the position and alignment of the bars in a single joint in the slab is unsatisfactory then the next two joints shall be inspected. If only one joint of the three is defective, the rate of checking shall be increased to one joint per day until the Engineer is satisfied that compliance is being achieved. In the event of non-compliance in two or more successive joints, fresh trial lengths shall be constructed adopting any necessary alteration to concrete mix, paving plant or methods until the dowel bar position and alignment are satisfactory.

9.12.7.4. **Repair of pavement with exposed dowels:** When the Engineer instructs for the exposure of dowels, such area shall be repaired as under:

After the dowel bars have been examined, the remainder of the concrete shall be removed over a width of 500 mm on each side of the line of the joint and reinstated to the satisfaction of the Engineer. The dowels shall be inserted on both sides of the 1 m wide slab by drilling holes and grouting with epoxy mortar. Plastic sheaths shall be provided on dowels on one of the joints so that it is made active. The joint grooves shall then be widened and sealed.

9.13. **Final Surface Test**

The final surface test shall be made after the curing period and after the removal of the material used for curing. The surface shall be of correct alignment, grade and camber specified. The surface level, as measured by surface levels taken on a grid points at 5 or 6.25 m longitudinally and 3.5 m transversely or any specified grid, shall not have a tolerance greater than +5 mm or -6 mm. The maximum allowable difference between the road surface and the underside of a 3 m straight edge placed parallel with or at right angles to the centre line of the road shall be 3 mm for pavement constructed with mechanised method and 6 mm for semi-mechanical or manual construction. Any spots higher than the correct surface as prescribed above, shall be ground down with an approved scabbler/grinding tool to the required level and textured by alternative means say by cutting grooves or scabbling the surface.

9.14. **Removing Forms**

Forms shall not be removed from freshly placed concrete until it has set, or at least 12 hours, whichever is later. They shall be carefully removed in such a manner that no damage is done to the edges of the pavement. After the forms have been removed, the slab edges shall be cleaned and any limited honey-combed areas pointed up with 1:2 cement sand mortar, after which the sides of the slab shall be covered with wet hessian for curing. Slabs with excessive honey-combing as a result of inadequate compaction shall be removed between nearest transverse joints.

9.15. Concreting during Monsoon Months

When concrete is being placed during monsoon months and when it may be expected to rain, sufficient supply of tarpaulins or other waterproof cloth shall be provided along the line of work in addition to the portable tents. Any time when it rains, all freshly laid concrete which has not been covered for curing purposes shall be adequately protected by means of tarpaulins or other waterproof cloth. Any concrete damaged by rain shall be removed and replaced. Any damage caused to the surface or texture shall be corrected as decided by the Engineer.

9.16. Concreting in Hot Weather

As placing of concrete in air temperatures above 35°C, is associated with defects, like, loss of workability through accelerated setting, formation of plastic shrinkage cracks, etc., it is recommended that unless adequate precautions are taken, no concreting shall be done in conditions more severe than the above. The procedures recommended for adoption in case of hot weather concreting are given in IRC:61 "Tentative Guidelines for the Construction of Cement Concrete Pavements in Hot Weather."

As the temperature of concrete mix is not to exceed 30°C, it is desirable to instal a chilling plant so that the temperature of the mix can be controlled in hot weather.

9.17. Concreting in Cold Weather

Except by specific written authorisation from the Engineer-in-Charge, concreting shall not be continued when a descending air temperature in the shade and away from artificial

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

When concrete is likely to be subjected to freezing the use of air entraining agent is mandatory. The air content in the concrete shall be 5±1.5 per cent.

When specific written authorisation is granted to permit concreting at temperatures below those specified above, equipment to heat the aggregates and water shall have to be provided. In addition, use of calcium chloride as an accelerator when so indicated may be permitted. The amount of calcium chloride solution used shall not exceed about 2.3 litres per bag (50 kg nett) of cement and this solution shall be considered as a part of the mixing water. This solution shall be prepared by dissolving 45 kg of granulated or flaked calcium chloride in about 95 litres of water. Normally ordinary portland cement as per IS:269-1976 alone shall be used when calcium chloride is employed as an additive. Also it is recommended that when calcium chloride is proposed to be used, there should be no steel reinforcement in the concrete pavement.

Concreting heating equipment capable of producing concrete that will have temperature of at least 15°C and not exceeding 30°C at the time of placing it between the forms shall be provided. The aggregates shall be heated prior to being loaded into the concrete mixer. The equipment used shall heat the mass uniformly and shall preclude the possible occurrence of overheated zones which might affect the concrete properties. Water used for mixing shall not be heated beyond 66°C. Material containing frost, ice, snow or lumps of hardened mass shall not be used. Heating methods which alter or prevent the entrainment of the required amount of air in the concrete shall not be adopted.

During placement of concrete, tarpaulin covers or other readily removable coverings should closely follow the placing of concrete, so that only a few metres of the finished slab are exposed to the outside air at any one time. The coverings may be so arranged that heated air, where provided, could be freely circulated on top of the pavement. The coverings may be further covered by layers of straw or other insulating materials, no sooner the wet concrete is strong enough to take their load.

When concrete is being placed in cold weather and the air temperature is expected to fall below 2°C, the air surrounding the concrete shall be maintained at a temperature of 15°C for at least 3 days and not less than 4°C for a period of not less than 7 days.

Any concrete damaged by frost action shall be removed and replaced.

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

For more details about concreting in cold weather, see Supplementary Note, N.6 ***(Appendix-B)***.

9.18. Work on Gradients

The progress on gradient of all operations of placing, compacting and finishing of concrete should proceed from the lower to the higher reaches. The concrete mix shall be stiffer than that used on level reaches. Therefore, slump of concrete mix in such gradients should be adjusted from field trials.

9.19. Protection of Concrete

Suitable barricades shall be erected and maintained and watchmen employed to exclude traffic from the newly constructed

pavement for the period wherein prescribed, and these barriers shall be so arranged as not in any way to interfere with or impede traffic on any lane intended to be kept open and necessary signs and lights shall be maintained clearly indicating any lanes open to the traffic. Where, as shown on the plans or indicated in the special provisions, it is necessary to provide for traffic across the pavement, suitable and substantial crossings to bridge over the concrete shall have to be provided. Such crossings, as constructed, shall be adequate for the traffic and approved by the Engineer-in-Charge.

Any part of the pavement damaged by traffic or other causes occurring prior to its final acceptance shall be repaired or replaced in a manner satisfactory to the Engineer-in-Charge. The pavement shall be protected against all traffic usage including that of construction traffic.

9.20. Preparation and Sealing of Joint Grooves

9.20.1. **General:** All transverse joints in surface slabs shall be sealed using sealants and joints shall not be sealed before 14 days after construction.

9.20.2. Preparation of joint grooves for sealing

9.20.2.1. Joint grooves usually are not constructed to provide the maximum width specified in the drawings when saw cut joints are adopted. They shall be widened subsequently by sawing before sealing. Depth/width gauges shall be used to control the dimension of the groove during widening process.

9.20.2.2. If rough arrises develop when grooves are made, they shall be ground to provide a chamfer approximately 5 mm wide. If the groove is at an angle upto 10 degree from the perpendicular to the surface, the over-hanging edge of the sealing groove shall be sawn or ground perpendicular. If spalling occurs or the angle of the former is greater than 10 degrees, the joint sealing groove shall be sawn wider and perpend cular to the surface to encompass the defects upto a maximum width, including any chamfer, of 25 mm for transverse joints and 15 mm for longitudinal joints. If the spalling cannot be so eliminated then the arrises shall be repaired by an approved thin bonded arris repair using cementitious materials, like, epoxy or polymer concrete.

9.20.2.3. All grooves shall be cleaned of any dirt or loose material by air blasting with filtered, oil-free compressed air. If need arises, the Engineer may instruct cleaning by pressurised water jets. Depending upon the requirement of the sealant manufacturer, the sides of the grooves may have to be sand blasted to increase the bondage between sealant and concrete.

9.20.2.4. The groove shall be cleaned and dried at the time of priming and sealing.

9.20.2.5. Before sealing the temporary seal provided for blocking the ingress of dirt, soil, etc. shall be removed. A highly compressible heat resistant paper-backed debonding strip as per drawing shall be inserted in the groove to serve the purpose of breaking the bond between sealant and the bottom of the groove and to plug the joint groove so that the sealant may not leak through the cracks. The width of debonding strip shall be more than the joint groove width so that it is held tightly in the groove. In the case of longitudinal joints, heat resistant tapes may be inserted to block the leakage through bottom of the joint.

9.20.3. **Sealing with sealants**

9.20.3.1. When sealants are applied, an appropriate primer shall also be used if recommended by the manufacturer and it shall be applied in accordance with his recommendation. The

sealant shall be applied within the minimum and maximum drying times of the primer recommended by the manufacturer. Priming and sealing with applied sea'ants shall not be carried out when the naturally occurring tempe ature in the joint groove to be sealed is below 7°C.

9.20.3.2. If hot applied sealant is used, it shall be heated and applied from melter and pourer. Hot sealants shall be rubberised bitumen type. For large road projects, sealant shall be applied with extruder having flexible hose and nozzle. The sealant shall not be heated to a temperature higher than the safe heating period, as specified by the manufacturer. The dispenser shall be cleaned out at the end of each day in accordance with the manufacturer's recommendations and reheated material shall not be used.

9.20.3.3. Cold applied sealants with chemical formulation, like, polysulphide/silicone/or other similar formulation may be used. These shall be mixed and applied within the time limit specified by the manufacturer. If primers are recommended they shall be applied neatly with an appropriate brush. The Movement Accommodation Factor (MAF) shall be more than 10 per cent. The groove configuration is different for polysulphide and silicone. Silicone, a single chemical formula, hardens by absorbing moisture from the air and hence it should be placed in a thinner layer vis-à-vis polysulphide. Accordingly, the depth/width ratio of grooves should be modified. Besides the curing time of silicone is more than that of polysulphide.

9.20.3.4. The sealants applied at contraction phase of the slabs would result in bulging of the sealant over and above the slab. The right temperature and time for applying the sealant shall be determined first. Thermometer shall be installed on a pole in the site for facilitating control during the sealing operation.

9.20.3.5. Sealant shall be applied, slightly to a lower level than the slab with a tolerance of 3 ± 1 mm.

9.20.3.6. During sealing operation, it shall be seen that no air bubbles are introduced in the sealant either by vapours or by the sealing process.

9.20.3.7. Preformed sealing strips of neoprene are also used for sealing joints. The strips made of hollow section are kept pressed during insertion. Thus the strip is always under compression and does not allow any moisture to ingress in the joint groove. This technique also will require primer.

9.20.3.8. **Testing of applied sealants:** The sealant should not be more than six months old and a certificate to this effect stating that the sealant complies with the relevant standard should be obtained before approval for use.

9.21. Opening to Traffic

In general, traffic shall be excluded from the newly constructed pavement for a period of 28 days where Ordinary Portland Cement, Portland Blast Furnace Slag Cement and Portland Pozzolana Cement are used, or for a period of 7 days where Rapid Hardening Cement is used. In all cases, before the pavement is opened to traffic it shall be cleaned and the joints shall be sealed as per Clause 9.20.

9.22. Quality Control

9.22.1. **Sampling and testing of beam and cube specimens:** At least two beam and two cube specimens, one each for 7 days and 28 days strength testing shall be cast for every 150 cum (or part thereof) of concrete placed during construction. On each day's work, not less than three pairs of beams and cubes shall be made from the concrete delivered to the paving plant.

Each pair shall be from a different delivery of concrete and tested at a place to be designated by the Engineer. Groups of four consecutive results from single specimens tested at 28 days shall be used for assessing the strength for compliance with the strength requirements. The specimens shall be transported in an approved manner to prevent sudden impact causing fractures or damage to the specimen. The flexural strength test results shall prevail over compressive strength tests for compliance.

A quality control chart indicating the strength values of individual specimens shall be maintained for continuous quality assurance. Where the requirements are not met with, or where the quality of the concrete or its compaction is suspect, the actual strength of the concrete in the slab shall be ascertained by carrying out tests on cores cut from the hardened concrete at such locations. The cores shall be cut at the rate of 2 cores for every 150 cum of concrete. The results of crushing strength of tests on these cores shall not be less than 0.8 times the corresponding crushing strength of cubes, where the height to diameter ratio of the core is two. Where height to diameter ratio is varied, then the necessary corrections shall be made in calculating the crushing strength of cubes in the following manner.

The crushing strengths of cylinders with height to diameter ratios between 1 and 2 may be corrected to correspond to a standard cylinder of height to diameter ratio of 2 by multiplying with the correlation factor obtained from the following equation:

$$f = 0.11\,n + 0.78$$

Where,

f = correlation factor and

n = height to diameter ratio

The corrected test results shall be analysed for conformity with the Specification requirements for cube samples. Where the core tests are satisfactory, they shall have precedence for assessing concrete quality over the results of moulded specimens. The diameter of cores shall not be less than 150 mm.

If, however, the tests on cores also confirm that the concrete is not satisfying the strength requirements, then the concrete corresponding to the area from which the cores were cut should be replaced, i.e., at least over an area extending between two transverse joints where the defects could be isolated or over larger areas, if necessary, as assessed by additional cores and their test results. The equivalent flexural strength at 28 days shall be estimated in accordance with Clause 4.1.2.

In order to ensure that the specified minimum strength at 28 days is attained in the specified per cent as per the selected tolerance level of all test beams, the mix shall be proportioned to give an average strength at 28 days exceeding the specified strength by 3 times the standard deviation calculated first from the flexural strengths of test beams made from the trial mix and subsequently from the accumulating result of flexural strengths of job control test beams.

The standard deviation shall be re-calculated from the test results obtained after any change in the source or quality of materials and the mix shall be adjusted as necessary to comply with the requirements.

An individual 28 days strength below the specified strength shall not be evidence for condemnation of the concrete concerned if the average 28 days strength of this beam plus the preceding 5 and succeeding 4 beams exceeds the specified strength by Za times standard deviation and provided that there is no other evidence that the concrete mix concerned is substandard.

Beams shall be made each day in pairs at intervals, each pair being from a different batch of concrete. At the start of the work, and until such time as the Engineer may order a reduction in the number of beams required, at least six pairs of beams and cubes shall be made each day, one of each pair for testing at 28 days for determination of the minimum permissible flexural strength and the other for testing at 7 days for the Engineer to assess the quality of the mix. When the first thirty number of 28 days results are available, and for so long as the Engineer is satisfied with the quality of the mix, he may reduce the number of beams and cubes required.

During the course of construction, when the source of any material is to be changed, or if there is any variation in the quality of the materials furnished, additional tests and necessary adjustments in the mix shall be made as required to obtain the specified strength.

The flexural strengths obtained on beams tested before 28 days shall be used in conjunction with a correlation between them and the 28 days flexural strengths to detect any deterioration in the quality of the concrete being produced. Any such deterioration shall be remedied without awaiting the 28 days strengths but the earlier strengths shall not constitute sole evidence of non-compliance of the concrete from which they were taken.

Concrete shall not comply with the specification when more than one test beam in a batch has a 28 days strength less than the specified strength and the average 28 days flexural strength of the batch of 4 beams is less than the specified strength plus Za times the standard deviation of the batch, where Za has values given in Table 10.

TABLE 10. TOLERANCE LEVEL

Tolerance Level	Za	Percentage of Tests below Minimum
1 in 15	1.50	6.7 per cent
1 in 20	1.65	5 per cent
1 in 40	1.96	2.5 per cent
1 in 100	2.33	1 per cent

Should the concrete fail to pass the specification for strength as described above, the Contractor may, at his own expense, elect to cut cores from the suspect concrete as per direction of the Engineer. From the relation between cube strength and flexural strength, the core strength shall be converted to flexural strength.

The equivalent flexural strength at 28 days shall be the estimated in-situ strength multiplied by 100 and divided by the age-strength relation obtained from Table given in N.1.11 ***(Appendix-A)***.

Any concrete that fails to meet the strength requirement shall be removed and replaced at Contractor's expense.

9.22.2. **In-situ density:** The density of the compacted concrete shall be such that the total air voids are not more than 3 per cent. The air voids shall be derived from the difference between the theoretical maximum dry density of the concrete calculated from the specific gravities of the constituents of the concrete mix and the average value of three direct density measurements made on cores at least of 150 mm diameter. Three cores shall be taken from trial lengths and in first two km length of the pavement, while the slab is being constructed during normal working. The proportions of the mix and the vibratory effort imparted, i.e., the frequency and magnitude of vibration shall be adjusted to achieve the maximum density.

All cores taken for density measurement in the trial section shall also be checked for thickness. The same cores shall be made use of for determining in-situ strength. In case of doubt, additional cores may be ordered by the Engineer and taken at locations decided by him to check the density of concrete slab or the position of dowel/tie bars without any compensation being paid for the use.

In calculating the density, allowance shall be made for any steel in cores.

Cores removed from the main carriageway shall be reinstated with compacted concrete mix used for pavement works. Before filling the fine mix, the sides shall be hacked and cleaned with water. Thereafter, cement-sand slurry shall be applied to the sides just prior to filling the concrete mix.

9.22.3. **Pavement thickness:** All precautions and care shall be to taken to construct pavement having uniform thickness as called for on the plan.

Thickness of the cement concrete pavement shall be calculated on the basis of level data of the cement concrete pavement and the underlying sub-base taken on a grid of 5 m x 3.5 m or 6.25 m x 3.5 m, the former measurement being in longitudinal direction or any other grid recommended by the Engineer.

A day's work is considered as a 'lot' for calculating the average thickness of the slab. In calculating the average thickness, individual measurements which are in excess of the specified thickness by more than 10 mm shall be considered as the specified thickness plus 10 mm.

Individual areas deficient by more than 25 mm shall be verified by the Engineer by ordering core cutting and if in his opinion the deficient areas warrant removal, they shall be removed and replaced with concrete of the thickness shown on the plans.

When the average thickness for the lot is deficient by the extent shown in Table 11, the Contract unit price will be adjusted as per this Table 11 and payment can be made for reduced thickness.

TABLE 11. PAYMENT ADJUSTMENT FOR DEFICIENCY IN THICKNESS

Deficiency in the average thickness of day's work	Per cent contract unit price payable
Upto 5 mm	100
6-10 mm	87
11-15 mm	81
16-20 mm	75
21-25 mm	70

In the stretch where deficiency of average thickness is more than 25 mm, cores shall be cut to ascertain the deficiency as directed by the Engineer. Section whose thickness is deficient by 26 mm or more is identified with the help of cores. Such slabs shall be removed and reconstructed at the cost of the Contractor. During such rectification work, care shall be taken to replace full slab and to the full depth.

Through some typical examples, the application of penalty clause for deficient pavement thickness has been explained in ***Appendix-D***.

9.22.4 **Surface levels:** The levels of the subgrade and different pavement courses as constructed, shall not vary from those calculated with reference to the longitudinal and cross-profile of the road shown on the drawings or as directed by the Engineer beyond the tolerances mentioned in Table 12.

TABLE 12. TOLERANCES IN SURFACE LEVELS

1.	Subgrade	+ 20 mm – 25 mm
2.	Granular Sub-base/WBM Layer	+ 10 mm – 10 mm
3.	Dry lean concrete or rolled concrete	+ 6 mm – 15 mm
4.	Cement concrete pavement*	+ 5 mm – 6 mm

*This may not exceed -8 mm at 0- 30 cm from the edges.

Provided, however, that the negative tolerance for wearing course shall not be permitted in conjunction with the positive tolerance for base/sub-base course.

For checking compliance with the above requirement for subgrade, sub-base courses, measurements of the surface levels shall be taken on a grid of points placed at 6.25 m longitudinally and 3.5 m transversely or any other grid approved by the Engineer. For any 10 consecutive measurements taken longitudinally or transversely, not more than one measurement shall be permitted to exceed the tolerance as above, this one measurement being not in excess of 5 mm greater then the permitted tolerance.

For checking compliance with the above requirement for concrete pavements, measurements of the surface levels shall be taken on a grid of 6.25 m x 3.5 m or 3.75 m or any other grid directed by the Engineer. In any length of pavement, compliance shall be deemed to be met for the final road surface, only if the tolerance given above is satisfied for any point on the surface.

9.22.5. **Surface regularity of pavement courses:** The longitudinal profile shall be checked with a 3 metre long straight edge/moving straight-edge as desired by the Engineer at the middle of each traffic lane along a line parallel to the centre line of the road.

The maximum permitted number of surface irregularities shall be as per Table 13.

Table 13. Maximum Permitted Number of Surface Irregularities

Irregularity	Surfaces of Carriageways and Paved Shoulders			
	4 mm		7 mm	
Length (m)	300	75	300	75
National Highways/ Expressways	20	9	2	1
Roads of lower category	40	18	4	2

Note : Category of each section of road as described in the Contract.

The maximum allowable difference between the road surface and underside of a 3 m straight-edge when placed parallel with, or at angles to the centre line of the road at points decided by the Engineer shall be:

for pavement surface	4 mm
for granular sub-base/base courses and sub-bases under concrete pavements	10 mm

9.22.6. **Horizontal alignment:** The horizontal alignment shall be checked with respect to the centre line of the carriageway as shown in the drawings. The edges of the carriageway as constructed shall be corrected within a tolerance of ±10 mm therefrom.

9.22.7. **Acceptance criteria for cracked concrete slabs:** Concrete slabs may develop cracks of minor to serious nature unless appropriate precautions are taken to prevent their occurrence either during the construction phase or post-construction period. Cracks can appear generally due to the following reasons:

(a) Plastic shrinkage of concrete surface due to rapid loss of moisture

(b) Drying shrinkage

(c) High wind velocity associated with low humidity

(d) High ambient temperature

(e) Delayed sawing of joints

(f) Rough and uneven surface of the base on which concrete slabs are constructed

(g) Combination of the above factors

The slabs with full depth cracks are totally unacceptable as it amounts to structural failure. Besides, other cracks which are deep and are likely to progress in depth with time are also to be considered as serious in nature. Fine crazy cracks, however, are not serious. An acceptance criteria for cracked concrete slabs are:

The concrete slabs can be accepted in the following situations:

(a) Plastic shrinkage cracks – the discrete crack which is less than 500 mm length and with its depth of penetration less than half the thickness of the slab and which does not intersect with a longitudinal edge or formed joint. The cumulative length of such cracks in each slab shall not be more than 1.0 m length. Cores can be cut to ascertain the depth of cracks where doubt arises.

(b) Fine hairline crazy cracks

The concrete slabs are to be rejected where the cracks formed are not complying with the above stipulation. Therefore, the slabs which are to be rejected are:

(i) Slabs with cracks running transversely or longitudinally penetrating to full depth and length of the slab.

(ii) Slabs with cracks which are penetrating to more than half the depth.

(iii) Discrete crack which is more than 500 mm length although its depth of penetration is less than half of the depth.

The maximum permitted number of surface irregularities shall be as per Table 13.

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(ii) Slabs with cracks which are penetrating to more than half the depth.

(iii) Discrete crack which is more than 500 mm length although its depth of penetration is less than half of the depth.

(iv) When the total length of all discrete cracks is more than 1.0 m whose depth of penetration is less than half the depth.

9.22.8. **Summary of control tests:** Table 14 gives a summary of frequency of testing of pavement quality concrete.

TABLE 14. FREQUENCY OF QUALITY CONTROL TESTS FOR PAVING QUALITY CONCRETE

1.	**Levels, Alignment and Texture**	
	(i) Strength	Clause 9.22.1
	(ii) In-situ density	Clause 9.22.2
	(iii) Pavement thickness	Clause 9.22.3
	(iv) Surface levels	Clause 9.22.4
	(v) Surface regularity	Clause 9.22.5
	(vi) Horizontal alignment	Clause 9.22.6
	(vii) Acceptance criteria for cracked concrete slabs	Clause 9.22.7
	(viii) Alignment of joints, widths, depths of dowel grooves	To be checked @ one joint per 400 m length or a day's work whichever is more.
	(ix) Surface regularity both transversely and longitudinally	Once a day or one day's work, without disturbing the curing operation.
	(x) Alignment of dowel bars and their accuracy/tie bars	To be checked in trial length and once in every 2 km as per Clause 8.3.4.2.
	(xi) Texture depth	Clause 9.9.4
2.	**Quality of Materials and Concrete**	
	Control tests for materials and concrete shall be as under :	
	(1) Cement physical and chemical tests IS:269 IS:455 IS:1489 IS:8112 IS:12269	Once for each source of supply and occasionally when called for in case of long/improper storage. Besides, the Contractor also will submit daily test data on cement released by the manufacturer.

	(2) Coarse and Fine aggregate (i) Gradation IS:2386 (Pt. 1)	One test for every day's work of each fraction of coarse aggregate and fine aggregate, initially; may be relaxed later at the discretion of the Engineer.
	(ii) Deleterious constituents IS:2386 (Pt.2)	-do-
	(iii) Water absorption IS:2386 (Pt. 3)	Regularly as required subject to a minimum of one test a day for coarse aggregate and two tests a day for fine aggregate. This data shall be used for correcting the water demand of the mix on daily basis.
	(3) Coarse and Fine aggregate (i) Los Angeles Abrasion Value or Aggregate Impact Test IS:2386 (Pt. 4)	Once for each source of supply and subsequently on monthly basis.
	(ii) Soundness IS:2386 (Pt. 5)	Before approving the aggregates and every month subsequently.
	(iii) Alkali aggregate reactivity IS:2386 (Pt. 7)	-do-
	(4) Water Chemical Tests IS:456	Once for approval of source of supply, subsequently only in case of doubt.
	(5) Concrete (i) Strength of concrete IS:516	2 cubes and 2 beams per 150 cum or part thereof (one for 7 days and other for 28 days strength) or minimum 6 cubes and 6 beams per day's work whichever is more.
	(ii) Core strength on hardened concrete IS:516	As per the requirement of the Engineer, only in case of doubt.

	(iii) Workability of fresh concrete-Slump Test IS:1199	One test per dumper load at both batching plant site and paving site initially when work starts. Subsequently sampling may be done from alternate dumper.
	(iv) Thickness determination	From the level data of concrete pavement surface and sub-base at grid points of 5/6.25 m x 3.5 m. Cores may be cut in case the Engineer desires.
	(v) Thickness measurement for trial length	3 cores per trial length.
	(vi) Verification of level of string line in the case of slip form paving and steel forms in the case of fixed form paving	String line or steel forms shall be checked for level at an interval of 5.0 m or 6.25 m. The level tolerance allowed shall be ± 2 mm. These shall be got approved 1-2 hours before the commencement of the concreting activity.

9.23. **Measurement for Payment**

9.23.1. Cement concrete pavement shall be measured as a finished work in square metres with specified thickness. The volume to be paid for will be calculated on the basis of thickness and plans shown on the project drawings and adjusted for the deficiency in thickness. The full payment will be made to this item after 28 days of the concrete is found to be satisfactory.

The unit for measurement for concrete pavement shall be the cubic metre of concrete placed, based on the net plan areas for the specified thickness shown on the drawings or directed by the Engineer. The rate shall include all provisions of this specification and shall include the provision of all materials

including polythene film, concrete, stock piling, mixing, transport, placing, compacting, finishing, curing together with all formwork, and including testing and submission of test certificates and records. No deduction shall be made in measurement for openings provided that the area of each is less than 0.5 sqm. The unit rate as entered in the Bill of Quantities shall include the full costs of contraction, expansion, construction, and longitudinal joints. It shall also include joint filler, keys, caulking rod, debonding strip, sealant primer, joint sealant, dowel bar and tie rod complete.

Appendix-A

SUPPLMENTARY NOTES

N.1. Concrete

N.1.1. **Desirable properties of pavement concrete :** For road work, the concrete should have sufficient workability to permit of thorough compaction, and adequate compressive and flexural strength; it should also be dense, resistant to weather, capable of resisting the abrasive and impact action of traffic, finished with an even surface to give a good riding quality and provided with a surface, such as, to maintain a high resistance to skidding throughout its life.

N.1.2. **Workability**

The workability of the mix should be just sufficient to enable the concrete to be compacted fully by whatever method is employed. It should not be higher than necessary for this purpose, as this will lead to segregation, surface laitance, difficulty in maintaining the concrete to its true profile on gradients and crossfalls, and a reduction in strength due to excessive water content. The workability required will depend very largely on the method of compaction employed.

N.1.3. **Strength**

N.1.3.1. **General:** The quality of concrete is normally assessed by measuring its compressive strength because this is the easiest and most convenient test to make. For pavings, however, it is the flexural strength rather than the compressive strength of concrete which determines the degree of cracking and thus the performance of the road, and it is imperative to control the quality on the basis of flexural strength. Wherever direct

flexural strength tests are not possible, this may be done indirectly through correlation of compressive and flexural strengths. As recommended in Clause 4.1.: , for each particular case, therefore, correlation between the two l as to be established at the laboratory mix design stage, for the particular materials involved. In case quality of concrete is to be controlled through compressive strength tests, the correlation will apply so long as the quality of materials remains unchanged.

Rigid pavements are designed normally for flexural strength in the range of 4 to 5 MPa, but the recommended strength is 4.5 MPa as specified in Clause 4.1.4.

N.1.3.2. **Variations in strength:** When adopting a concrete mix to provide a given strength at a certain age, variations in strength may occur even from batch to batch. These are caused by variations in quality of cement, in the grading of aggregates. in batching, in the degree of compaction, and in weather conditions. Good control during the manufacture and placing of concrete will, therefore, reduce the variation in concrete strength.

N.1.3.3. **Variations in strength due to variation in quality of cement:** Investigations have shown rather wide variations in concrete strengths at early ages on account of variations in the quality of cement used. The relevant Indian Standard Specifications ensure minimum strength requirements, but do not control variations above the minimum and the strengths of cement commercially supplied can vary substantially. Concrete mix should, therefore, be designed using representative samples of cement actually to be used in the construction. In case the strength of subsequent cement supplies varies substantially, the mix should be redesigned.

N.1.3.4. **Variation in strength due to degree of control:** A cube crushing strength for concrete of 30-40 MPa at 28 days has been generally found to give a flexural strength of 4-5 MPa; the average strength for mix design will be higher than this depending upon the tolerance level as noted earlier. As the inherent variability of concrete will result in occasional strengths which are higher and lower than the normal range of variability, it is reasonable to allow a small proportion of the results to fall below the specified minimum value. The tolerance level to be adopted depends upon the importance of the project and the facilities available for quality control.

The Table below gives the various tolerance levels and the associated standard normal variable za.

Tolerance Level	Standard Normal Variable za
1 in 15	1.50
1 in 20	1.64
1 in 40	1.96
1 in 100	2.33

If a higher level of 1 in 100 is desired, which is the case for high quality modern highway pavement, and the minimum compressive strength desired is 40 Mpa, the mix should be designed for a strength of:

40 +2.33 x Standard Deviation

N.1.4. **Degree of Compaction**

Particular attention should be paid in constructing concrete roads to the methods of compacting the concrete. It is of the utmost importance from strength consideration that maximum compaction should be achieved without segregation. When high efficiency vibrating or other machines are used to compact the concrete from the top surface only, very little trouble would normally be experienced with concrete layers upto 350 mm thick,

provided the concrete has adequate and uniform workability. With commercially available screed vibrators of low amplitudes, this thickness is of the order of 125 mm. With inadequate vibration or where the compacting effort does not correspond to the thickness to be compacted will suffer from honeycombing due to presence of excess voids. The presence of 5 per cent voids in the concrete will reduce the strength from that of fully compacted concrete by about 30 per cent and the presence of 10 per cent voids will reduce the strength by 60 per cent. These voids are different from those produced by air entraining agents. The Engineer-in-Charge should, therefore, satisfy himself that the concrete gets properly compacted throughout the depth. Careful observation of the side surface of concrete after the removal of form work will help in identifying the honey-combed area to some extent. In case of doubt, breaking of a trial slab or drilling of cores may be resorted to for confirming the efficacy of the vibrating effort.

N.1.5. **Durability**

Chemical attack on concrete in roads is not normally serious enough to warrant particular precautions. Where, however, soils are impregnated with deleterious salts in injurious amounts, protection of concrete from direct contact with such soils may be achieved by providing a suitable capillary cut-off as described in Clause 6.4. Where sulphate attack is probable, depending on the degree of severity, sulphate resistant-cements or portland blast furnace slag cements or portland pozzolana cements or cements with pozzolonic admixtures, such as, burnt clay pozzlana or fly ash may be used. In all cases, concrete shall be well compacted, strong and dense. Pozzolanic admixture to cement or portland pozzolana cement may also be found useful in areas where alkali-reactive aggregates cannot be precluded from use in concrete road construction.

N.1.6. **Resistance to Abrasion**

The resistance of concrete to abrasion is normally very high when good quality hard aggregates are used. The use of rounded or aggregate, which wears away at the same rate as the cement matrix in the top course, may in time tend to polish and produce a slippery surface. Besides, when the road is to be used by steel tyred or tracked vehicles, such as, iron-tyred bullock carts, tanks, etc., the use of certain types of aggregates encourage rapid abrasion. It has been established that with good quality concrete of an average compressive strength of the order of 45 MPa (corresponding flexural strength being of the order of 5 MPa) or greater, good resistance to abrasion can be secured with any of the better class aggregates. In the case of concrete of lower strength, the type of aggregate becomes progressively more important; and the best results are obtained by using a good, tough aggregate, such as, granite, basalt or trap. Results would not be satisfactory when comparatively brittle materials, such as, flint are used.

N.1.7. **Riding Quality**

Producing regular surface of concrete is very closely connected with careful spreading, accurate setting and bedding of the side forms, and standard of workmanship in constructing joints and in finishing. The concrete mix should be of uniform consistency and such that when screeded it holds up to crossfalls and gradients without deformation, and yet is sufficiently workable at the edges of the slabs.

The uniform spreading of the concrete with requisite surcharge that will ensure maximum density after compaction will minimise surface irregularities.

The surface should be checked regularly with a straight

edge 3.0 m long, and the permissible tolerance over this length should not exceed 4 mm for machined-laid pavement and 6 mm for semi-mechanised or manual construction.

Use of moving straight edge for checking surface regularity is recommended.

Great care should be taken in constructing joints so that the edges of concrete on the two sides of a joint are at the same level.

It is only by careful attention to the standard of surface finish from the commencement of construction that good riding quality can be obtained.

N.1.8. **Surface Texture**

It is not possible at present to define the surface texture of a concrete road in terms of its durability and resistance to skidding. It is, however, known that the concrete should not be worked to such a degree during compaction that laitance appears on the surface, and that, given well-proportioned concrete; a satisfactory surface can be produced by standard methods of compaction.

N.1.9. **Use of Admixtures**

An admixture is a material added in very small quantities to a concrete mix to improve some of its desirable properties. It may be understood that an admixture is no substitute for a well produced, adequately compacted and well placed concrete. The types of admixtures considered here are air-entraining agents, accelerators, retarders, plasticisers and superplasticisers.

The use of certain admixtures to entrain air in concrete is stipulated in some specifications. The air is entrained in the form of numberless discrete and microscopic bubbles evenly distributed through the mass and normally occupying in total from 3 to 6 per cent of the volume of the concrete. Such concrete is better resistant to the frost, less liable to segregation and bleeding and more workable than concrete with no air-entrainment. The strength can be restored to the original value by small adjustments in the mix proportions. Because of increased workability due to incorporation of air-entraining agent, the water-cement ratio can be somewhat lowered so that the loss of strength due to air-entrainment is compensated. Whilst air-entrainment does not appear to be necessary in most parts of India to increase the frost resistance of concrete in road slabs, as in other countries, it may have advantages, by virtue of the greater cohesion and workability it develops, in facilitating the production of a good riding surface and in reducing flow on gradients and crossfalls.

Accelerators are used to accelerate the setting and hardening of cement concrete for (i) effecting economy in curing and formwork by speeding up the progress of the concrete works, (ii) concreting in cold weather, the rate of hardening being slow at very low temperatures and (iii) emergency repairs by producing a flash set, sometimes even in minutes. The most common accelerator that has been successfully used is calcium chloride, which increases the rate of heat evolution; this is very beneficial in cold weather (sub-zero temperatures), but when used in hot weather, the initial stiffening can be too rapid. The quantity of calcium chloride to be used should ordinarily not exceed 2 per cent by weight of cement used. It is important to see that it (calcium chloride) should be thoroughly dissolved in the mixing water, and that the solution is evenly distributed throughout the batch. The use of calcium chloride is not permitted when reinforcement is provided, due to the possibility of corrosion.

Having an opposite effect to that of accelerators, retarders are used to delay the setting and hardening of concrete. They are

used mainly for (i) concreting in hot weather, where the setting time may get reduced (due to high temperature) to the extent that it may not be possible to complete compaction and finishing operations before the concrete begins to set, (ii) ready mixed concrete which is to be transported, where the time for transportation to the site, laying, compaction and finishing has to be extended, before the concrete begins to set. Some retarders tend to reduce the rate of development of strength and also reduce the ultimate strength. Experiments have shown that sugar, when used upto a maximum of 0.05 per cent by weight of cement, can be very effective in retarding the setting time of concrete. It may, however, be noted that quantities of sugar in excess of 0.05 per cent by weight of cement may prove to be harmful.

Plasticisers are used as water-reducing agents, so that for a given workability, the water-cement ratio can be reduced to achieve a higher strength as compared to mix without the additive. They are also used to reduce the heat of hydration in mass concrete, by reducing the cement content for a given workability. The increased workability got with the use of plasticisers, assists placement in inaccessible locations. The components of water-reducing admixtures are surface-active agents, which alter the physico-chemical forces at the interface between two phases. The agents are absorbed on the surface of the cement particles, which gives them a negative charge, which causes mutual repulsion, leading to their dispersal. Even air bubbles are repelled and cannot attach themselves to the cement particles. The negative charge causes a sheath of oriented water molecules around each particle which separates them. The water, free from the flocculated system, is thus available to lubricate the mix, thereby increasing its workability. The decrease in mixing water varies between 5 and 15 per cent, and depends on the cement content, aggregate type, presence of pozzolana or admixture, etc. Trial mixes should be made to ensure non-occurrence of segregation, bleeding or slump loss. The use of plasticisers normally leads to increased early and long-term strengths. The dosage shall be as per the manufacturer's recommendation. The admixtures shall conform to IS:9103–1999. Some plasticisers have set retarding properties, while some other have accelerating properties, and so the selection depends on individual requirements.

Normal water reducers based on lignosulphonic acids and hydrocarboxylic acids (which are processed carbohydrates) are well established in concrete practice and are capable of reducing water requirements by about 10-15 per cent. However, larger amounts of such admixtures introduced for effecting higher water reductions, have undesirable effects on setting, bleeding, segregation and strength development. A new class of water reducers, chemically different from the above-mentioned water reducers and plasticisers, which have come into practice recently, are the superplasticisers. These are high range water reducers and are capable of reducing water content by about 20 per cent. The dosage levels are higher than with conventional water reducers, but undesirable side effects are very much reduced. Superplasticisers are used to produce flowing concrete for special placing situations at inaccessible locations, in placement of pavement (needs only nominal vibration) or floor slabs, in the production of very high strength concrete using normal workability but very low water-cement ratio, which do not permit easy placement in congested reinforcement and in pumped concrete. Superplasticisers are sulphonated melamine-formaldehyde condensates (SMF) or sulphonated napthalene-formaldehyde condensates (SNF). Other formulations imparting high water reduction in concrete are modified lignisulphonates (MLS), sulphonic acid esters, carbohydrate esters, etc. Superplasticisers have a capacity to disperse, without adverse side

effects, the cement agglomerates normally found when cement is suspended in water. The dispersion is promoted by the sulphonic acid being absorbed onto the surface of cement particles, causing them to become negatively charged and thus mutually repulsive. This leads to increase in workability at a given water/cement ratio, from an initial slump of about 50 mm to a slump in excess of 100 mm. Before using them in concrete road projects both laboratory and field trials are to be carried out. Pozzolonic admixtures, such as, burnt clay pozzolana or fly ash could also be employed for conditions explained under "Durability" or for other reasons subject to satisfactory prior testing of the resulting concrete. In cold weather concreting, calcium chloride in small quantity is sometimes used to accelerate the development of strength. Calcium chloride should, however, be used where there is no steel reinforcement in the concrete. Superplasticisers are generally added towards the end of mixing.

N.1.10. **Computation of Concrete Strength**

This Code has been prepared on the assumption that careful control will be exercised with constant supervision in respect of production and placement of concrete. The use of weigh batching, carefully graded aggregates, frequent moisture content determination on aggregates and regular control of workability are required to keep the variation in strength of the finished concrete as low as possible.

The requirement that not more than 1 in 100 (or any such value) of the test samples shall show flexural strength of less than 4.5 MPa at 28 days and that the "co-efficient of variation" shall not be more than a certain per cent can be examined and the "co-efficient of variation" or "standard deviation" of the available test results are calculated and the lower control limit (LCL) worked out therefrom. To meet the requirements, the lower control limit should not be less than the specified minimum strength. The standard deviation is calculated by summing the squares of the differences of individual test values from their average, dividing by less than number of values, and taking the square root of the result:

Standard deviation, $\sigma = \sqrt{\Sigma(X - \overline{X})^2 / n-1}$

Co-efficient of variation, v = 100 x σ /8

Where,

X = individual cube of strength,
$\overline{X}$ = mean cube strength, and
n = number of specimens, and
t = tolerance level factor given in N.1.3.4.

Note: The values of za given in para N.1.3.4 are applicable when a large number of samples are tested. For small samples, the values can be taken from the following Table :

Sample size (no. of samples)	Tolerance level			
	1 in 15	1 in 20	1 in 40	1 in 100
10	1.65	1.81	2.23	2.76
20	1.58	1.72	2.09	2.53
30	1.54	1.70	2.04	2.46
α (Infinite)	1.50	1.64	1.96	2.33

Illustrative Example: It is desired to have a concrete of compressive strength of 28 MPa, which is known to give a flexural strength of 4 MPa. The quality control that can be exercised gives a tolerance of 1 in 15. Preliminary compressive strength tests indicate a standard deviation of 2.8 MPa.

The design mix should have a strength of: 28+1.50 x 2.8 = 33.2 MPa.

Taking compressive strength results of 10 field test cubes (as given in Table below) to be analysed statistically and adopting a tolerance level factor of 1.65 corresponding to a tolerance level of 1 in 15 for the sample size of 10 cubes:

Cube strength (X) MPa	Difference from mean ($\overline{X}$) MPa	Difference² ($\overline{X}$)² (MPa)²
29.82	-3.22	10.37
30.23	-2.81	7.90
33.04	—	—
35.14	-2.11	4.45
33.04	—	—
34.45	1.4	1.99
27.42	-5.62	31.58
36.56	3.52	12.39
36.26	3.22	10.37
34.45	1.41	1.91
330.42	Total	80.76

Statistical parameters :

Mean strength, $\overline{X}$ = 330.42/10 =33.04 MPa
(Standard deviation)² = Σ ($\overline{X}$)²/n-1 = 80.76/10-1 = 8.97 MPa
∴ Standard deviation (σ)

= $\sqrt{\Sigma(X - \overline{X})^2 / n-1}$ = 8.97 = 3 MPa

Check :

LCL (Lower Control Limit) = mean strength – (Tolerance level factor of 1.65) x standard deviation

= 33.04 - 1.65 x 3

= 28.09 kg/sqcm

In the above case, although one cube out of ten tested showed strength of less than 28 MPa, it could be assumed that this was a freak result and the Specifications were being met, as the LCL is higher than the minimum stipulated strength of 28 MPa.

N.1.11. Correction for the Strength of Cubes for Ages Greater than 28 days

The Table below suggests correction of strength for cubes in kg/sqcm to be deducted from the strength as determined by the test to the corresponding strength at 28 days for the purpose of guidance only. For cores, the correction may be taken as three-quarters of the tabulated figures.

TABLE : AGE-STRENGTH RELATION OF CONCRETE (RELATED TO 100 PER CENT AT 28 DAYS)

DAYS	0	2	4	6	8
0	—	41.0	60.0	71.0	77.5
10	81.5	85.0	87.5	90.0	92.0
20	94.0	96.0	97.5	98.5	100.0
30	101.0	102.0	103.5	104.5	105.5
40	106.5	107.0	108.0	109.5	110.0
50	110.5	111.0	112.0	112.5	113.0
60	114.0	114.5	115.0	115.5	116.0
70	116.5	117.0	117.5	118.0	118.5
80	119.0	119.5	119.5	120.0	120.5
90	121.0	121.5	122.0	122.0	122.5
100	123.5	123.5	123.5	124.0	124.5
110	125.0	125.0	125.5	125.5	126.0
120	126.0	126.5	127.0	127.0	127.5
130	127.5	128.0	128.5	128.5	129.0
140	129.0	129.5	129.5	130.0	130.0
150	130.5	130.5	131.0	131.0	131.5
160	131.5	132.5	132.0	132.0	132.5
170	132.5	132.5	133.0	133.0	133.5
180	133.5	134.0	134.0	134.5	134.5
190	135.0	135.0	135.0	135.5	135.5
200	135.5	135.5	136.0	136.0	136.5
210	136.5	136.5	137.0	137.0	137.0
220	137.0	137.5	137.5	137.5	138.0
230	138.0	138.5	138.5	138.5	138.0
240	139.0	139.0	139.0	139.5	139.5
250	139.5	140.0	140.0	140.0	140.0
260	140.5	140.5	140.0	140.0	140.0
270	141.0	141.0	141.5	141.5	141.5
280	142.0	142.0	142.0	142.5	142.5
290	142.5	142.5	142.5	142.5	142.5
300	143.0	143.0	143.0	143.0	143.5
310	143.5	143.5	144.0	144.0	144.0
320	144.0	144.5	144.5	144.5	144.5
330	144.5	145.0	145.0	145.0	145.0
340	146.0	146.0	146.0	146.0	146.0
360	146.0	146.5	146.5	146.5	146.5

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Appendix-B

SUPPLMENTARY NOTES

N.2 Arrangement of Joints

N.2.1. Staggered Joints

It has been observed tnat where transverse joints have been staggered on either side of a longitudinal joint, sympathetic cracking has often occurred in line with the joint in the adjacent slab; therefore, it is desirable that joints be constructed in line across the full width of the pavement.

N.2.2. Skew Joints

The use of skew joints increases the risk of cracking at the acute angled corners as described in N.2.3 and may also tend to make the slabs move sideways. Thus transverse joints should, as far possible, be at right angles to the edges to the pavement.

N.2.3. Acute-angled Corners

Wherever possible, acute-angled corners should be avoided in the layout of road and airfield slabs as the stresses due to loading become exceedingly high. Under the conditions of the corners warping upwards so that they are completely unsupported, the stresses at the corners of various angles, calculated theoretically and expressed in terms of the stress at a right-angled corner, are approximately as follows:

Corner angle	Stress
90°	100 per cent
70°	145 per cent
50°	210 per cent

However, if acute-angled corners are unavoidable, as sometimes is the case at intersections, the corners should be

strengthened either by increasing the slab thickness at this point, or by using heavy reinforcement or by both.

The shapes and dimensions of the slabs, in transitioning from one width to another or where changes in direction are necessary, should be such as easily negotiated by traffic, pleasing to the eye and also permit of satisfactory compaction and finishing through normal equipment without the aid of special tools. The arrangements should also facilitate adjustment of camber and superelevation along convenient lines.

N.2.4. Spacing of Joints

The spacing of transverse joints depends on several factors, the more important of which are the co-efficient of thermal expansion of the concrete, the temperature during placing, the frictional restraint of the subgrade to the movement of the slab, the thickness of the slab and the amount of the reinforcement. For unreinforced concrete slabs, the spacing of joints should be such as to obviate the formation of uncontrolled cracks which would open and give rise to serious spalling. For reinforced slabs, the spacing of joints should be related to the weight of reinforcement so that the opening of hair cracks is effectively controlled. Where adequate reinforcement is employed only the expansion joint is needed, but where smaller quantities of reinforcement are used, the combination of the expansion and contraction joints would have to be provided. Even if light reinforcement is used, joints can be spaced at much wider intervals, than in unreinforced slabs.

Expansion joints should be so placed that they will permit thermal expansion over a range of temperature from the lowest at which the slab between two consecutive expansion joints is laid to the maximum likely to be attained.

The spacing of expansion joints has been a matter of discussion because of varied practices, and ranges from twenty metres to a few hundred metres. The present practice is to omit expansion joints altogether and provide them at culvert and bridge abutments. However, at such locations special precautions shall have to be taken to protect the slab as explained later.

Contraction Joints are spaced as under:

Slab thickness (cm)	Maximum contraction joint spacing (m)	Weight of reinforcement in welded fabric (for reinforced pavements only) (kg/sqcm)
Unreinforced slabs		
10	4.5	—
15	4.5	—
20	4.5	—
25	4.5	—
30	5.0	—
35	5.0	—
Reinforced slabs		
10	7.5	2.2
15	13.0	2.7
20	14.0	3.8

Note: Where reinforcement is used in the form of mild steel bars, equivalent sectional areas corresponding to the sectional areas of the welded wire fabric should be employed.

Spacing of longitudinal joints is determined by the lane widths to be provided in the carriageway. Where vibrating screeds are used, it shall be limited to 4 m.

N.3. Reinforcement

N.3.1. Basis of Design

The particular function of reinforcement in concrete slabs is to hold together fractured faces of the slabs after cracks have

occurred. It does not appreciably increase the flexural strength of the unbroken slab when used in quantities which are considered economical. Where the slabs are provided with adequately spaced joints to control cracking, reinforcement has virtually no function. Current practice is to omit reinforcement altogether.

N.4. Load Transfer Devices

N.4.1. General

Load transfer devices in concrete pavements are provided in the form of dowel bars.

N.4.2. Dowel Bars

Dowel bars are built as an integral part of transverse joints. They are usually mildsteel round bars of short length, whose half length is bonded into concrete on one side of the joint and its other half length is prevented from bonding with concrete; in addition, a recess is provided at the slip ends to accommodate the movement of the slabs through deformation of the premoulded joint filler during the expansion of concrete. Where they are used to full depth transverse contraction joints, this end recess is not provided. When used, they permit the joint to open and close but hold the slab ends on each side of the joint as nearly as possible at the same level. The deflection of one slab under load is resisted by the other slab (when connected by dowels), which, in turn, is caused to deflect and thus carry a portion of the load imposed upon the first slab. Where dowels are used across a transverse joint, they should be distributed over the full length of the joint. If an assembly of dowels functions perfectly and the load were concentrated close to the joint, about 45-50 per cent of the load would be transferred to the adjacent slab and each slab would be subjected to about the same unit load stress. Since the wheel loads are not concentrated at the slab ends, it is not theoretically necessary to transfer exactly half of the load. Therefore, they are so designed that they will be capable of transferring 40 to 45 per cent of the gross controlling wheel load to the adjacent slab.

In designing a system of dowels, it is first necessary to calculate the load transfer capacity of a single dowel. Since failure can occur either by shear or bending of the bar or by crushing of the concrete below the dowel bars, the strength is governed by the minimum capacity determined for the above conditions of failure. All of these are influenced by the width of the joint opening, allowable tensile and shear stress in the steel, diameter of the dowel bar, length of the dowel bar embedded in concrete and the allowable bearing stress on the concrete.

The second step in the design is to determine the load transfer capacity of a series of uniformly spaced dowels that make up the system. This is influenced by their spacing, the position in respect of the wheel load, load transfer capacity of a single dowel bar, pavement thickness, modulus of subgrade reaction (k) and centre spacing of the wheels on the axle carrying gross controlling wheel load. The design procedure for dowels is indicated in IRC:58 "Guidelines for the Design of Rigid Pavements for Highways".

N.5. Tie Bars

Tie bars are used across the joints of concrete pavements wherever it is necessary or desirable to ensure firm contact between slab faces or to prevent abutting slabs from separating.

Tie bars may be used across longitudinal joints in slabs of uniform thickness. When used at such locations, tie bars are not required for structural reasons, their only function being to prevent the separation of the slabs, especially at fills or curves. When so used, they may be provided at longer spacings and permitted to take higher working stresses.

Tie bars are not designed to act as load transfer devices.

Tie bars are designed to withstand tensile stresses only. The maximum tension in the tie bars across any joint is equal to the force required to overcome friction between pavement and subgrade, from the joint in question to the nearest free joint of edge: The diameter and spacing of the tie bars are computed in the following manner :

The area of steel required per m length of joint may be computed by using the following formula:

$A = bfW/S$

In which

A = area of steel in sqcm required per m length of joint,

b = distance between the joint in question and the nearest free joint or edge in m,

f = co-efficient of friction between pavement and subgrade (usually taken at 1.5),

W = weight of pavement slab per sq. metre in kg, i.e., 24 kg/sqm per cm thickness, and

S = allowable working stress of steel in kg/sqcm.

The length of any tie bar should be at least twice that required to develop a bond strength equal to the working stress of the steel. Expressed as a formula, this becomes :

$L = 2SA/BP$

In which

L =	length of tie bar	cm
S =	allowable working stress in steel	kg/sqcm
A =	cross-sectional area of one tie bar	sqcm
P =	perimeter of tie bar	cm
B =	max. permissible bond stress	kg/sqcm

The following Table reproduced from the Guidelines gives design details of the tie bars:

DETAILS OF TIE BARS FOR LONGITUDINAL JOINT OF TWO-LANE RIGID PAVEMENTS

Slab Thickness (cm)	Tie Bar Details				
	Diameter(d) (mm)	Max. Spacing (cm)		Minimum Length (cm)	
		Plain bars	Deformed bars	Plain bars	Deformed bars
15	8	33	53	49	53
	10	52	83	56	61
20	10	39	62	56	61
	12	56	90	63	69
25	10	31	50	56	61
	12	45	72	63	69
	14	61	98	70	77
30	10	26	42	56	61
	12	37	60	63	69
	16	66	106	77	85
35	10	22	36	56	61
	12	32	51	63	69
	16	57	91	77	85

Note: These calculations have been made for a slab configuration of 3.5 m x 5.0 m

The recommended details are based on the following values of different design parameters :

S = 1250 kg/sqcm, B = 17.5 kg/sqcm for plain bars and S = 2000 kg/sqcm and B = 24.6 kg/sqcm for deformed bars; and W = 24 kg/sqm per cm of slab thickness

Length of ties bar shown above has been increased by 20 cm to compensate for:

(a) For pointed length of 10 cm in the middle of ties rod

(b) 5 cm to compensate for placement error laterally.

N.6. Concreting in Cold Weather

N.6.1. General

In temperate climates where freezing conditions may last only for a few days at a time, it is generally advisable and more economical to stop concreting operations rather than to adopt costly precautionary measures. Where, however, it is absolutely necessary to continue these operations and the high cost is considered to be justified in the interest of work, some or all of the following precautions should be taken, their extent depending on the weather conditions and the degree of exposure envisaged:

(i) Avoid the use of frozen aggregates;

(ii) Warm the aggregates by means of indirect fire, or by passing steam or hot air through the stockpiles;

(iii) Protect the subgrade against frost or keep it warm by means of braziers so that it does not freeze when the concrete is laid on it;

(iv) Use Rapid-Hardening Portland Cement or ordinary incorporate calcium chloride with the Rapid Hardening or Ordinary Portland Cements;

(v) Heat the mixing water to 66°C; and

(vi) Provide thick layers of straw or other insulating material on the surface as soon as the concrete is hard enough to sustain it without detriment. In case of delay in doing this, light covers, like, 2-3 layers of hessian cloth may be placed over the green concrete until such time as the insulating material can be supplied.

All these cold-weather concreting methods should be planned well in advance of expected low temperatures. The necessary special equipment and materials must be available at the work site before low temperatures occur.

N.6.2. Preparation for Concreting

Before concrete is placed in any form or around any reinforcement or on any surface, all ice, snow and frost should be completely removed and the temperature of all surfaces to be in contact with concrete should be raised above the freezing point. No concrete should be laid on a frozen subgrade or on one that contains frozen material.

N.6.3. Placement Temperatures

The laying of road pavement slabs with fresh concrete temperatures below about 4°C is undesirable because of very slow development of strength and the necessity for more prolonged curing; besides, with air temperatures around or below 0°C there is the danger of freezing. On the other hand, temperatures of fresh concrete exceeding 30°C are undesirable due to the higher water requirement, possible premature stiffening, difficulties in keeping the concrete moist, development of internal stress and likelihood of cracking when concrete contracts on cooling. For most constructions, the desirable temperature of concrete at placement is between 15°C and 24°C.

N.6.4. Safe Temperatures

Generally, it is considered safe to maintain concrete at a temperature of not less than 15°C for 3 to 4 days or to a temperature of not less than 5°C for 7 to 8 days after casting.

Air-entrained concrete containing 1 per cent of calcium chloride by weight of the cement requires only about half these periods of protection at these temperatures. At the end of the curing period, artificial heating should be discontinued and housings removed in such a manner that the fall in temperatures at any point in the concrete will be gradual and will not exceed

5°C, in 24 hours. In case the temperature is allowed to drop too rapidly, excessive shrinkage will result in the surface and cause cracking.

The surface temperature of the hardened concrete should not be permitted to exceed about 35°C at any time during the curing period.

Record should be kept of the temperatures of outside air, enclosure and concrete surface.

N.6.5. Protection

Arrangements for covering or housing newly placed concrete should be adequate to maintain in all parts of the concrete the recommended curing temperature and moisture conditions. Because heated air is likely to be dry, all concrete surfaces should be kept continuously moist.

An insulating layer for covering concrete may be conveniently composed polyethylene sheet overlaid with a layer of straw and finally with a second layer of water-proof paper. Straw, 15 cm to 30 cm thick is likely to protect concrete in air temperatures as low as -4°C.

N.6.6. Heating of Materials

For air temperatures not lower than -1°C, the mixing water should be heated to bring the temperature of concrete at the mixer to between 10°C and 20°C. For air temperatures below -1°C, both water and the fine aggregate should be heated to bring the temperature of concrete at the mixer to between 15°C and 24°C. When air temperatures fall still lower, coarse aggregate should also be heated. When either aggregate or water is heated to a temperature in excess of 38°C, loading of the mixer should be so carried out that cement does not come in contact with the hot materials. Aggregate should be heated in such a manner that frozen lumps are eliminated and that overheating or excessive drying is avoided. At no point should the aggregate temperature exceed 100°C, and the average temperature of an individual batch of aggregate should not exceed 66°C. Under no circumstances shall the concreting operations continue when the air temperature is less than -7°C.

N.6.7. **Accelerators and Anti-freeze Compounds**

Upto 2 per cent of calcium chloride may be added to the mix to accelerate hardening of concrete at low temperatures, provided no future injurious effects from increased alkali-aggregate reaction or sulphate attack are envisaged. The U.S. Bureau of Reclamation uses 1 per cent of calcium chloride in much of its cold weather concrete. The calcium chloride shall not be used when reinforcement is provided in the concrete.

Appendix–C

BRIEF DESCRIPTION OF SPECIFICATIONS ON SEALING COMPOUNDS

I. BS:5212:1975 on Specifications for Cold Poured Joint Sealants for Concrete Pavements

The standard covers the specifications for fuel resistant cold poured polymer-based sealants for joints in concrete roads, airfields and other exposed pavements. The specification lays down requirement of various properties of sealant and the methods of test. The primers suggested for use with the sealant must be tested with the sealant and hence no special test is commended.

The sealant shall satisfy the following requirements:

(i) **Application life**

For hand applied sealants, the application life after mixing shall be 2 hrs at 25± 1°C and 50 ± 5 per cent relative humidity and for machine applied sealants it is as agreed between the supplier and the purchaser.

(ii) **Shelf life**

The base and curing components shall be capable of being readily mixed to form a compound which complies with this standard upto the manufacturers stated expiry date after storage in the original unopened containers.

(iii) **Tack-free time**

The sealant shall not adhere to the polyethylene film when tested as per the recommended test.

(iv) **Resistance to flow**

The tests are conducted at 5°C, 25°C and 60°C with samples being, (a) horizontal (b) at 2.5° inclination, and (c) at 75° inclination. The sealant shall not exhibit a difference in depth greater than 4mm in (a) and (b) cases and the flow in the case of (c) shall not exceed 2mm.

(v) **Recovery**

The recovery when tested as per standard test shall be a minimum of 75 per cent.

(vi) **Adhesion and cohesion in tension and compression**

The total area of the face of the test block from which the sealant becomes completely separated during the standard test shall not exceed 10 mm^2. The depth of separation shall nowhere exceed 3 mm from the surface of the test block.

(vii) **Resistance to heat ageing**

When tested as per a standard test, the sealant shall not lose more than 5 per cent of its mass after 7 days cure and also the recovery after a standard test shall be a minimum of 75 per cent and the initial identification shall be not more than 2.0 mm.

(viii) **Test in tension and compression**

The specimen shall satisfy the requirement of tension and compression in a standard test.

(ix) **Resistance to fuel immersion**

The mass of the sealant against the standard test fuel shall not increase more than 5 per cent nor decrease more than 10 per cent after 7 days cure. Also the recovery when tested in accordance with standard test shall be a minimum of 75 per cent and the initial indentation shall be not more than 2.0 mm. The specimen of sealant also shall satisfy the requirement of test in tension and compression.

II. IS:11433 (Part I) 1985: Specifications for One Part Gun-Grade Polysulphide Based Joint Sealants

The specification deals with polysulphide based sealant containing polysulphide polymer and a curing system which is activated by exposure to moisture and cures to a rubber-like solid.

Recovery

The sealant is considered as satisfactory if it exhibits recovery of not less than 75 per cent and if the tensile force required to extend the specimen is not less than 25 N or greater than 300 N, as per standard test.

Mass loss after heat ageing

The sealant shall not have mass loss which includes

volatile content not exceeding 10 per cent. The sealant shall not exhibit cracks, bubbles or chalking as per standard test.

Test for cyclic adhesion

Adhesion and cohesion shall be considered satisfactory if after three cycles, the total area (length x depth) of failure does not exceed 100 mm^2 per specimen when tested as per a standard test.

Test for adhesion in peel

The specimen shall not fail when tested for adhesion in peel when applied to surfaces, like, aluminium, stainless steel, cement mortar. Adhesion to glass after sunlamp exposure through glass and adhesion after heat ageing shall also be satisfied as per standard tests.

III. Standard Specification for Joint Sealant, Hot-Applied, Elastomeric-Type, for Cement Concrete Pavements; ASTM Designation D:3406-95

Scope

This specification covers an elastomeric-type one component, hot-applied concrete joint sealant, resistant to weathering, for use in sealing joints and cracks in concrete pavements.

General Requirement

The joint sealant after its application shall form a resilient and cohesive compound that is resistant to weathering, and shall effectively seal joints in concrete throughout separated cycles of thermal expansion and contraction, and against the infiltration of moisture and incompressibles. It shall not flow from the joint or be picked up by vehicle tyres. The joint sealant shall be free of internal voids due to placement or that develop subsequently.

Physical Requirements

The safe heating temperature shall be marked on all the containers and shall be provided to the testing agency before any laboratory tests are begun. The safe heating temperature shall be a minimum of 11°C higher than the manufacturer's recommended application temperature. The sealant shall have the physical properties as under:

(i) **Cone penetration, non-immersed -at 25°C ± 0.1°C** 150g, for 5 seconds shall not exceed 130 units

(ii) **Flow** – there shall be no flow after 72 hours at 70 ± 1°C

Bond

The sealant shall be tested at – 17.8 ± 1.1°C for three complete cycles of 50 per cent extension each. All three specimens shall satisfy the following requirements :

Specimen which is non-immersed: No specimen shall crack, undergo separation, or result in other opening in the sealing compound and the concrete blocks.

Water immersed: No specimen shall crack, undergo separation, or result in other opening in the sealing compound and the concrete blocks.

Resilience: When tested at 25 ± 0.1°C, the recovery shall be a minimum of 60 per cent.

Resilience, oven-aged: When conditioned in a forced draft oven maintained at 70 ± 1°C for 24 ± 2h, and tested at 25 ± 0.1°C, the recovery shall be a minimum of 60 per cent.

Artificial weathering: After 160 h exposure, the joint sealant shall not flow, show tackiness, the presence of an oil like film or reversion to a mastic like substance, form surface blisters, either intact or broken, form internal voids, have surface crazing, cracking, hardening, or loss of rubber like properties. Evidence of physical change in the surface of the material by visual and tactile examination shall constitute failure of this test.

Tensile adhesion: The average of three test specimens shall be a minimum of 500 per cent elongation.

Flexibility: When conditioned in a draft oven maintained at 70 ± 1°C for 72h, and bent at 90° over a 6.4mm dia mandrel, the specimen shall have no indication of surface crazing or cracking.

Appendix–D

Illustrative Examples Explaining the Application of Penalty Clause for Concrete Slab Constructed to Deficient Thickness

Example 1

A concrete pavement of 340 mm thickness is required to be constructed as per the contract drawing, whereas, the average thickness of the slabs constructed was 322 mm as per Clause 9.22.3. The unit rate of concrete pavement is Rs.3350/- cum. Calculate the revised unit rate payable to the Contractor.

The deficiency in thickness = 340 - 322 mm = 18 mm

As per Clause 9.22.3, the unit rate of concrete slabs is to be adjusted by multiplying a factor of 75 per cent.

The unit rate payable to the concrete slabs deficient in thickness:

= 3350 x 75/100 = Rs.2512.50 per cum

The unit rate to be paid Rs.2512.50 per cum.

Example 2

A concrete pavement of 320 mm thickness is required to be constructed as per the contract drawing, whereas, the average thickness of the slab constructed was 292 mm. Unit rate of concrete is Rs.3500 per cum. Calculate the revised unit rate.

The deficiency in thickness = 320 - 292 mm = 28 mm

As per Clause 9.22.3, no payment is due to the Contractor as the deficiency is more than 25 mm. On the contrary, the contractor will have to replace the deficient slabs at his own cost.

But the contractor can locate slabs deficient by more than 25 mm by cutting cores and replace them with fresh slabs which may improve the average thickness. With this approach, he will be able to get reduced payment for other slabs.

Example 3

A concrete pavement of 300 mm thickness is to be constructed but the slab constructed has an average thickness of 296 mm thickness. The unit rate of construction is Rs.3220/- per cum of concrete. Calculate the revised unit rate to be paid to the Contractor.

The deficiency in thickness = 300 - 296 = 4 mm

As per Clause 9.22.3, deficiency in thickness upto 6 mm is to be ignored and the slabs are to be paid at full unit rate.