

**CODE OF PRACTICE
FOR
CONSTRUCTION OF JOINTED PLAIN
CONCRETE PAVEMENTS**

(Fifth Revision)



**INDIAN ROADS CONGRESS
2017**

**CODE OF PRACTICE
FOR
CONSTRUCTION OF JOINTED PLAIN
CONCRETE PAVEMENTS**

(Fifth Revision)

Published by:

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector-6, R.K. Puram,
New Delhi-110 022

NOVEMBER, 2017

Price : ₹ 1000/-
(Plus Packing & Postage)

IRC:15-2017

First Published	:	July, 1965
First Revision	:	December, 1970
Second Revision	:	December, 1981
Third Revision	:	February, 2002
Reprinted	:	September, 2003
Reprinted	:	October, 2005
Fourth Revision	:	May, 2011
Reprinted	:	April, 2014
Fifth Revision	:	November, 2017

(All Rights Reserved. No part of this publication shall be reproduced, translated or transmitted in any form or by any means without the permission of the Indian Roads Congress)

Printed by India Offset Press, Delhi - 110 064
1000 Copies

CONTENTS

S.No.	Description	Page No.
	Personnel of the Highways Specifications and Standards Committee	i-ii
1.	Introduction	1
2.	Scope	2
3.	Material	3
4.	Proportioning of Concrete	10
5.	Tools, Plants & Equipment	12
6.	Preparation of Subgrade, Sub-base and Laying of Separation Membrane	16
7.	Weather Limitations	20
8.	Joints	24
9.	Storage & Handling of Materials	42
10.	Construction	43
11.	Trial Length	63
12.	Quality Control	67
13.	Opening to Traffic	85
	Appendix – A: Photographs of PQC Widening	86

**PERSONNEL OF THE HIGHWAYS SPECIFICATIONS
AND STANDARDS COMMITTEE
(As on 23.06.2017)**

1	Kumar, Manoj (Convenor)	Director General (Road Development) & Special Secretary to Govt. of India, Ministry of Road Transport and Highways, New Delhi
2	Singh, B.N. (Co-Convenor)	Addl. Director General (Incharge), Ministry of Road Transport and Highways, New Delhi
3	Verma, Dr. S.K. (Member Secretary)	Chief Engineer (R) S,R & T, Ministry of Road Transport & Highways, New Delhi

Members

4	Bamezai, Prof. (Dr.) Gita	R&D, Indian Institute of Mass Communication, New Delhi
5	Basar, Toli	Chief Engineer, PWD, Arunachal Pradesh
6	Bhanot, Balraj	Chairman, TED, Bureau of Indian Standards, New Delhi
7	Bongirwar, P.L.	Secretary (Retd.), PWD Maharashtra
8	Gupta, D.P.	DG(RD) & AS (Retd.), Ministry of Road Transport and Highways, New Delhi
9	Jain, Prof. (Dr.) S.S.	Professor, Indian Institute of Technology, Roorkee
10	Jain, R.K.	Chief Engineer (Retd.), PWD Haryana
11	Kadiyali, Dr. L.R.	Chief Executive, L.R. Kadiyali & Associates, New Delhi (Expired on 18.02.2016)
12	Lal, Bhure	Chairman, Environment Pollution Control Authority, Delhi
13	Lal, Chaman	Engineer-in-Chief, Gurugram Metropolitan Development Authority, Haryana
14	Narain, Sunita	DG, Centre for Science and Environment, New Delhi
15	Nashikkar, J.T.	JMD, Maharashtra State Road Development Corporation Ltd., Mumbai
16	Pandey, R.K.	Member (Projects), National Highways Authority of India, New Delhi
17	Parida, Prof. (Dr.) M.	Dean, SRIC, Indian Institute of Technology, Roorkee
18	Pateriya, Dr. I.K.	Director (Tech), National Rural Roads Development Agency, New Delhi
19	Pawar, Ajit	Secretary (Retd.), PWD Maharashtra
20	Porwal, Dr. S.S. (VSM)	ADG (Retd.), Border Roads Organisation, New Delhi
21	Raju, Dr. G.V.S.	Engineer-in-Chief (Retd.), Roads & Building, Andhra Pradesh
22	Rawat, M.S.	Executive Director, AECOM India Pvt. Ltd.
23	Sarangi, D.	CGM, National Highways Authority of India, New Delhi
24	Sharma, M.P.	Chief Engineer, Ministry of Road Transport and Highways, New Delhi
25	Sharma, S.C.	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi

26	Sheokand, Balbir Singh	Executive Engineer, PWD Haryana
27	Singh, Nirmaljit	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi
28	Singh, Pawan Kumar	GM, 3M India Ltd.
29	Sinha, A.V.	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi
30	Tawade, D.O.	Member (T), National Highways Authority of India, New Delhi
31	The Director, (Chandra, Dr. Satish)	Central Road Research Institute, New Delhi
32	The Director General, (Shrivastava, Lt. Gen. S.K.)	Border Roads Organisation, New Delhi
33	The Director General, (Mathur, Vishnu)	Society of Indian Automobile Manufactures, New Delhi
34	The Engineer-in-Chief, (Sharma, Lt. Gen. Suresh)	Military Engineer Services, New Delhi
35	Tickoo, Bimal	Secretary (T), PWD Jammu
36	Tiwari, Prof. (Dr.) Geetam	Professor, Indian Institute of Technology, New Delhi
37	Varshney, Sharad	Superintending Engineer, Ministry of Road Transport and Highways, New Delhi
38	Verma, G.L.	MD, Engg and Planning Consultants Ltd., New Delhi

Corresponding Members

1	Baluja, Dr. Rohit	President, Institute of Road Traffic Education, New Delhi
2	Bhowmik, Sunil	Engineer-in-Chief (Retd.), Tripura
3	Kandasamy, C	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi
4	The Director, (Patil, Capt. (Dr.) Rajendra B. Saner)	Central Institute of Road Transport, Pune

Ex-Officio Members

1	President, Indian Roads Congress	(Pradhan, N.K.), Engineer-in-Chief cum Secretary, Works Department, Odisha
2	Director General (Road Development) & Special Secretary to Govt. of India	(Kumar, Manoj), Ministry of Road Transport and Highways, New Delhi
3	Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

CODE OF PRACTICE FOR CONSTRUCTION OF JOINTED PLAIN CONCRETE PAVEMENTS

1. INTRODUCTION

The Standard Specification and Code of Practice for Construction of Concrete Road was first published in July 1965. It was revised in 1970 and the second edition was brought out in December, 1981. The third edition was brought out in the year of 2002. The fourth edition of the document was published in 2011. Since then the technology for road construction has undergone considerable changes and MORT&H Specifications for Road and Bridge Works has been revised. Some special requirements like widening of existing four lane concrete road to six lane and construction of four lane concrete pavement in place of existing two lane bituminous road have arisen. Some problems relating to the construction of transition slab between rigid and flexible pavement, corrosion of dowel bars and damage done to the slabs by vibratory trails have been observed in concrete pavements constructed in the last few years. The use of Ground Granulated Blast Furnace Slag (GGBFS) and Metakaolin as mineral admixture, Poly-Carboxylate Ether based High Range Water Reducing Admixtures, string-less paving system for paving concrete, Magnetic Pulse Induction technique for checking alignment of dowel bars have emerged and being practiced for better construction of concrete roads.

Therefore a need was felt to update the standard to include the latest development in the area of construction of concrete roads. The revised draft was prepared by the subgroup comprising of Shri Binod Kumar, Shri R.K. Jain, Shri Raman Kumar, and Shri Rajesh Madaan, members of the Rigid Pavement Committee. The Rigid Pavement Committee (H-3) deliberated on the document in a series of meetings and finalised it in its meeting held on 27th May, 2017. The revised draft was placed before the Highways Specifications and Standards Committee (HSS) in its meeting held on 23rd June, 2017. The HSS committee approved the draft with some suggestions including the change in the title of the code. The draft revised as per the suggestions of HSS and with changed title of “Code of Practice for Construction of Jointed Plain Concrete Pavements” was approved by the Council of IRC after taking on board the comments of the members in its 212th Mid-Term Council meeting held on 14th & 15th July, 2017 at Udaipur.

The Composition of H-3 Committee is as given below:

Jain, R.K.	Convenor
Arora, V.V.	Co-Convenor
Ganju, Col. (Retd.) V.K.	Member-Secretary

Members

Avtar, Ram	Reddy, S.S.
Bongirwar, P.L.	Sengupta, J.B.
Gajria, Maj. Gen. (Retd.) K.T.	Sharma, M.P.
Gupta, Prof. (Dr.) P.K.	Sheokand, B.S.
Indoria, R.P.	Srivastava, R.K.
Jain, L.K.	Tare, Prof. (Dr.) Vandana
Joshi, Brig. Girish	Thakar, Vikas
Kumar, Binod	Thombare, Vishal
Kumar, Raman	Tipnis, Col. (Retd.) Manoj
Madaan, Rajesh	Trivedi, Anil
Maiti, Dr. S.C.	Venkatesha, M.C.
Nayak, Sanjay	Rep. of UltraTech Cement Ltd.
Ramana, Dr. G.V.	(Jain, A.K. upto 17.08.2016 thereafter Ramachandra, Dr. V.)

Corresponding Members

Justo, Prof. (Dr.) C.E.G.	Ramchandani, S.M.
Pandey, Prof. (Dr.) B.B.	Veeraragavan, Prof. (Dr.) A.

Ex-Officio Members

President, Indian Roads Congress	(Pradhan, N.K.), Engineer-in-Chief cum Secretary, Works Department, Odisha
Director General (Road Development) & Special Secretary to Govt. of India	(Kumar, Manoj), Ministry of Road Transport & Highways
Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

2. SCOPE

2.1 This Code of Practice is intended to bring uniformity in practice for the construction of jointed plain concrete pavements, including preparation of the subgrade and sub-base underneath these pavements.

2.2 The Code deals with various aspects of jointed plain concrete pavement construction, like materials, equipment, proportioning of materials, measurement, handling of materials, mixing, subgrade & sub-base preparation, formwork, joints, reinforcement of concrete, placing, finishing, curing, evaluation for acceptance criteria etc.

2.3 The present code incorporates relevant provisions of the latest version of codes listed below. For further details wherever required, these codes may be referred.

- i) IRC:43 “Recommended Practice for Plants, Tools and Equipment required for Construction and Maintenance of Concrete Roads” (*First Revision*)
- ii) IRC:44 “Guidelines for Cement Concrete Mix Design for Pavements”
- iii) IRC:57 “Recommended Practice for Sealing of Joints in Concrete Pavements”
- iv) IRC:85 “Recommended Practice for Accelerated Strength Testing & Evaluation of Concrete” (*First Revision*)
- v) IRC:114 “Guidelines for Use of Silica-Fume in Rigid Pavement”
- vi) IRC:117 “Guidelines for the Structural Evaluation of Rigid Pavements with Falling Weight Deflectometer”
- vii) IRC:118 “Guidelines for Design and Construction of Continuously Reinforced Concrete Pavement (CRCP)”
- viii) IRC:SP:17 “Recommendations about Overlays on Cement Concrete Pavements”
- ix) IRC:SP:46 “Guidelines for Design and Construction of Fibre Reinforced Concrete Pavements”
- x) IRC:SP:49 “Guidelines for the Use of Dry Lean Concrete as Sub-Base for Rigid Pavement”
- xi) IRC:SP:76 “Guidelines for Conventional and Thin Whitetopping”
- xii) IRC:SP:83 “Guidelines for Maintenance, Repairs and Rehabilitation of Cement Concrete Pavements”

2.4 Some aspects of jointed plain concrete pavements are dealt in respective standards of IRC. Reference to these standards has been drawn in the text where ever relevant.

3. MATERIALS

3.1 Cement

Any of the following types of cement capable of achieving the design strength may be used. The minimum 28 days compressive strength of the cement should not be less than 43 MPa.

- i) Ordinary Portland Cement IS:269 (43 Grade and 53 Grade) including 5% performance Improver (Mineral admixture etc. as per IS:269)
- ii) Portland-Pozzolana Cement IS:1489 (Part 1)
- iii) Portland Slag Cement, IS:455
- iv) Composite Cement (blended with granulated slag & fly ash), IS:16415

If the soil around concrete pavement has soluble salts, like sulphates in excess of 0.5 per cent, the cement used shall be Sulphate Resisting Portland Cement, IS:12330. The limits

of sulphate concentration (as sulphur trioxide) is that limit where either it is more than 0.2% in subgrade soil or more than 0.3% in ground water. Cement used in both DLC and pavement quality concrete in such situations should be sulphate-resistant. If chlorides are present, Sulphate Resisting Cement shall not be used, and in such case Portland Slag Cement should be used.

Cement to be used may preferably be obtained in bulk. If cement in paper bags is proposed to be used, there shall be bag-splitters with the facility to separate pieces of paper bags and dispose them off suitably. No paper pieces shall enter the concrete mix. Bulk cement shall be stored either in vertical or horizontal silos. The cement shall be subjected to acceptance tests prior to its use.

3.2 Admixtures

3.2.1 *Chemical Admixtures*

Admixtures conforming to 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 embedded steel. 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 for improving the workability of the mix and to reduce bleeding, the total quantity of air in air-entrained concrete as a percentage of the volume of the concrete shall have 4.5 ± 1.5 per cent entrained air for 31.5 mm maximum size of aggregate and 5.0 ± 1.5 per cent for 19 mm maximum size of aggregate. In freezing weather, use of air entraining agent is recommended to counter the freezing and thawing effect with 5.5 ± 1.5 per cent entrained air for 31.5 mm maximum size of aggregate and 6.0 ± 1.5 per cent for 19 mm maximum size of aggregate. The maximum quantity of chemical admixture shall be 2 per cent by weight of cementitious materials (cement + fly ash/ground granulated blast furnace slag/silica fume).

3.2.2 Compatibility and optimum dose of the particular admixture (from a specific manufacturer) with the specific cement type (from a particular manufacturing plant) to be used, shall be established by Marsh Cone Test as per ASTM C939. Concrete mix should be designed for a combination of a particular cement and admixture, and admixture supplier and type cannot be substituted without test confirming the required results.

3.2.3 *Mineral Admixtures*

Mineral admixtures can improve the workability, long term strength and durability of concrete. The following materials may be added as mineral admixtures subject to their availability and corresponding policy guidelines regarding their usage by the Central/ State Governments.

3.2.3.1 *Fly ash (as per IS:3812 (Part 1))*

Fly ash upto 25 per cent by weight of Cementitious Material (CM) may be mixed at site with Ordinary Portland Cement (OPC) 53/43 Grade. The fly ash shall conform to IS:3812 (Part I). Fly ash of no other Grade shall be used.

Site mixing of fly ash shall be permitted only after ensuring availability of the equipments at site for uniform blending through a specific mechanized facility with automated process control like batch mix plants conforming to IS:4925 and IS:4926. Site mixing will not be allowed otherwise.

3.2.3.2 *Ground Granulated Blast Furnace Slag*

Factory manufactured ground granulated blast furnace slag (as per IS:10875) upto 50 per cent by weight of cementitious material may be mixed at site with Ordinary Portland Cement of 43/53 Grade. Regular tests shall be conducted on GGBFS at a testing frequency of 1 test per 100 MT of slag to ensure the quality.

3.2.3.3 *Silica fume*

Silica fume up to 10 per cent by weight of OPC (as per IS:15388, IRC:SP:114 and IRC:44, if specified in design may be used.

3.2.3.4 *Metakaolin*

Metakaolin is obtained by calcinations of pure and refined kaolinitic clay at a temperature between 650 and 850 °C followed by grinding to a fineness of 700 to 900 m²/kg. Metakaolin conforming to IS:16354 may be used upto 20 per cent of the cementitious material.

3.3 **Aggregates**

3.3.1 Aggregates for pavement concrete shall be complying with IS:383. The limits of deleterious materials shall not exceed the requirements set out in IS:383.

3.3.2 The aggregates shall be free from chert, flint, chalcedony or silica in a form that can react with the alkalis 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 (SO₃) shall not exceed 0.25 per cent by weight. In case the aggregates are not free from dirt, the same may be washed and drained for at least 72 hours before batching.

No aggregate which has water absorption more than 2 per cent shall be used in concrete mix. All 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, irrespective of their water absorption.

3.3.3 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 combined flakiness and elongation index shall not be more than 35 per cent. Aggregate Impact Value (AIV) shall not be more than 30 per cent. Limestone aggregate may be used conforming to IS:383. The maximum size of coarse aggregate shall not exceed 31.5 mm in PQC and 26.5 mm in case of DLC.

Continuously graded aggregates may be used, depending on the combined grading of the coarse and fine aggregate.

Iron slag aggregate, steel slag aggregate up to 30 per cent, Recycled Concrete Aggregate (RCA) up to 30 per cent of total coarse aggregate can be used in Dry Lean Concrete (DLC) only.

3.3.4 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 : 1.0%

Coal and lignite : 1.0%

Material passing IS sieve No. 75 micron :

i) Natural sand : 3% by weight of natural sand

ii) Crushed Stone sand : 12% by weight of crushed stone

iii) Blend of natural sand and crushed stone sand: shall not exceed 8% by total weight of fine aggregates (IS:383)

Although IS:383 permits in the case of stone crushed sand, the fines passing 75 microns up to 15 per cent, this provision should be used with caution when crushed stone sand 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. The grading zone of fine aggregates as per IS:383 shall be within the limits as given in **Table 1**.

Table 1 Fine Aggregates Requirements of Different Grading Zone

IS Sieve Designation	Percentage Passing for		
	Grading Zone I	Grading Zone II	Grading Zone III
10 mm	100	100	100
4.75 mm	90 - 100	90 - 100	90 - 100
2.36 mm	60 - 95	75 - 100	85 - 100

1.18 mm	30 - 70	55 - 90	75 - 100
600 micron	15 - 34	35 - 59	60 - 79
300 micron	5 - 20	8 - 30	12 - 40
150 micron	0 - 10	0 - 10	0 - 10

The fine aggregates conforming to any one of the above three grading zones may be used. From grading Zones I to III, the fine aggregate grading becomes progressively finer and therefore the ratio of fine aggregate to coarse aggregate should be progressively reduced. In all cases concrete mix should be properly designed as per IRC:44 recommendations.

In case of grading in all Grading Zones falls outside the limits of any particular grading Zone of sieves other than 600 micron IS: Sieve by an amount not exceeding 5 per cent for a particular sieve size, (subject to cumulative amount of 10 per cent), it shall be regarded as falling within that grading zone. This tolerance shall not be applied to percentage passing the 600 micron IS: Sieve or to percentage passing any other sieve size on the coarse limit of grading Zone I.

For crushed stone sands, the permissible limit on 150 micron IS Sieve may be increased to 20 per cent in **Table 1** above. The use of crushed stone sand is permitted in PQC, however, percentage of fines passing 75 micron IS Sieve in case of PQC shall not exceed 12 per cent.

3.3.5 Combined Grading

Table 2 and **3** is recommended for combined gradation of fine and coarse aggregate in case of Dry Lean Concrete (DLC) and Paving Quality Concrete (PQC) respectively.

Table 2 Aggregate Gradation for Dry Lean Concrete

Sl. No.	Sieve Size	Percentage passing by weight
1	26.50 mm	100
2	19.0 mm	75-95
3	9.50 mm	50-70
4	4.75 mm	30-55
5	2.36 mm	17-42
6	600 micron	8-22
7	300 micron	7-17
8	150 micron	2-12
9	75 micron (Wet Sieving)	0-5

The above grading is applicable both for natural sand and crushed stone sand. For finding the fraction passing 75 micron, wet sieving of whole aggregate sample shall be performed.

Table 3 Aggregate Gradation for Pavement Quality Concrete

Sieve Designation	Percentage Passing		
	31.5 mm Nominal Size	26.5 mm Nominal Size	19 mm Nominal Size
37.5 mm	100	100	100
31.50 mm	90-100	100	100
26.50 mm	85-95	90-100	100
19.0 mm	68-88	75-95	90-100
9.50 mm	45-65	50-70	48-78
4.75 mm	30-55	30-55	30-58
600 micron	8-30	8-30	8-35
150 micron	0-10	0-10	0-12
75 micron (Wet Sieving)	0-5* 0-2**	0-5* 0-2**	0-5* 0-2**

*Crushed Sand, **Natural sand

3.4 Water

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

3.5 Steel Dowel Bars and Tie Bars

These shall conform to the requirements of IS:432 and IS:1786 as relevant. The dowel bars shall conform to IS:432 of Grade I. Tie bars shall be Thermo- Mechanically Treated (TMT) bars conforming to IS:1786 and grade of Fe 500. If steel mesh is used, it shall conform to IS:1566. The steel shall be coated with appropriate anti-corrosive coating as per IS:13620.

3.6 Temperature Reinforcement

Whenever the steel bars are used as temperature, reinforcement bars, those shall be deformed TMT (Thermo Mechanically Treated) bars as per IS:1786 and shall preferably be welded. Where spot welding is not possible these bars can be tied with binding wire 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/m². The steel mesh may be placed in the upper half of the slab between say 50-75 mm below the top surface and to be sufficiently above the dowel bars such as not to cause any interference to their movement. Welded wire mesh (spot welded in manufacturing plant) may also be used as temperature reinforcement.

3.7 Materials for Joint Sealing

3.7.1 *Joint Sealing*

The joint sealing compound shall be of hot poured, elastomeric type or cold polysulphide/polyurethane/silicon type having flexibility, durability and resistance to age hardening. Manufacturer's certificate shall be produced by the contractor for establishing that the sealant is not more than six months old and stating that the sealant complies with the relevant standard mentioned below.

The material for cold poured joint sealant shall conform to any one of the following:

Polysulphide	IS:11433 (Part I), BS:5212 (Part II)
Polyurethane	BS:5212
Silicon	ASTM D5893-04

If the sealant is of hot poured type, it shall conform to IS:1834 or ASTM: D 3406, as applicable. Hot poured joint sealing compound should not be heated above 180°C and also over long duration; both are not permitted as it will lose its properties due to overheating. Material once heated cannot be reheated again for use. Hence, the quantity of material to be heated should be such that it is used fully. The overheated or reheated material will be rejected. Therefore, quantity of sealing compound required for one operation of joint sealing work shall only be heated.

3.7.2 *Pre-moulded joint filler*

Synthetic 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 firm compressible material and having compressibility of 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 length which shall not be less than one lane width. If two pieces are joined to make up full width, the joint shall be taped such that no slurry escapes through the joint. Holes to accommodate dowel bars shall be accurately bored or punched out to give a sliding fit on the dowel bars. IS:1838 (Part 1) and IS:10566 may be referred for more details.

3.7.3 *Preformed Seals*

The pre-formed joint sealing material shall be a vulcanized elastomeric compound using polychloroprene (Neoprene) as the base polymer. The joint seal shall conform to requirements of ASTM D 2628.

3.8 Fibers

Fibers may be used subject to the provision in the design to reduce the shrinkage cracking and improve post-cracking residual strength. The fibers may be steel fiber as per IRC:SP:46 or polymeric synthetic fibers. The polymeric synthetic fibers will be within the following range

of specifications:

- Effective Diameter 8 – 300 micron for micro fibers
0.20 mm – 1.2 mm for macro
Fibers/steel fibers
 - Length 6-18 mm (micro), 40-65 mm (Macro)
 - Specific gravity 0.91 to 1.36
 - Suggested dosage 0.6 - 2.5 kg/m³ for micro fibers
2.0 – 8.0 kg/m³ for macro fibers
- Actual dosage may be taken from Table 3 of IRC:SP:46
Techno-economical consideration should also be kept in view.
- Usage shall be regulated/designed as stipulated in IRC:44, IRC:SP:46 and IS:456.
 - Water absorption shall be less than 0.45 per cent
 - Melting point shall not be less than 160°C.
 - The aspect ratio shall vary from 200 to 2000.
 - Synthetic fibers shall have good alkali and UV light resistance.
 - Slump: 25±10 mm for Pave Construction; 40±10 mm for Manual construction

4. PROPORTIONING OF CONCRETE

4.1 Proportioning of Materials

For the design of PQC IRC:44 shall be referred.

4.1.1 In case of dry lean concrete, mix design shall be done as per IRC:SP:49 and in case of PQC, guidance for mix design, may be taken from IRC:44 for ascertaining the flexural/compressive strength of cement concrete required to match with the prescribed design strength of concrete. As the stresses induced in concrete pavements are mainly flexural, it is required that their design is based on the flexural strength of concrete in all major projects. 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 IRC:44. 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 likely to be obtained in the field as to ensure the minimum strength is achieved in the field for this purpose.

4.1.2 For concrete roads, flexural strength of concrete is the design criteria. For all major projects, flexural strength of the mix shall be determined by third point loading of flexural beams (150 mm x 150 mm x 700 mm) as per IS:516. Determination of flexural strength by correlating with cube strength (compressive strength) shall not be allowed for major projects, as the correlation is not well established.

Where it is proposed to estimate the flexural strength by correlating with cube compressive strength, the correlation should first be established with laboratory tests by testing minimum 30 specimens of cubes as well as beams prepared from the same mix which is to be used in the field.

4.1.3 Where facilities for testing beams with three point loading are not available, in such cases, the mix design may be carried out by using compressive strength values and there after flexural strength will be determined as per correlation between flexural strength with compressive strength given below.

$$f_{cr} = 0.7 \sqrt{f_{ck}} \quad \dots\dots\dots (1)$$

Where f_{cr} is the Flexural strength in MPa or N/mm² and f_{ck} is the characteristic compressive strength in MPa or N/mm² as per IS:456. For design of cement concrete mixes, guidance may be taken from IRC:44.

4.2 Cement Content

The minimum cement content for the mix corresponding to achieve flexural strength of 4.5 MPa in the field at 28 days is given in para 4.2.1.

4.2.1 Minimum cement content shall be 360 kg/m³ for all type of cements i.e. OPC, PPC, PSC and composite cement. In case fly ash (as per IS:3812- Part 1) is blended at site, the quantity of fly ash shall be restricted to 25 per cent by weight of CM and the quantity of OPC in such a blend shall not be less than 310 kg/m³. In case of GGBFS, minimum cement content shall be 250 kg. If this minimum OPC content is not sufficient to produce concrete of the specified strength, it shall be increased as necessary. The OPC content, however, shall not exceed 450 kg/m³ of concrete.

4.3 Approximate Proportions

The approximate proportions by weight 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 should be expressly understood that this information is only for the convenience of the bidder and does not relieve the bidder from the requirement of proper mix design for the specified characteristic strength.

4.4 Job Mix

The job 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. Contractor must make efforts to get the mix proportion approved at least one and a half month in advance of commencing paving operation in trial length.

4.5 Water Content and Workability

4.5.1 The maximum free water-cement or water-cementitious material ratio of the concrete mix shall be 0.40. At such a low water cement ratio and on account of long distances over which concrete needs to be transported in road projects, use of superplasticizers is inevitable for achieving the desired workability. The superplasticizers conforming to IS:9103-1999 are generally desirable for road works. The quantity of admixtures shall be determined by trials.

The requirement of workability depends upon the equipment used for the compaction and the method of placement of concrete. The control of workability in the field shall be exercised by the slump test as per IS:1199. The slump in the range of 20 to 30 mm for concrete laid with slip form paver and 40 to 60 mm for concrete laid with fixed-form paver is reasonable. However, it may be modified depending upon the site requirement and got approved by the engineer.

The probable time for transporting concrete from mixing plant to paving site should be specified. During this time delay slump loss takes place, and concrete mix design should account for the slump loss.

4.5.2 Workability tests shall be carried out on every tipper or dumper at batching and mixing plant site and paving site initially when the work commences but subsequently the frequency can be reduced to alternate tipper or as per the instructions of the engineer.

5. TOOLS, PLANTS & EQUIPMENT

5.1 General

All tools, plants & equipments 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. These shall have to be inspected by the Engineer 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 good 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, Plants & Equipment (also refer to IRC:43)

5.2.1 Specifications for different tools, equipment and appliances are given in IRC: 43 "Recommended Practice for Plants, Tools and Equipment required for Construction and Maintenance of Concrete Roads". 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, Plants and Equipment for Fully Mechanised Concrete Pavements:

(a) Subgrade

- (i) Compaction equipment (three-wheeled steel static roller or tandem roller, pneumatic roller, vibratory roller (10 to 12 tonnes), or plate compactor, baby roller, monkey (impact) compactor or any other suitable device)
- (ii) Watering devices (water tankers/lorries, bhisties/water carriers or watering cans, water sprinkler or browser fitted with pump)
- (iii) Motor grader
- (iv) Rotavator/disc harrow/tillers

(b) Lower Sub-base (GSB/WMM)

- (i) Pug-mill/Batch Mix plant for granular sub-base/WMM
- (ii) Dumpers
- (iii) Levelling instrument
- (iv) Paver finisher with electronic sensor
- (v) Motor grader
- (vi) Vibratory rollers of 10-12 tonnes weight

(c) Dry Lean Concrete Sub-base

- (i) Batching plant with 4 or more bin-hoppers
- (ii) Dumpers/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) Scabbler for correcting surface regularity
- (x) Levelling instrument

(d) Paving Quality Concrete

- (i) Batch mix plant with 4 or more bin hoppers including chilling plant with suitable matching capacity, cement bag splitter and cement pumping arrangement
- (ii) Dumpers/tippers/transit mixers
- (iii) Power shovel(JCB)/Back Hoe
- (iv) Crawler mounted excavator operated on rubber belts for spreading concrete in front of paver
- (v) Tractor compressor for cleaning the surface before paving PQC
- (vi) Slip-Form Paver or Fixed-Form Paver with all requisite appliances for levelling, alignment etc.
- (vii) Side forms/side rails for fixed form pavers

- (viii) Devices for measuring concrete temperature, wind velocity and air humidity at site
- (ix) Slump cone
- (x) Joint cutting machine (concrete saw), early entry saw
- (xi) Dowel Bar Inserter (DBI), if automatic dowel insertion system is adopted as in slip form paving
- (xii) Dowel cradles/chairs, for manual dowel placement or automatic Dowel Bar Inserter (DBI)
- (xiii) Steel bulk-heads for construction joints
- (xiv) Tie bar supporting assembly or automatic tie bar inserter
- (xv) Guide-wires for slip-form pavers and stakes
- (xvi) Texturing and curing machine
- (xvii) Hand held trowel for localised surface finishing
- (xviii) Liquid curing compound sprayer and Equipment for fog or mist spray
- (xix) Steel mobile bridges (for manual finishing of surface wherever required)
- (xx) Portable pavement protection tents (preferably 150 m length) for hot season operation
- (xxi) Vacuum controlled extruder for silicon sealants and Gun for placing polysulphide
- (xxii) Scabbler
- (xxiii) Total Station/Auto-levelling instrument
- (xxiv) Digital Vernier Callipers
- (xxv) Hessian/burlap drag

(e) Concrete Production (If necessary)

- (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

(f) Transportation, Laying and Compaction of Concrete (If necessary)

- (i) Wheel barrows/iron pans
- (ii) Rail, form- work and wooden bridges
- (iii) Spades
- (iv) Concrete vibrators (pocker, surface and vibrating screed)

- (v) Wooden hand tampers
- (vi) Tipping trucks/dumpers

(g) Finishing Operation: Surface and Joints: (If necessary)

- (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
- (vi) Edging tools including double-edging tools
- (vii) Canvas belts
- (viii) Long handled brooms
- (ix) Saw-cutting machines
- (x) Scabbler (for grinding local high spots)
- (xi) Levelling instrument/Total Station

(h) Curing

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

(i) Cleaning and Sealing of Joints

- (i) Iron raker/Scraper
- (ii) Wire/Coir brush
- (iii) Pneumatic air blower/air compressor
- (iv) Tool for mixing two component sealants
- (v) Vacuum controlled extruder for silicon sealants
- (vi) Primer brush
- (vii) Gun for placing polysulphide

5.2.2 For all projects fully mechanised construction is recommended. Semi-mechanised construction may be used in exceptional cases only.

5.2.3 Specifications for tools, equipment and appliances required for special applications are given in the following codes/standards. These may be referred as required.

- (i) IS: 4926-2003- Ready Mixed Concrete- Code of Practice
- (ii) IS: 5892: 2004- Concrete Transit Mixer- Specifications
- (iii) IS: 5500 (part1): 2004 Vibratory Roller General Requirements Part 1: Self Propelled Tandem Drum
- (iv) IS: 4925:2004 Concrete Batching and Mixing Plant- Specifications

- (v) IS:5500 (Part 2):2004 Vibratory Roller General requirements Part 1: Self Propelled Single Drum
- (vi) IRC:57 “Recommended Practice for sealing of Joins in Concrete Pavements”

6. PREPARATION OF SUBGRADE, SUB-BASE AND LAYING OF SEPARATION MEMBRANE

6.1 General

The embankment/subgrade shall be prepared as under: The existing surface shall be cleared and grubbed. The two passes of roller shall be given after light spray of water. The initial levels will be recorded. The embankment shall be laid as per specifications.

The Pavement Quality Concrete (PQC) shall be laid on two layers of sub-base. Granular sub-base (GSB) acting as a lower sub-base and Dry Lean Concrete (DLC) acting as upper sub-base. GSB, the lower sub-base shall be laid over a subgrade of minimum 500 mm compacted thicknesses. Subgrade shall be of selected earth complying the following requirements:

- (i) No soft spots are present in the subgrade.
- (ii) The subgrade shall have a minimum CBR of 8 per cent.
- (iii) The camber and super-elevation of subgrade shall be same as that of the DLC & PQC.

6.2 Capillary Cut-off

6.2.1 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 capacity besides non-uniform support. Several measures, such as, lowering the sub-soil water table by drainage measures, raising of the embankment or provision of a capillary cut-off may be provided for mitigating this deficiency. It should be investigated for arriving at the optimum solution.

6.2.2 The capillary cut-off may be a layer of coarse or fine sand, graded gravel, bituminised material, geo-composite, or an impermeable membrane.

6.2.3 Capillary cut-off/blanket layer, of required thickness may be placed over compacted subgrade layer. Cut-off with bituminised or other materials may be provided in any of the following ways:

(i) Coarse or fine sand or graded gravel

The minimum thickness of these materials shall be 150 mm. Whenever, sand/gravel 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 geo-textile material.

(ii) Geo-composite/Geo-filter layer

Geo-composite fabrics may also be used to function as capillary cut-off.

6.2.4 For more details about mitigating the adverse effects of high water table, reference may be made to IRC:34 “Recommendations for Road Construction in Areas affected by Water Logging, Flooding and/or Salts Infestation”.

6.3 The Sub-base

6.3.1 The Sub-base provided under the concrete slabs comprises Granular Sub base (GSB) as lower sub-base and Dry Lean Concrete (DLC) which is provided over GSB as upper sub-base. Permeability coefficient of GSB shall be at least 300 m/day.

6.3.2 The material to be used for the GSB shall be natural sand, crushed gravel, crushed stone, or combination thereof depending upon the grading required. The material shall be free from organic or other deleterious constituents and shall conform to the IS:383.

6.3.3 **Table 4** prescribes six grading for Granular Sub-Base (GSB). GSB layer shall comprise of two layers. For lower layer called as filter/separation layer Grading I, II, V or VI shall be used. For upper layer called as drainage layer, Grading III or Grading IV shall be used. Minimum compacted thickness shall be 100 mm for each layer. Alternatively, geo-composite layer may also be used. If geo-composite layer is used as separation layer then minimum 150 mm thick GSB, Grading III or Grading IV shall be provided as drainage layer on top of geo-composite layer. However, the use of geo-composite layer should be resorted to only if it is economically viable.

6.3.4 *Physical Requirements of Aggregates used in GSB*

The material shall have a 10 per cent fines value of 50 kN or more (for sample in soaked condition) when tested in compliance with IS:2386 (Part IV) 1963. The water absorption value of the coarse aggregate shall be determined as per IS:2386 (Part III). If this value is greater than 2 per cent, the soundness test shall be carried out on the material delivered to site as per IS:383.

6.3.5 *Strength of Sub-Base*

In addition to the requirements of minimum CBR of 8 per cent along with other physical requirements like density (98 per cent of the modified Proctor lab MDD) when compacted and finished.

6.3.6 This shall be verified by performing CBR tests in the laboratory as required on specimens remoulded at field dry density and moisture content.

Table 4 Grading for Granular Sub-Base Material (MORTH)

IS Sieve Designation	Per cent by weight passing the IS sieve					
	Grading I	Grading II	Grading III	Grading IV	Grading V	Grading VI
75.0 mm	100	-	-	-	100	-
53.0 mm	80-100	100	100	100	80-100	100
26.5 mm	55-90	70-100	55-75	50-80	55-90	75-100
9.5 mm	35-65	50-80	-	-	35-65	55-75
4.75 mm	25-55	40-65	10-30	15-35	25-50	30-55
2.36 mm	20-40	30-50	-	-	10-20	10-25
0.85 mm	-	-	-	-	2-10	-
0.425 mm	10-15	10-15	-	-	0-5	0-8
0.075 mm	<5	<5	<5	<5	-	0-3
CBR, Minimum	30 %	30%	30%	30%	-	-

The material passing 425 micron (0.425 mm) sieve for all the grading when tested according to IS:2720 (Part 5) shall have liquid limit and plasticity index not more than 25 and 6 per cent respectively.

6.4 Modulus of Subgrade Reaction “k”

Rigid pavement is designed by using the corresponding modulus of subgrade reaction “k” value of subgrade/sub-base, as the case may be. “k” value is normally determined from plate load test as per details given in IRC:58. For the convenience of field engineers, correlation between CBR and “k” value (the modulus of subgrade reaction) is given in **Table 5**.

Table 5 Approximate “k”- Value Corresponding to CBR Values for Homogeneous Soil Subgrade

CBR Value (%)	5	7	10	15	20	50	100
‘k’-Value (MPa/m)	42	48	55	62	69	140	220

6.5 DLC Sub-base, Modified “k” Value

6.5.1 Dry Lean Concrete (DLC) conforming to IRC:SP:49 shall be used as upper sub-base for concrete pavements. The use of granular sub-base or sub-base constructed out of semi rigid material may also be used. The equivalent “k” value for different type of upper sub-bases (like DLC/semi rigid materials/cement treated or stabilized sub-base/granular sub-base) corresponding to “k” value of the subgrade is required to be known for design of rigid pavement.

6.5.2 **Table 6** gives the ‘k’ values of granular and cement treated sub-bases for three types of subgrade soils.

Table 6 “K” Values Over Granular and Cement Treated Sub-Base

“k”-value of sub grade (MPa/m)	Effective “k” (MPa/m) over untreated granular layer sub-base of thickness in mm			Effective “k” (MPa/m) over cement treated sub-base of thickness in mm		
	150	225	300	100	150	200
28	39	44	53	76	108	141
56	63	75	88	127	173	225
84	92	102	119	-	-	-

6.5.3 Table 7 gives “k” values for Dry Lean Concrete (DLC) design as per IRC:SP:49 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 Table 5 or Table 6 and be constructed in accordance with the respective specifications.

Table 7 – “k” Values for Dry Lean Concrete Sub-Base

“k”- value of Subgrade MPa/m	48	55	62
Effective “k” over 100 mm DLC MPa/m	208	278	389
Effective “k” over 150 mm DLC MPa/m	277	417*	-

* Maximum k value shall be 300 MPa/m. In calculating other values as per proportion, the value of 300 MPa/m shall be taken instead of 417 MPa/m.

6.5.4 Thickness of DLC sub-base should be minimum 150 mm. The surface finish of the sub-base shall be smooth. The average compressive strength of each consecutive group of 5 cubes shall not be less than 7 MPa at 7 days. For PQC bonded to DLC, the 7-day strength of DLC should not be less than 10 MPa. If it is desired to have PQC bonded to DLC, the surface of DLC is to be roughened with wire brush within 3-6 hours of laying.

6.5.5 Where the embankment consists of clay having liquid limit more than 50 per cent, such as, black cotton soil, the subgrade soil should be stabilised with lime and cement or any other approved stabilizer (achieving minimum CBR 15 per cent) with a minimum thickness of 500 mm. Alternatively, black cotton soil should be replaced with suitable soil of minimum CBR of 8 per cent.

6.5.6 In water-logged areas and where the sub-grade soil is impregnated with deleterious salts, such as, sodium sulphate etc. in excess of permissible limits, a capillary cut-off should be provided before constructing the sub-base.

6.5.7 The granular sub-base shall be in a moist condition at the time the DLC is placed as per IRC:SP:49. There shall, however, be no pools of water or soft patches formed on the sub-base surface.

6.6 Separation Membrane

A separation membrane shall be used between the PQC and the DLC sub-base unless PQC is designed as bonded to DLC sub-base. Separation membrane shall be impermeable Polyethylene sheet 150 micron thick as per IS:2508, transparent or white in colour laid flat with minimum creases. The minimum width of the separation membrane shall be 3.5 m. Before placing the separation membrane, the sub-base shall be swept clean of all the extraneous materials using air compressor. Wherever overlap of plastic sheets is necessary, the same shall be at least 300 mm. The separation membrane may be nailed to the lower layer with concrete nails.

In summer (when ambient temperature is more than 25°C), before placing separation membrane, the existing DLC surface shall be moist with water.

Alternatively, non-woven geo-textile, 4 mm thick, may also be used as separation layer between PQC and DLC.

7. WEATHER LIMITATIONS

7.1 Concreting in Hot Weather

Placing of concrete in ambient 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 when the ambient temperature is more than 35°C.

7.1.1 The ambient temperature above 35°C, relative humidity below 25 per cent and/or wind velocity of more than 15 km/h constitute conditions necessitating precautions to be taken for concreting to avoid plastic shrinkage cracking. The associated problem involved in concreting in hot weather affect the production, placement and curing of concrete.

7.1.2 A higher temperature of the fresh concrete results in rapid hydration and leads to accelerated setting of concrete. The slump of concrete decreases and hence the water demand increases in hot weather. Plastic shrinkage cracks may develop in concrete due to evaporation of water from the surface of the concrete. No concreting should be done when the concrete temperature is above 30°C. To bring down the temperature of concrete, chilled water or ice flakes should be used. In addition to chilled mixing water, cooling of aggregates is also desirable. It is advisable to install a chilling plant, so that the temperature of the concrete mix can be controlled in hot weather. A ready to use chart to calculate the rate of evaporation of water from the concrete for the construction of cement concrete pavement is given in **Fig. 1**. If the rate of evaporation is expected to be above 1 kg/m² per hour near the top of the surface, precautions against plastic shrinkage cracking are necessary. The surface shall be continuously kept wet by slight fogging/misting and by the use of tents/covers to minimize wind speed or providing wet hessian cloth before continuous curing i.e. after 24 hours of laying.

7.1.3 Plastic shrinkage crack of width 0.2 mm in case of normal weather condition and 0.3 mm in case of moderate/severe weather condition may be the nucleus for other types of damage due to water penetrating through them. Due to increased tensile stresses, these cracks may develop into structural cracks with passage of time. Plastic shrinkage cracks reduce abrasion resistance of surface and wearing of surface due to traffic will be faster.

7.1.4 A good quality concrete, which is strong, impermeable and durable against abrasion, chemical attack and adverse effects of weather can only be achieved with suitable choice of materials, proper mix proportioning and satisfactory controls at all stages of producing, placing and curing of concrete.

7.1.5 Mixing water has the greatest effect on lowering the temperature of concrete. The temperature of water is easier to control than that of another ingredient. The use of cold mixing water will reduce the temperature of placing of concrete to some extent. The reduction of water temperature can be most economically accomplished by adding ice flakes to it. The ice should be manufactured from non-chlorinated water.

7.1.6 Due to high temperature, the hydration of concrete is faster and rapid stiffening of concrete results in increased water demand. Use of rapid hardening cement or 53 grades OPC shall be avoided in case of hot weather concreting. The aggregates may be kept shaded to protect from direct sun rays. They may also be sprinkled with cold water.

7.1.7 To off-set the accelerating setting of concrete in hot weather and to reduce increased demand, set retarding and water-reducing admixture should be used. However, as some of the admixture can cause undesirable secondary effects such as reduction in ultimate strength of concrete or increase of bleeding of concrete, it is recommended that prior experience or test data should be available, before their use. The temperature of aggregates, water and cement should be maintained at the lowest practical levels, so that the temperature of concrete is below 30°C, at the time of placement.

7.1.8 The concrete mixer or transit mixer could be painted white on the outer side and cover with wet hessian cloth to inhibit absorption of heat from sun and air. The location of batching and mixing units should be as close as possible to the site of placement. The sub-base shall be sprinkled with cold water, just prior to placement of concrete to keep the sub-base cool but it should be surface dry at the time of placement.

7.1.9 Weather has profound impact on curing. The process of hydration of cement is faster in summer than in winter. Immediately after consolidation and surface finish, concrete shall be protected from evaporation of moisture. Fogging or misting of the concrete surface before and after final finishing and texturing is very effective way to minimize evaporation and reduce plastic shrinkage cracking. It cools and raises the relative humidity of the air just above the concrete surface to lessen rapid evaporation. Initial curing shall be done using curing compound which will be sprayed on the cement concrete surface when no free water

is visible on the surface and texturing has been completed. Wet hessian cloth should be gently placed after the curing compound has lost its sheen. In place of wet hessian cloth, concrete surface may also be covered with plastic sheet from all sides. Wet curing shall continue thereafter at least for 14 days in case of OPC and 16 days where blended cement or fly ash admixed PQC has been used. There shall be sufficient supply of wet hessian cloth for initial curing.

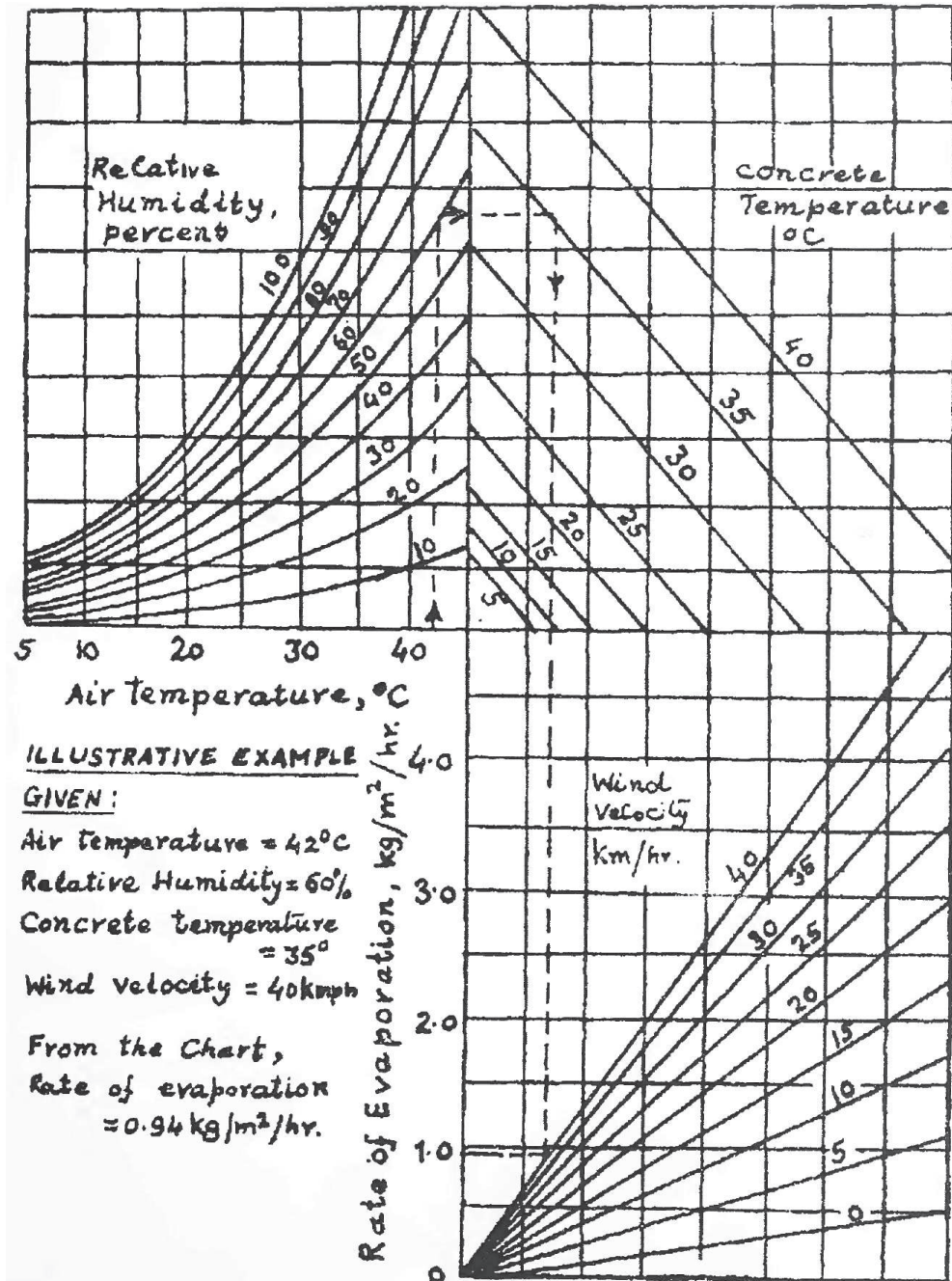


Fig. 1: Chart for calculation of rate of evaporation of surface moisture of concrete from air temperature and relative humidity, concrete temperature and wind velocity. (enter the chart on the temperature scale and proceed as shown by dotted line, till the rate of evaporation is reached)

7.2 Concreting in Cold Weather

7.2.1 When concrete is being placed in cold weather and the air temperature is expected to fall below 20°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. Except by specific written authorization from the Engineer-in-Charge, concreting shall not be continued when a falling air temperature in the shade and away from artificial heat drops below 5°C, nor shall concreting be resumed until an increasing air temperature in the shade and away from artificial heat reaches 5°C.

7.2.2 When concrete is likely to be subjected to freezing and thawing the use of air entraining agent is mandatory. The air content in the concrete shall be 5.5 ± 1.5 per cent for 31.5 mm maximum size of aggregate and 6.0 ± 1.5 per cent for 19 mm maximum size of aggregate. For 26.5 mm size of aggregates air content in the concrete shall be 5.0 ± 1.5 per cent.

7.2.3 When specific written authorization 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 accelerating admixture can be used. The use of calcium chloride as an accelerator, or an accelerating admixture containing chloride can be permitted, if concrete does not have un-coated reinforcing steel. When concrete contains uncoated steel reinforcement, chlorides free accelerators e.g. calcium nitrite or calcium formate may be used.

7.2.4 Concrete heating equipment capable of producing concrete that will have temperature of at least 15°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 mix 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.

7.2.5 During placement of concrete, tarpaulin covers or other such readily removable coverings should closely follow the placing of concrete, so that only a few meters of the finished slab are exposed to the outside air at any point of time. The coverings may be so arranged that heated air, when 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.

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

7.2.7 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 efficacy of this method should be checked by constructing trial sections.

7.3 Frost Affected Areas

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 450 mm. For protection against frost, the balance between the frost depth (450 mm) and total pavement thickness should be made up with non-frost susceptible material. In frost affected areas, the sub-base may consist of any of the specifications having 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.

7.3.1 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.

7.3.2 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 IS 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 IS sieve: Max. 18 per cent passing 75 micron IS sieve.

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. It shall be ensured that vibrator should not contact the dowel bar, and the vibration operation does not misalign the dowels. In case of mechanised construction, working and their vibration/RPM of all the fixed vibrators shall be checked. There shall be two additional needle vibrators to compact the concrete near bulk head. Wherever, tie bars or dowel bars are inserted in the PQC, proper marking on the projecting surface of DLC will help to cut the joint at proper location.

Initial cut or a slot of 2.5 to 5 mm wide and having a depth equal to one-third to one-fourth the depth of the PQC slab at transverse and longitudinal joint is made as soon as the concrete

sets. Normally, in summer when ambient temperature is more than 30°C initial cutting may be carried after 4-8 hours of laying and in winter when ambient temperature is less than 30°C, initial cut may be done at 8-12 hours of laying. In any case initial cut of all the transverse and longitudinal joints shall be completed within 24 hours to avoid the random cracking. Subsequent widening of joint groove will be done after 14-16 days of casting concrete pavements. No sealing of joints shall be undertaken before 21 days of construction. All joints shall be sealed using sealants and joints shall be sealed when grooves are dry and clean and free from foreign object or loose material. Alternatively, compression seals or solid seals can also be used to seal the joints after initial cut without widening with the permission of Engineer.

Joint cutting equipment which can be used to cut joint at the early age of concrete is called as early-entry saw. This is light weight equipment and has a plate on both sides of saw to keep concrete pressed at the location of saw cutting to basically control raveling. With use of early-entry joint cutting equipment, joints can be cut even earlier than that mentioned above using early-entry saw with the permission of the Engineer. Early-entry saw cutting are dry-cuts so their blades are designed for use without water for cooling. The depth of cut shall be minimum 10 per cent subject to 30 mm minimum.

8.2 Types of Joints

There are four types of joints (IRC:57). These are:

- (i) **Expansion joint:** Expansion 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:** Contraction 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) **Longitudinal joint:** Longitudinal joint relieves stresses due to warping. These are commonly used for dividing the pavement into lanes when width of the slab becomes more than 4.5 m.
- (iv) **Construction Joint:** Construction joints are provided whenever day's construction operations start and stops/ends. These are full depth joints. Construction should be so planned that days construction activity may end at the location of regular contraction joint. It may also be provided where paving stops for more than half an hour due to stoppage of work.

Figs. 2 to 5 show the location of contraction and longitudinal joints. All joints shall be carefully installed in accordance with the location and details given in the plans. The details of different types of joints, sealing groove, their plan, cross section etc., are shown in **Figs. 6 to 10**. For details IRC:57 may be referred.

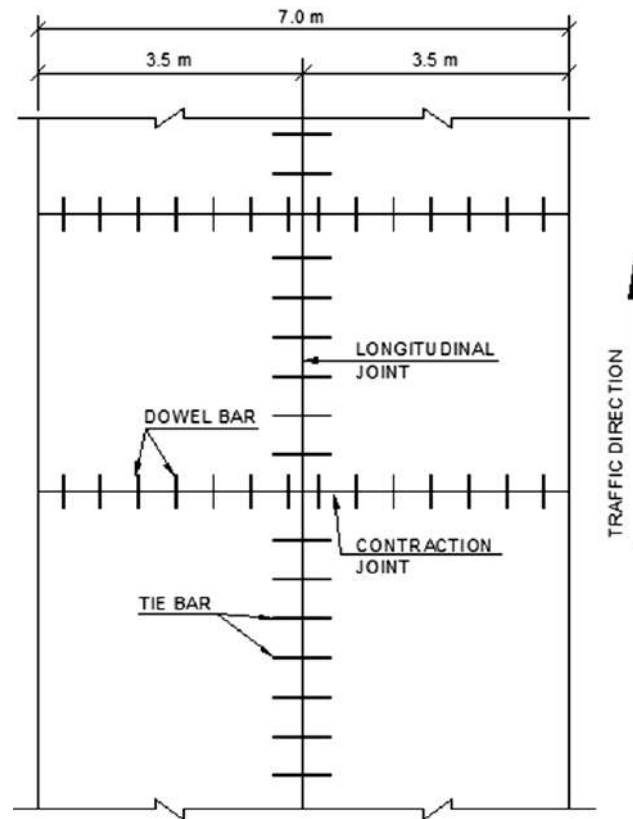


Fig. 2: Joints Configuration of Two Lane Road without Tied Shoulder

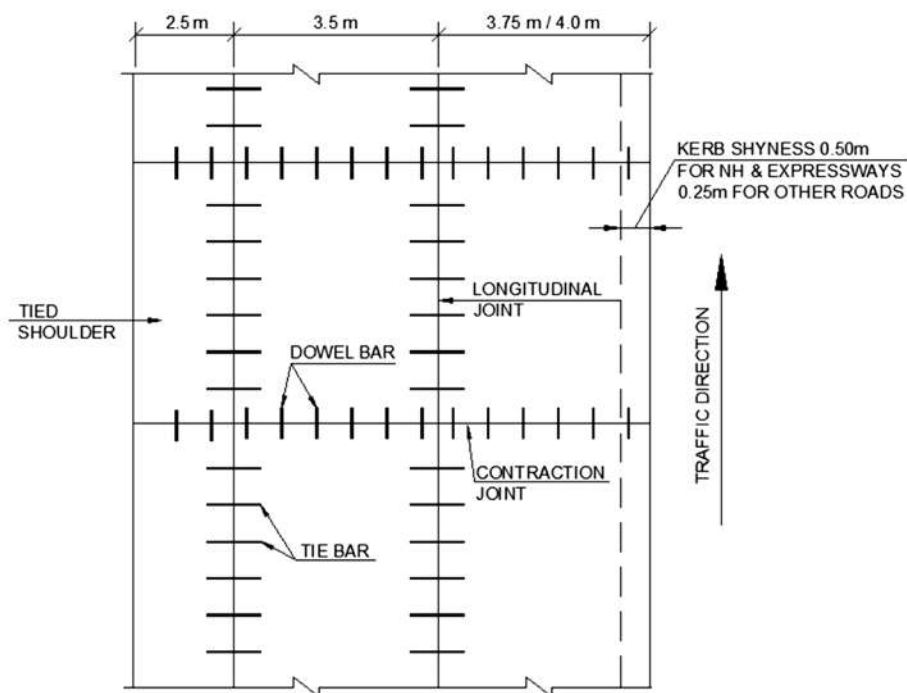


Fig. 3 Joints Configuration for each Carriageway of Four Lane Divided Road with Tied Shoulder (Half Cross-Section)

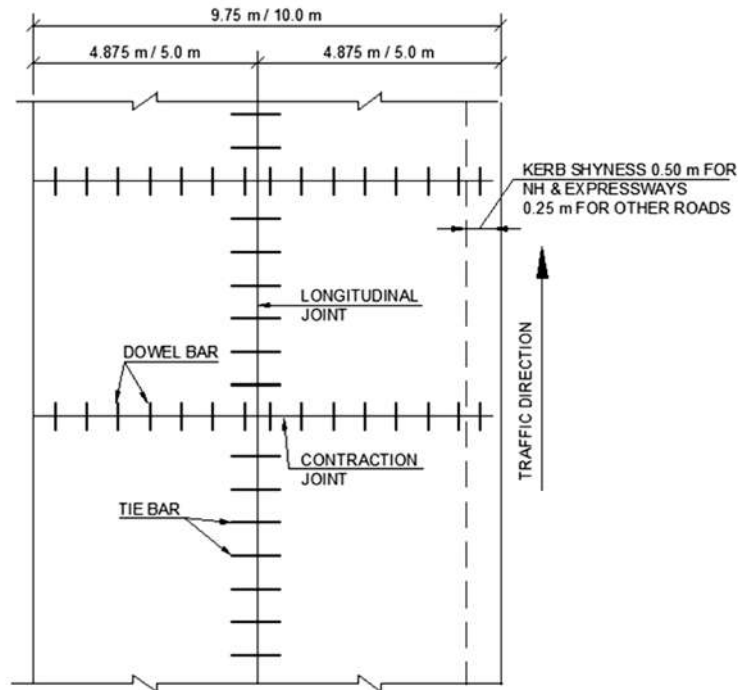


Fig. 4 Alternate Joints Configuration for each Carriageway of Four Lane Divided Road (Half Cross-Section)

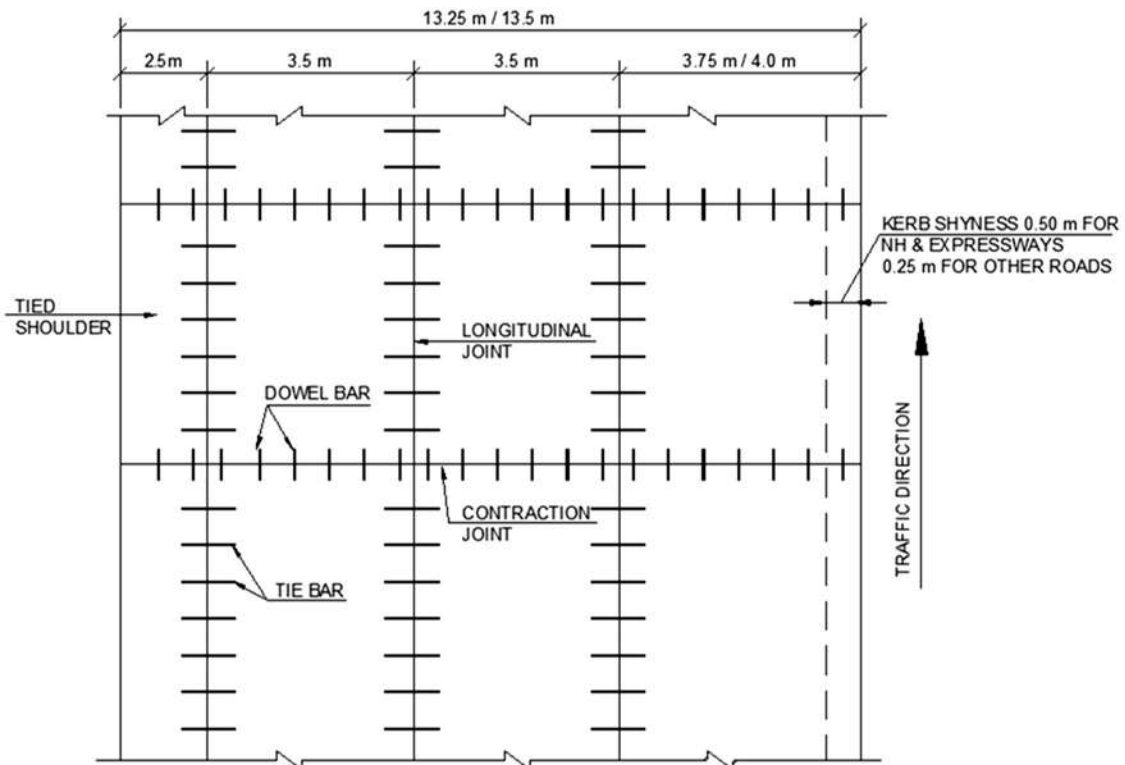


Fig. 5 Joints Configuration for each Carriageway of Six Lane Divided Road with Tied Shoulder (Half Cross-Section)

8.3 Transverse Joints

8.3.1 General

Transverse joints can be expansion, contraction or construction joints and shall be placed across the traffic direction as indicated on the drawing. These shall make a right angle with the centre line of the pavement. Contraction, construction and expansion joints shall be continuous from edge to edge of the pavement through all lanes constructed at the same or different times. These shall extend over the entire width of the pavement. The maximum transverse joint spacing shall be 4.5 m.

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 as per **Clause 8.6** and **8.7**.
- (v) The transverse joints at curves shall be radial in the direction of the radius.

8.3.2 Transverse Expansion Joints

They shall be of the dimensions and spacing as shown on the drawing. These shall be provided only where PQC abuts a bridge, under passes and culvert.

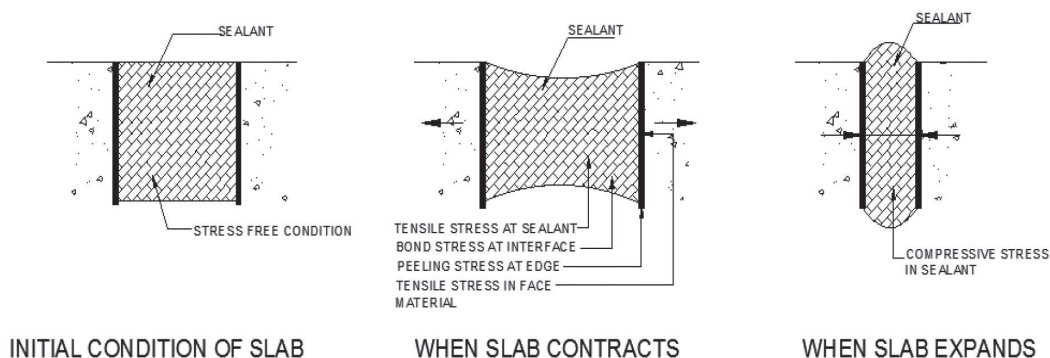


Fig. 6: Shape of Joint Sealing Groove

(Shape Factor = Depth of sealant/Width of sealant = 1.0-1.25 for Hot Poured Sealant and Cold Poured Polysulphide sealant in contraction/construction joint/longitudinal joint)

- = 0.75 for Cold Poured Silicon Sealant in contraction/construction joint/longitudinal joint
- = 0.50 for Expansion Joint

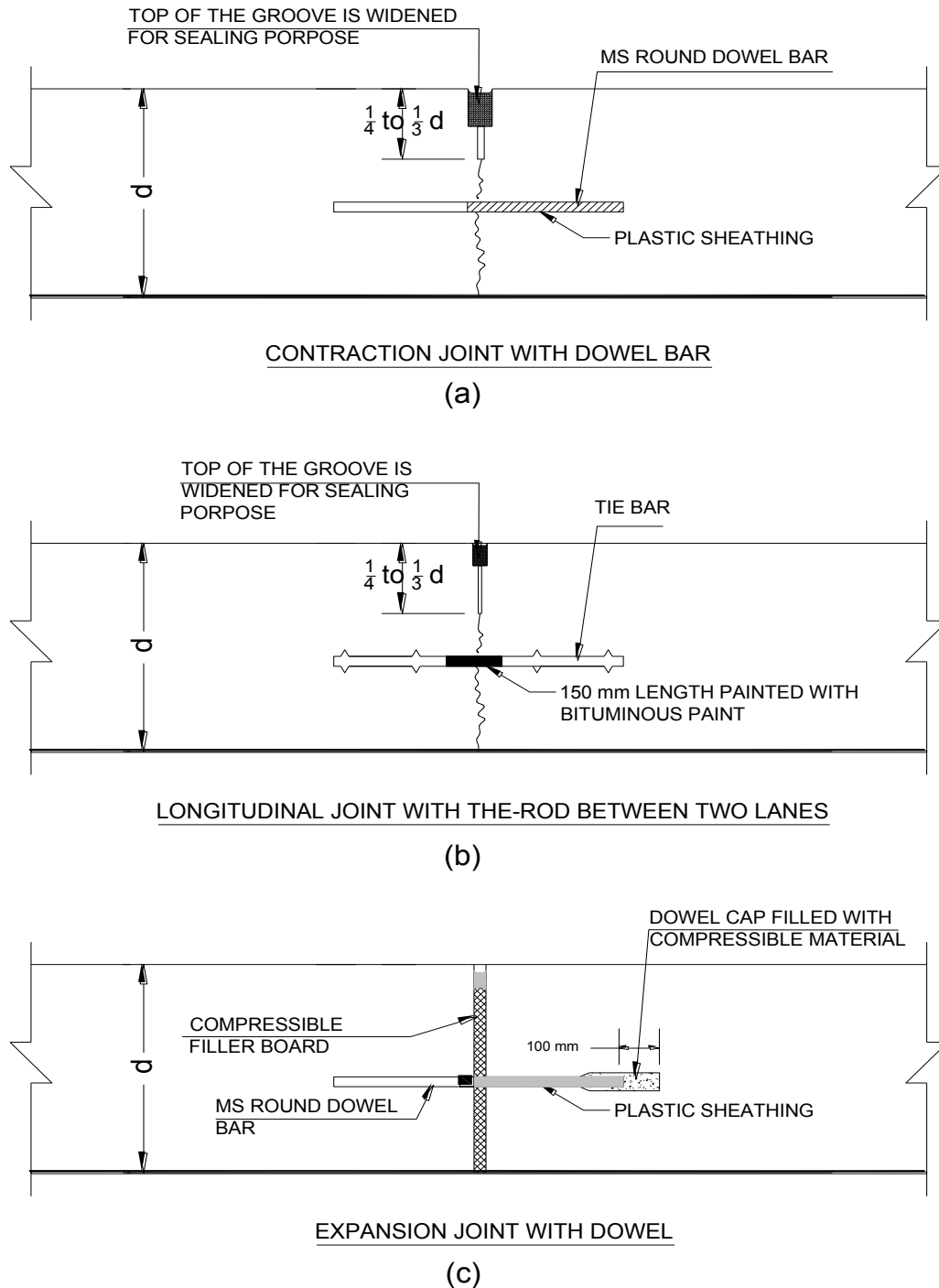
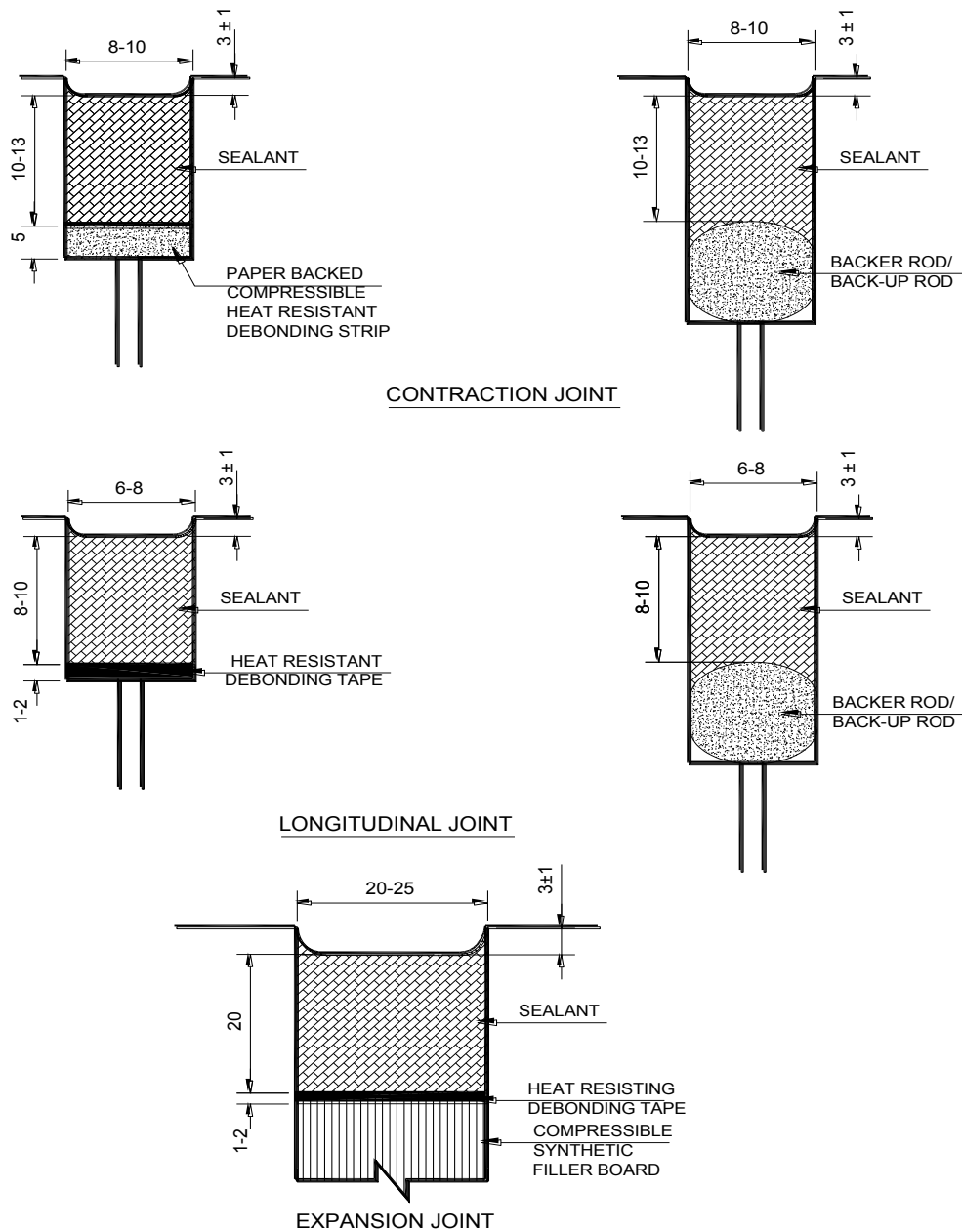


Fig. 7: Typical Cross – Section of Joints

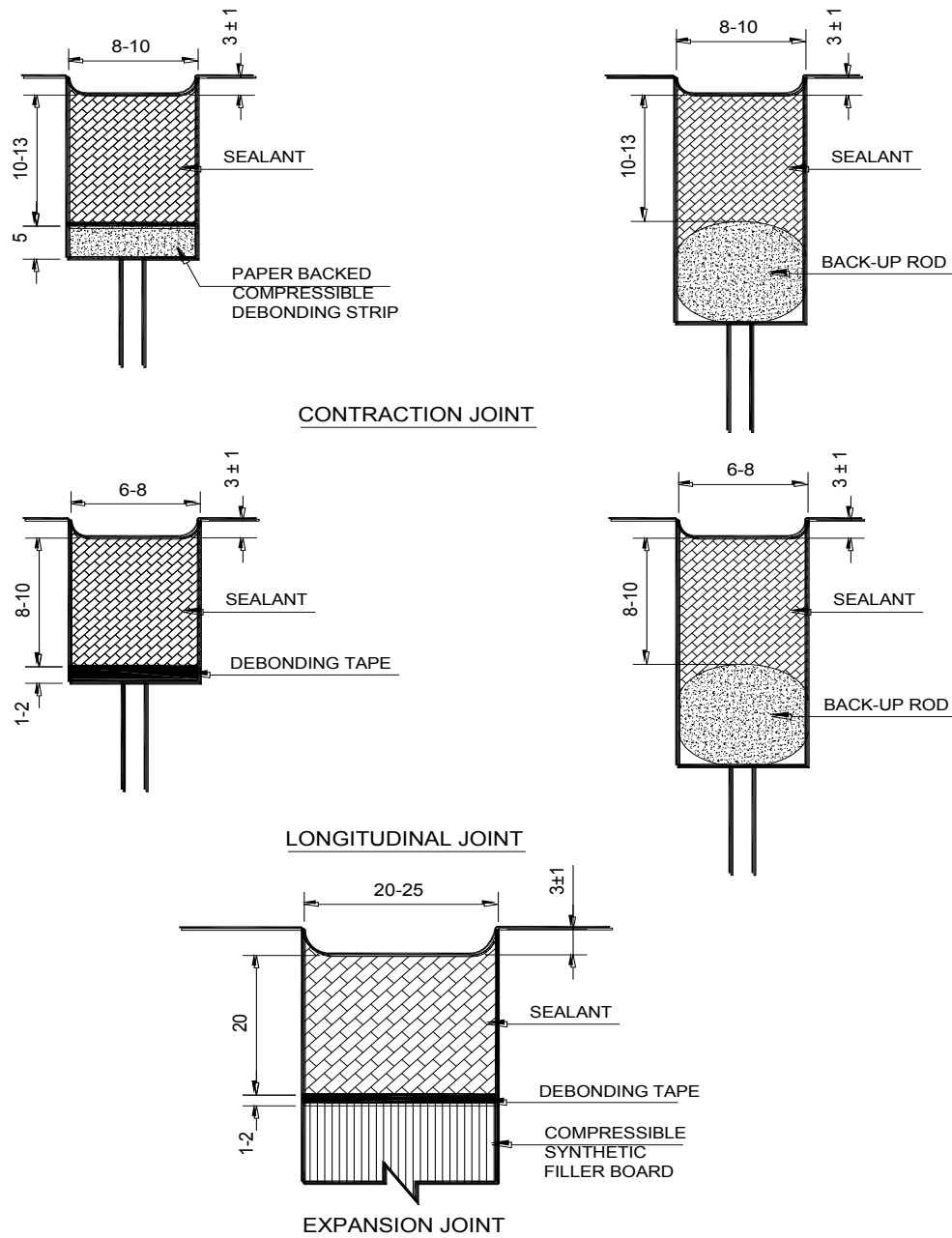
Note: Construction joint shall be same as contraction joint at (a) above with a butt type.



NOTES:

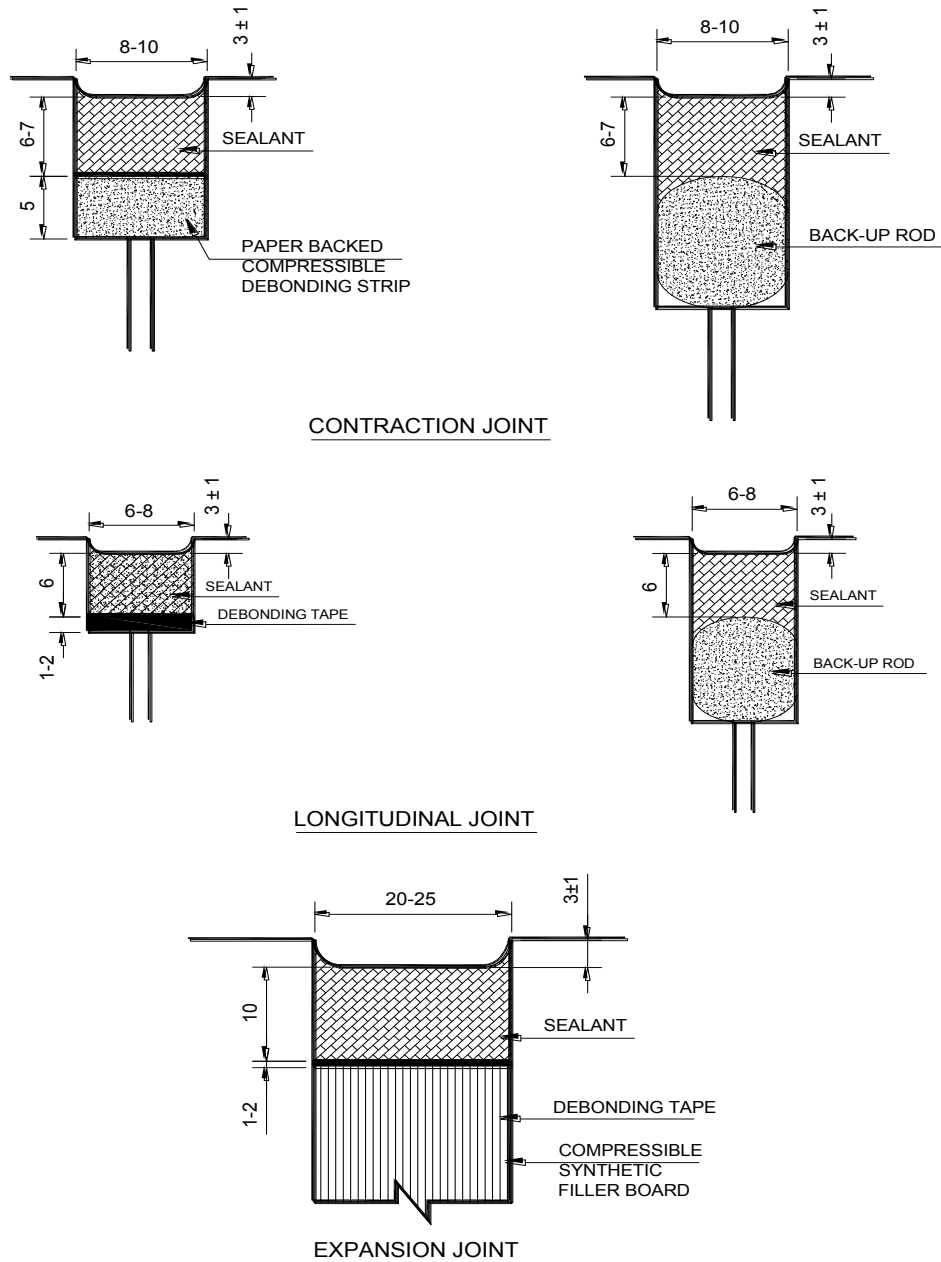
1. PAPER BACKING OF COMPRESSIBLE DEBONDING STRIP IS NOT NECESSARY IF THE STRIP IS NON-ABSORBENT TYPE.
2. JOINTS CAN BE SEALED BY ADOPTING ONE OF THE TWO OPTION OF DEBONDING STRIP/BACKER-ROD AS SHOWN.
3. DEPENDING UPON THE SEALANT MANUFACTURER'S RECOMMENDATION, THE SIDES OF THE GROOVE MAY HAVE TO BE SANDBLASTED/SAND PAPERED AND PRIMED.
4. THE GROOVE AND SEALANT DIMENSIONS SHOWN ARE ONLY FOR GUIDANCE.
5. BACKER ROD/BACK-UP ROD SHALL BE EXPANDED CLOSED-CELL POLYETHYLENE FORM.
6. ENDS OF THE SEALANT GROOVE SHALL BE PLUGGED BEFORE POURING SEALANT TO AVOID SPILLAGE LATERALLY.
7. ALL DIMENSIONS ARE IN mm.

Fig. 8: Sealing Details of Joints
(Grooves Suitable for Hot Poured Rubberized Bitumen Sealant)

**NOTES:**

1. PAPER BACKING OF COMPRESSIBLE DEBONDING STRIP IS NOT NECESSARY IF THE STRIP IS NON-ABSORBENT TYPE.
2. JOINTS CAN BE SEALED BY ADOPTING ONE OF THE TWO OPTION OF DEBONDING STRIP/BACKER-ROD AS SHOWN.
3. DEPENDING UPON THE SEALANT MANUFACTURER'S RECOMMENDATION, THE SIDES OF THE GROOVE MAY HAVE TO BE SANDBLASTED/SAND PAPERED AND PRIMED.
4. THE GROOVE AND SEALANT DIMENSIONS SHOWN ARE ONLY FOR GUIDANCE.
5. BACKER ROD/BACK-UP ROD SHALL BE EXPANDED CLOSED-CELL POLYETHYLENE FORM.
6. ENDS OF THE SEALANT GROOVE SHALL BE PLUGGED BEFORE POURING SEALANT TO AVOID SPILLAGE Laterally.
7. ALL DIMENSIONS ARE IN mm.

**Fig. 9: Sealing Details of Joints
(Grooves Suitable for Cold Poly-Sulphide Sealant)**



NOTES:

1. PAPER BACKING OF COMPRESSIBLE DEBONDING STRIP IS NOT NECESSARY IF THE STRIP IS NON-ABSORBENT TYPE.
2. JOINTS CAN BE SEALED BY ADOPTING ONE OF THE TWO OPTION OF DEBONDING STRIP/BACKER-ROD AS SHOWN.
3. DEPENDING UPON THE SEALANT MANUFACTURER'S RECOMMENDATION, THE SIDES OF THE GROOVE MAY HAVE TO BE SANDBLASTED/SAND PAPERED AND PRIMED.
4. THE GROOVE AND SEALANT DIMENSIONS SHOWN ARE ONLY FOR GUIDANCE.
5. BACKER ROD/BACK-UP ROD SHALL BE EXPANDED CLOSED-CELL POLYETHYLENE FORM.
6. ENDS OF THE SEALANT GROOVE SHALL BE PLUGGED BEFORE POURING SEALANT TO AVOID SPILLAGE LATERALLY.
7. ALL DIMENSIONS ARE IN mm.

**Fig. 10 Sealing Details of Joints
(Grooves Suitable for Cold Silicon Sealant)**

8.3.2.1 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. It may sometime be necessary to provide more number of expansion joints in succession in such locations to release the pressure. Expansion joints against culverts, underpasses etc. having RCC box structure should normally be avoided by taking the PQC over the deck of such structures. To deal with the lack of compaction in the vicinity of structures and subsequent settlement, RCC approach slabs must be provided on both sides abutting with DLC layer. Wherever, PQC is taken over the deck of structures, underpasses etc., saw cut transverse construction joints must be provided just above the deck and approach slabs on both sides to avoid full depth transverse cracks in PQC.

8.3.2.2 Dowel bars 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 200 mm dowel bars may not be provided (IS:6509). The pre-moulded 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 accurate placing of dowels at the end of the day may be achieved by means of sufficiently strong bulkheads made of steel sections with holes drilled along the centre line to accommodate the dowel bars in a mild steel section and clamping arrangement not allowing displacement of bars while placing and compacting concrete. 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 and keep all bars parallel to each other. A box section normally is adopted for such designs.

8.3.2.3 The bulkheads shall be securely fixed 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.

8.3.2.4 Sealing grooves can be formed by placing wooden or PVC strips of 20-25 mm x 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 (tapered) suitably.

8.3.2.5 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 *Contraction Joints*

These shall be placed as shown on the drawing and shall be of the weakened plane of “dummy” groove type. The groove is formed preferably by a joint cutting saw. This groove

is subsequently widened and sealed with sealant as shown in **Figs. 6 to 10**. Alternatively, in case of semi-mechanised construction 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 *Construction Joints*

These shall be formed 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. In case of emergency the joints should be placed only in the middle third of the specified contraction joint interval or slab length.

At all construction joints, bulkhead shall be used to retain the concrete and care shall be taken in striking off and finishing the concrete 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 of pavement, 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*

8.3.6 *Dowel Bars*

Dowel bars shall be in accordance with details/dimensions as indicated in the drawing and free from oil, dirt, loose rust or scale. These shall be coated with appropriate anti-corrosive coating as per IS:13620. Coated bars should be protected from scratching during handling, and should be manually recoated by epoxy or anti-corrosive paint wherever scratches are observed. For uniformity in thickness of coating, the coating done in factory environment is preferable. Coating shall be done within 4 hours of cleaning of bars from all rust. Cleaning is done by sand/shot blasting. 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. 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.

8.3.7 Design of dowel bars has been given in IRC:58. The minimum length of dowel bar shall be 500 mm keeping in view the requirement of load transfer and placement errors. The diameter and spacing of dowels shall be designed as per IRC:58.

8.3.8 The dowel bars 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 as given hereunder:

- (a) Horizontal or vertical rotational alignment ≤ 10 mm
- (b) Longitudinal shift ≤ 50 mm
- (c) Depth of dowel bar : mid-depth ± 25 mm

8.3.9 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, smooth, slide fit, 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.

8.3.10 Four bars shall be taken at random from stock or without any special preparation shall be covered by sheaths as required. The ends of the dowel bars which have been sheathed shall be cast centrally into concrete specimens 150 x 150 x 600 mm, made of the same mix proportions to be used in the pavement, but with a maximum nominal aggregate size of 31.5 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.

8.3.11 For expansion joints, a closely fitting cap 100 mm long with closed end consisting of G1 pipe or stiff plastic of 2 mm thickness 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 General

These joints are known as warping joints and can be formed by two different methods: (i) These can be of construction butt type formed by placing the concrete against the face of the slab cast earlier. The face of the slab cast 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 cut by a joint cutting machine. In case of four lane divided road, when a two-lane carriageway (7.25/7.5 m wide) with tied shoulder (2.5 m wide) is laid using full width paver, then, two longitudinal saw cut joints shall be provided- one between the inner and outer lane and the other between outer lane and tied concrete shoulder (**Fig. 3**). In place of two longitudinal joints, one longitudinal joint may also be provided in the centre of carriageway dividing the carriageway into two equal parts of 4.875/5.0 m width as per the design recommended by the designer (**Fig. 4**).

8.4.2 Tie bars

The bars shall be free from oil, dirt, loose rust and scale.

8.4.3 Tie bars are used across the longitudinal joints of concrete pavements to ensure firm contact between slab faces or to prevent abutting slabs from separating. Tie bars are not required for structural reasons, but their only function is to prevent separation of the slabs, especially at fills or curves. Tie bars are not designed to act as load transfer devices. Tie bars are designed to with stand tensile stresses only and provided at mid-depth.

8.4.4 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. The coating shall be dry when the tie bars are used.

8.4.5 Tie bars shall be laid automatically in a fully mechanised construction using slip form paver. For semi mechanised construction tie bars 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 top by vibration using tie bar inserter. This method ensures correct placement of the bars and re-compaction of the concrete around the tie bars. When the pavement is constructed in single lane width, tie rods are also inserted mechanically or manually from sides. During side insertion in fixed form paving these may be bent so that half length remains along the form. After removal of forms, bars shall be straightened using hollow GI pipe so that they extend into the concrete placed on the other half of the concrete slab.

8.4.6 Tie bars shall be positioned to remain within the middle third of the slab depth but well below the proposed sawing depth as indicated in the **Fig. 7 (b)**, normally parallel to the surface and 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. Typical tie bar details for use in double-lane rigid pavement with a lane width of 3.5 m are given in **Table 8**.

8.5 Arrangement of Different Types of Joints

8.5.1 For more details about arrangement of the different types of joints, IRC:57 may be referred. The joint spacing at curve portion may be reduced by 20-30 per cent. In general, slab configuration is considered as 3.5 m x 4.5 m. The length of the slab shall be either more or equal to its width.

8.5.2 *Anchor Beam and Terminal Slab Adjoining Bridge Structures*

Cement concrete slab 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 grade of concrete for anchor beam shall be the same as for 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.11**. In case of culverts, etc. where the PQC slabs are provided above the superstructure,

there is no need to construct anchor beam, approach slab and terminal slab. In case the PQC slab abuts with culvert structure, the construction of approach slab and terminal slab with anchor beam will be necessary.

Table 8– Details of Tie Bars for Longitudinal Joints of Rigid Pavements (Same as IRC:58)

Slab Thickness (mm)	Tie Bar Details				
	Diameter (d) (mm)	Max. Spacing (mm)		Minimum Length (mm)	
		Plain Bars	Deformed Bars	Plain Bars	Deformed Bars
150	8	330	530	440	480
	10	520	830	510	560
200	10	390	620	510	560
	12	560	900	580	640
250	12	450	720	580	640
300	12	370	600	580	640
	16	660	1060	720	800
350	12	320	510	580	640
	16	570	910	720	800

Note:

- 1) $S = 125$ MPa for plain bars, 200 MPa for deformed bars, Bond stress for plain bars = 1.75 MPa, for deformed bars = 2.46 MPa, $W = 24$ kg/m²/cm of slab.

Where, S is minimum tensile strength of steel, B is minimum bond strength of concrete with steel bar, W is the weight of concrete /cm²/cm.

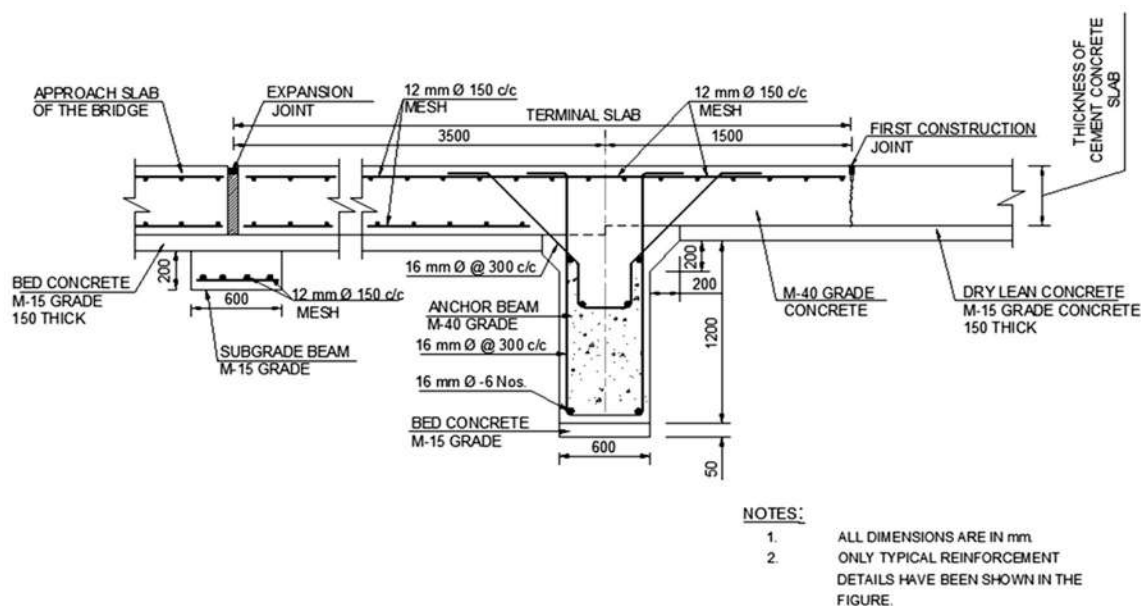


Fig.11 Details of Anchor Beam and Terminal Slab

8.6 Preparation of Joint Grooves for Sealing

8.6.1 Joint grooves are not constructed to provide the maximum width specified in the drawings when initial saw cut is made upto one-fourth to one-third of the slab depth. They shall be widened subsequently by sawing before sealing. Depth and width gauges shall be used to control the dimensions of the groove during widening process.

8.6.2 If spalling occurs or the angle of the former is greater than 10 degrees, the joint sealing groove shall be sawn wider and perpendicular to the surface to encompass the defects up to a maximum width including any chamfer, of 12 mm for transverse joints and 10 mm for longitudinal joints. If the spalling cannot be so eliminated then the arises shall be repaired by an approved thin bonded arises repair using cementitious materials, like, epoxy or polymer concrete.

8.6.3 All grooves shall be cleaned of any dirt or loose material by air blowing with filtered, oil-free compressed air. If need arises, cleaning by pressurized water jets may be done depending upon the requirement of the sealant, the sides of the grooves may have to be sand blasted to increase the bondage between sealant and concrete.

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

8.6.5 Before sealing, the temporary seal inserted before subsequent widening for blocking the ingress of dirt, soil etc. shall be removed. A highly compressible heat resistant paper-backed debonding strip as per drawing/IRC: 57 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 into the crack below. The width of debonding strip shall be slightly more than the joint groove width so that it is held tightly in the groove. In the case of hot sealant, heat resistant tapes may be inserted to block the leakage through bottom of the joint.

8.7 Sealing with sealants

8.7.1 When sealants are applied an appropriate primer shall also be used in accordance with the recommendation of the manufacturer. The sealant shall be applied within the minimum and maximum drying times of the primer. Priming and sealing with applied sealants shall not be carried out when the temperature of the pavement is below 7°C.

8.7.2 If hot applied sealant is used, it shall be heated and applied (after using raker) from melter and pourer as shown in **Figs. 12, 13 and 14**. Hot sealants shall be rubberized bitumen type. The 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 temperature, 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.

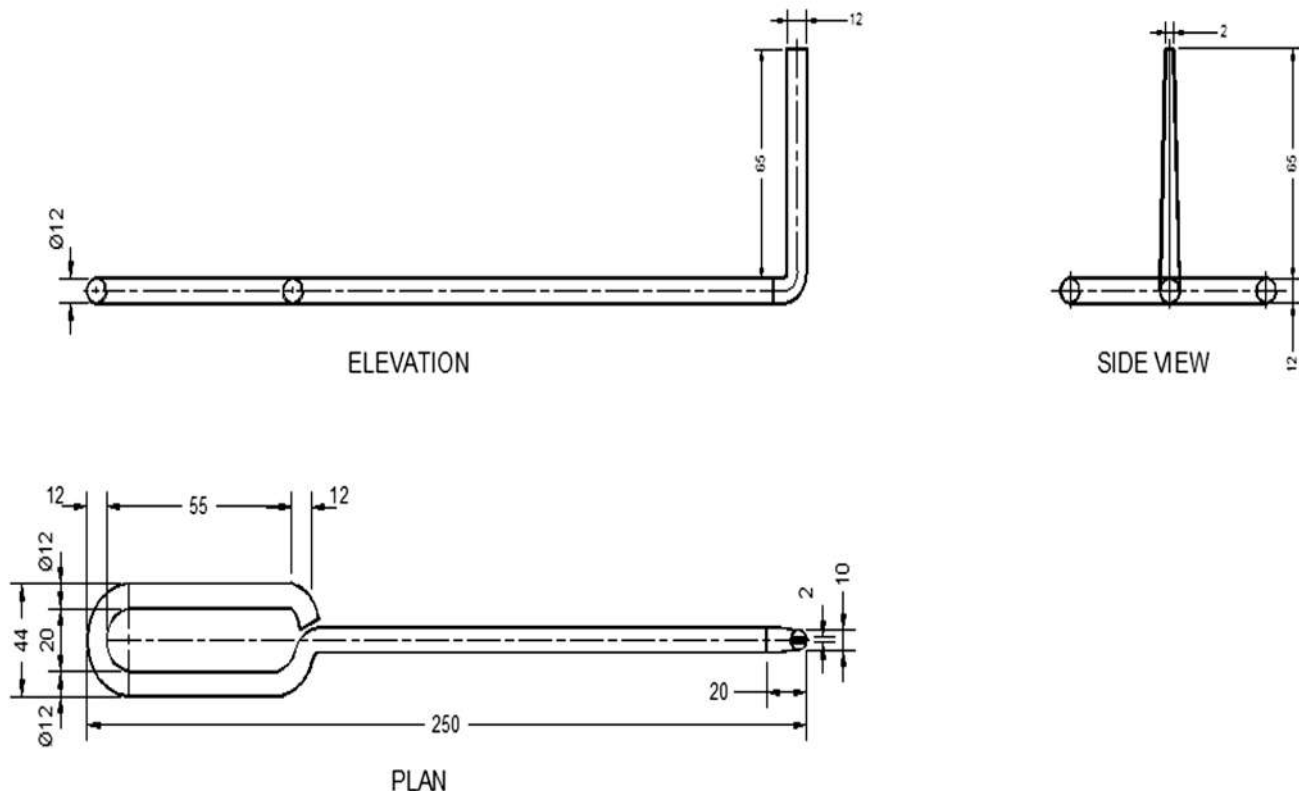


Fig. 12 Details of Raker

8.7.3 Cold applied sealants like, polysulphide/silicone/polyurethane or other similar material may be used as per IRC:57. These shall be mixed and applied within the time limit specified by the manufacturer. If primer is recommended it shall be applied neatly with an appropriate brush after cleaning the grooves/cut portion with compressed air. The Movement Accommodation Factor (MAF) shall be ± 10 per cent for bituminous sealant ± 25 per cent for poly sulphide sealant and for silicon sealant it shall be in the range of - 50 per cent to + 100 per cent. Silicon sealant can be compressed to its 50 per cent size whereas it can be stretched to 100 per cent without any change in the volume of sealant.

8.7.4 Movement Accommodation Factor (MAF) is defined as:

$$= (-) \frac{(\text{Compressed Width} - \text{Original Width}) \times 100}{\text{Original Width}}$$

$$= (+) \frac{(\text{Expanded Width} - \text{Original Width}) \times 100}{\text{Original Width}}$$

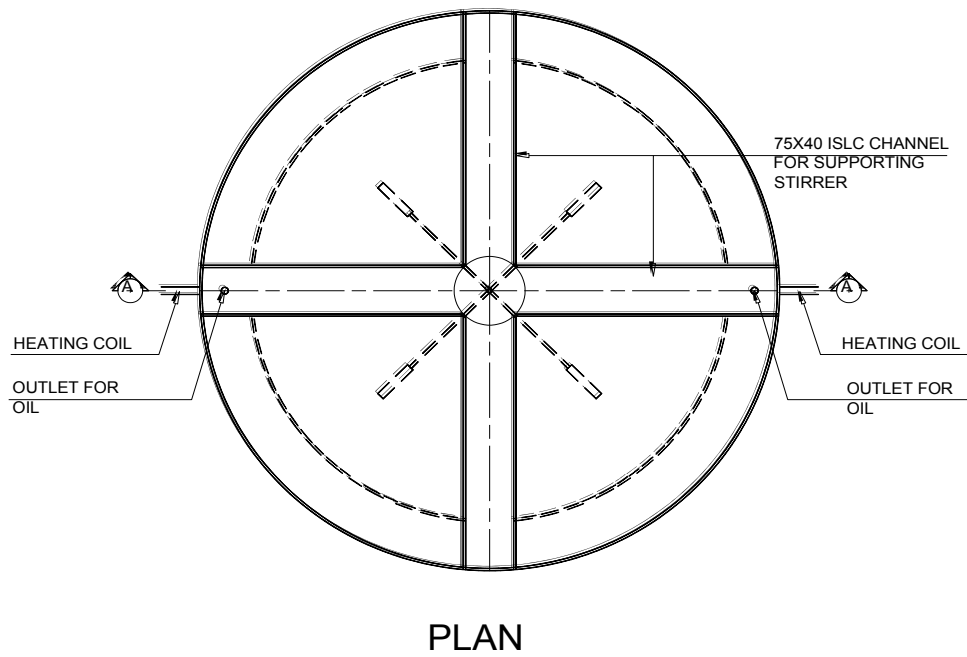
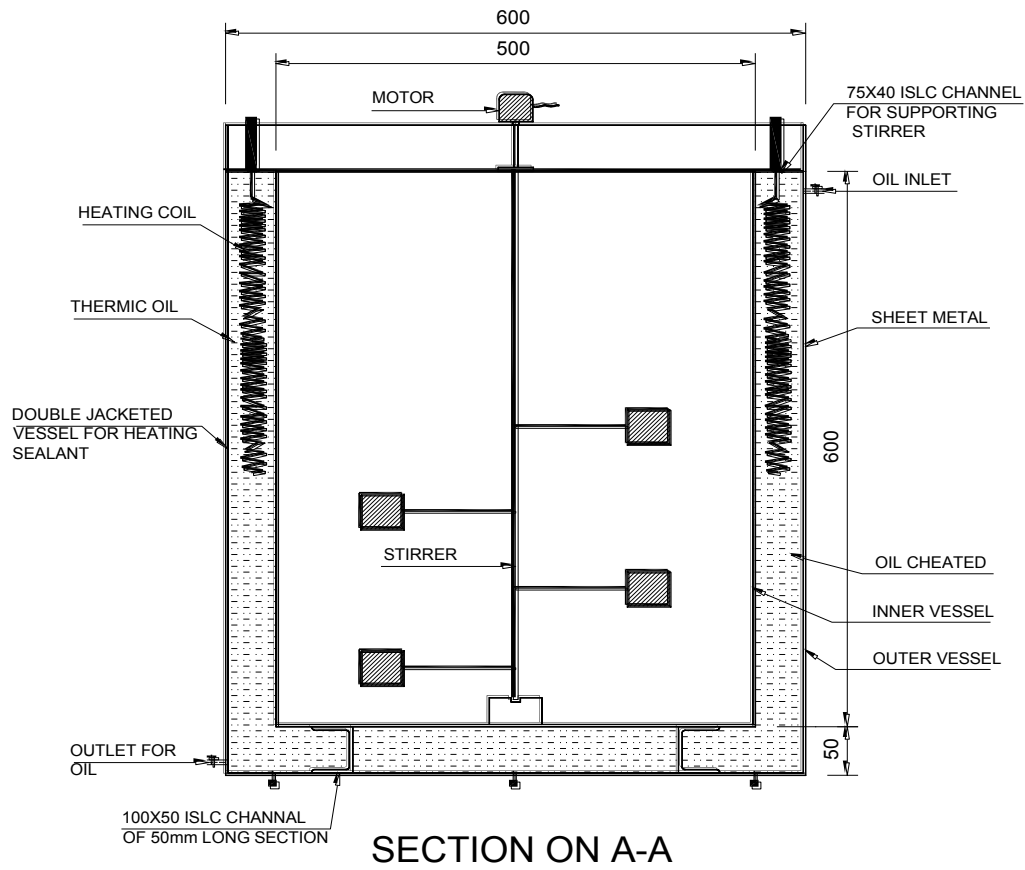


Fig. 13 Schematic View of a Sealant Melter

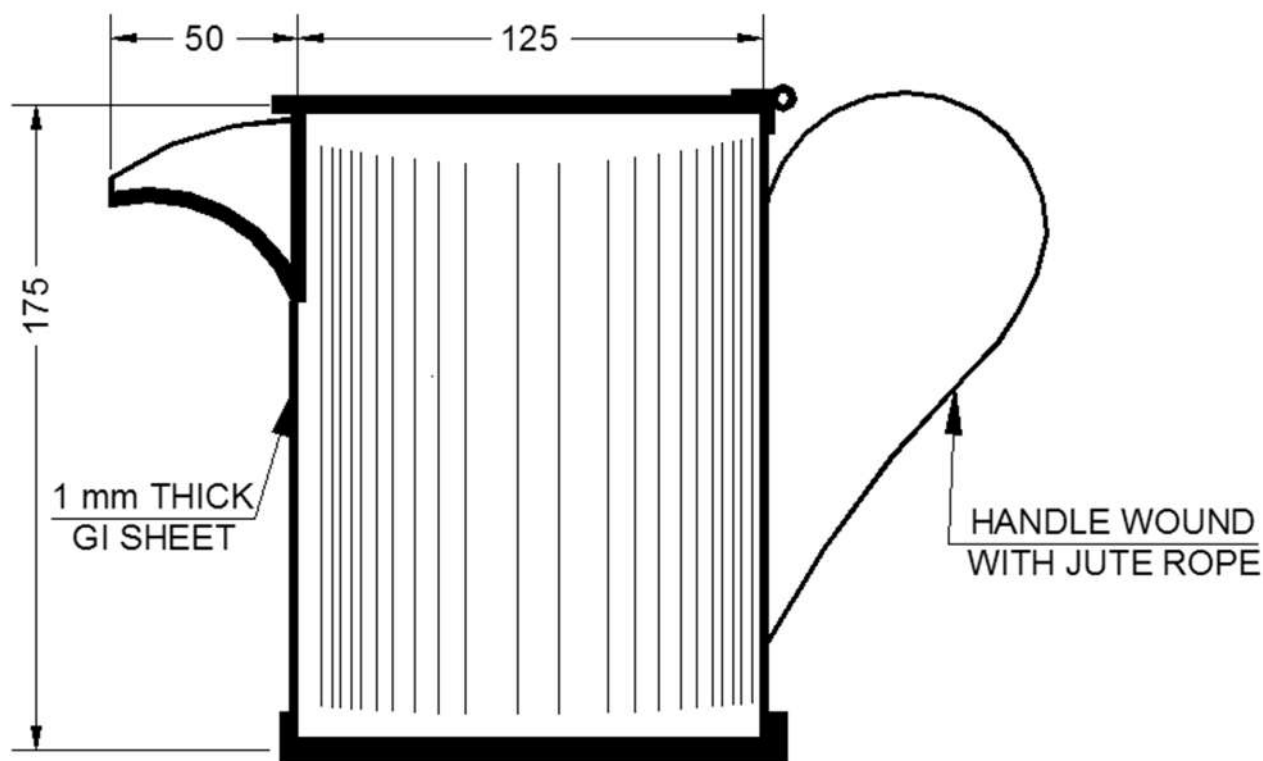


Fig. 14 A Pouring Kettle for Hot Poured Sealant

8.7.5 The groove configuration is different for poly-sulphide, silicone and polyurethane. Silicone, hardens by absorbing moisture from the air and hence it should be placed in a thinner layer vis-à-vis primer based poly-sulphide. Accordingly, the depth/width ratio of grooves should be modified. Besides the curing time of silicone is more than that of poly-sulphide.

8.7.6 The sealants applied during 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 as per manufacturer instructions.

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

8.7.8 During sealing operation, it shall be ensured that no air bubbles are introduced in the sealant either as vapours or voids by the sealing process.

8.7.9 Preformed/premoulded neoprene seals shall not be used for sealing the joints as these can be very easily removed/stolen from the joint. Where there are no chances of theft like internal roads in premises, these seals can be permitted. **Figs. 12 to 14** show the appliances used for joint sealing as per IRC:57 and IRC:43.

9. STORAGE AND HANDLING OF MATERIALS

9.1 General

A systems approach may be adopted for construction of the pavement. The Method Statement for carrying out the work, detailing all the activities including indication of time-cycle for 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 so that 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, cement is normally stored in large capacity horizontal/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.

9.2.2 Supply of cement should be co-ordinated such that its long period of storage is avoided. Its procurement and consumption should be planned so that it is not stored right through the rainy season. 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. Any cement stored more than 3 months, or more than 6 weeks during monsoon, shall be tested for its acceptance and also for revalidation of mix design.

9.2.3 Owing to the slightly deliquescent nature of rapid hardening cement and 53 grade 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 subjected to the approval of the Engineer. Aggregates stock piles may be made on ground if it is denuded of vegetation, levelled, compacted with good quality soil sub-base material and well drained. Aggregates near the bottom of the heap may get mixed with soil and shall not be used without washing. Aggregates from different sources and/or of different grading shall not be stacked together. Each 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 get blown away easily; it may be helpful to moisten the aggregates stacked in heaps on the ground.

9.3.3 Sufficient quantity of aggregates should be available in stock so that there is adequate supply of requisite aggregates is available. Stock piling aggregates for use beyond 2-3 months should be done cautiously as it is likely to be contaminated with dust and foreign matter.

9.3.4 The aggregates shall be handled from 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 a calibrated and approved weigh-batching plant and placed into the hopper of the mixer along with the necessary quantity of cement.

10. CONSTRUCTION

10.1 Fully Mechanised Construction

10.1.1 General

The batching plant shall include minimum four bins, weighing hoppers, and scales for the fine aggregate and for each size of coarse aggregate. More bins may be required to handle mineral admixtures like fly ash, GGBFS and also different types of sand like fine, coarse and crushed etc. 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. The batch mixing plant and concrete production shall be confirming to the requirements of IS:4929 and IRC:SP:96.

10.1.2 Bins and hoppers

Bins with minimum four numbers of adequate separate compartments shall be provided in the batching plant.

10.1.3 *Automatic weighing devices*

Batching plant shall be equipped to proportion aggregates and bulk cement by means of automatic weighing devices using load cells.

The batching plant shall have facility for adding at least two admixtures in the mixing pan.

The discharging mechanism shall have appropriate chutes, down pipes, etc. so that the discharged mix will not get segregated.

10.1.4 *Control Cabin*

An air-conditioned centralised control cabin shall be provided for automatic operation of the equipment.

10.1.5 *Batching by weight only is recommended.*

10.1.6 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 shall not normally be carried beyond 15 km of lead on a maintained road not requiring more than 40 minutes of travel time. Therefore, the location of the batching plant in a road project has to be decided carefully. The travel time from plant to construction site should be considered while designing the concrete mix for loss of slump during travel.

10.1.7 *Mixing*

10.1.7.1 *General*

The mixing of concrete shall be done in a plant equipped with appropriate mixture 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.

10.1.7.2 *Mixers*

Generally mixers shall be pan type, reversible type with single or twin shaft or any other mixer capable of efficiently mixing the aggregates, cement, water and admixtures into a thoroughly mixed and uniform concrete within the specific mixing period, and discharging the mixture, without segregation. In twin shaft mixer, mixing time is normally very low (about 6 m³ may be mixed in 20-30 seconds). Hydrometers for the measurement of the density of the admixtures shall be available at site. 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 for 60 seconds. 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 or whenever mixing is suspended for about an hour or more. The pickup and throw-over blades in the drum or drums shall be repaired or replaced when they are worn down by 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 for the each ingredient up to its maximum quantity being used in the mix at site in the beginning and thereafter at suitable interval not exceeding one month.

10.1.7.3 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.

10.1.7.4 The mixer shall normally be equipped with a 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.

10.1.7.5 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.

10.1.7.6 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.

10.1.7.7 The sequence of loading shall be coarse aggregates, fine aggregates, cement, fly ash/GGBFS or any other such mineral admixture if used. After dry mixing, water will be released from venture-meter. The superplasticizer mixed with the recommended percentage of water shall be added in the last. The quantities are to be programmed in the computer accordingly.

10.1.7.8 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.

10.1.8 *Time of Mixing*

The mixing of each batch will continue for 60 seconds 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.

10.1.9 *Retempering*

The retempering of concrete, i.e., remixing of concrete stiffened due to delay in placement with or without additional cement, aggregate or water shall not be permitted.

10.1.10 *Hauling of Concrete*

Freshly mixed concrete from the central batching and mixing plant shall be transported to the paver site by means of trucks/tippers of sufficient capacity in adequate numbers to ensure a constant supply of concrete. Tarpaulin covers shall be used for protection of concrete against the weather. The tipper trucks 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 day's work.

10.1.11 *Placing of Concrete*

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 90 minutes when the concrete temperature is more than 25 °C. If possible, 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.

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/metering gate and a screw auger device/plough 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.

10.1.12 *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 spray curing compound on 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 design and specifications. The paver shall be equipped with electronic sensors to pave the slab to the required thickness, camber, grade and alignment in the case of slip form pavers.

10.1.12.1 Paver shall have a dowel bar inserter to place the dowel bars at the time of laying of concrete. Dowel bar inserter should be capable of holding the dowels properly while inserting them. Insertion mechanism shall ensure proper consolidation of concrete around the inserted bars. If paver with dowel bar inserter is not available then dowels may be placed on baskets/dowel support chairs fabricated as per **Fig. 15**.

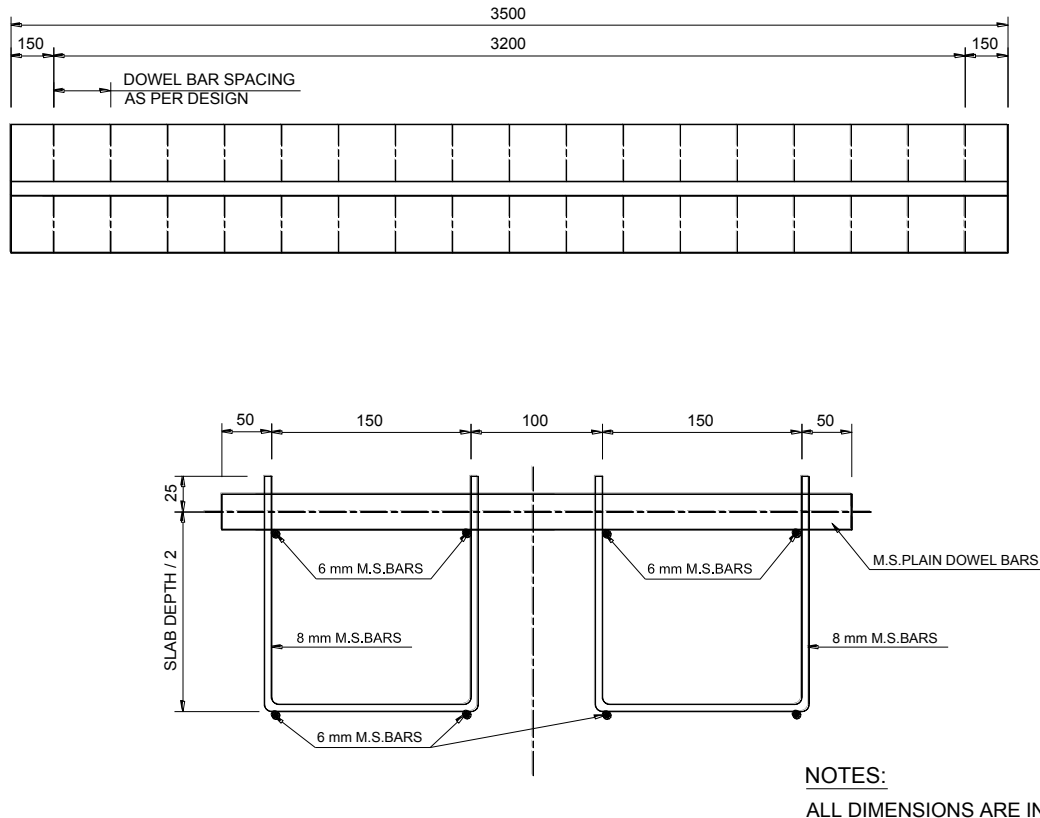


Fig. 15. Steel Chair for Supporting Dowel Bars

It is very important to check the position and alignment of placed dowels to control any joint failure in future. The alignment of dowel bars should be assessed using Magnetic Pulse Induction (MPI) device as per ASTM E3013/E3013M – 15. The MPI device can check efficiently and accurately the dowel alignment within few hours of concrete placement. The engineer should check the MPI report of each joint in the beginning to locate the joints of possible failure and correct them at the earliest. Later on if the engineer is satisfied with the MPI report, the checking frequency may be reduced to 25 per cent of joints.

10.1.12.2 Use of Guidewires

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.

10.1.12.3 The guidewires shall be supported on stakes not more than 6 m apart by connectors capable of fine horizontal and vertical adjustment. The stake to stake distance in case of paving at curve shall suitably be decreased. The guidewires shall be tensioned on the stakes so that a 500 gm weight shall produce a deflection of not more than 20 mm when suspended at the midpoint between any pair of stakes. The ends of the guidewires shall be anchored to fixing point or winch and not on the stakes.

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

10.1.12.5 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 also 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.

10.1.12.6 *Use of 3D Pave System (String less Paving)*

Instead of using guidewires, the concrete should preferably be paved with slip form pavers fitted with latest 3D Pave system based on Total Station. This system ensures very high level of accuracy in elevation, slope, automatic steering of the paver, and better riding quality.

10.1.13 *Construction by Slip Form Paver*

10.1.13.1 The slip form paving train (**Fig. 16**) shall consist of self-propelled paver machine (2/3/4 Tracks) 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.

10.1.13.2 The level of the conforming plate and finishing beams shall be controlled automatically from the guidewires installed as per **Clause 10.1.12.2** by sensors attached at the four corners of the slip form paving machine. The alignment of the paver shall be controlled automatically from the guidewires 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 guidewires or to the surface and edge of an adjoining hardened slab.

10.1.13.3 Slip form paving machines shall have vibrators of variable frequency and power, 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 up to 1.5 m per minute. 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.

The vibratory trails are resulted when vibrators vibrate at a very high frequency. To avoid vibratory trails, the frequency of vibrators should be adjustable in the range of 8000 to 10000 HZ at a paving speed of 0.8 to 1.0 m/minute.

The paver should have a vibrator sensing system to provide a real time readout of vibration frequency for all of the vibrators and to give an alarming signal to the operator in case of high or low frequencies or total loss of vibration. The variable vibration setting shall be provided in the machine. Hand held device may also be used for checking the vibration periodically.



Fig. 16. A View of Slip Form Paving Train

10.1.13.4 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.

10.1.13.5 The pace of construction of slabs shall desirably not be less than 0.5 to 1 m per minute. The capacity of the batching plant should be sufficiently more than this requirement so that the paver remains in motion without stoppage for want of mix. This factor is essential for achieving better riding quality.

10.1.14 Surface Texture**10.1.14.1 Tining**

After final floating and finishing of the slab and before application of the liquid curing membrane preferably two coats, the surface of concrete slabs shall be textured either in the transverse direction (i.e., at right angles to the longitudinal axis of the road) or in longitudinal direction (i.e., parallel to the centerline of the roadway). The texturing shall be done by tining the finished concrete surface by using rectangular steel tines. A beam or a bridge mounted with steel tines shall be equipped and operated with automatic sensing and control devices from main paver or auxiliary unit. The tining unit shall have facility for adjustment of the download pressure on the tines as necessary to produce the desired finish. The tining rakes shall be cleaned often to remove snots of slurry. The tines will be inspected daily and all the damaged and bent tines shall be replaced before commencing texturing. Tined grooves shall be 3 mm wide and 3 to 4 mm deep. Before commencing texturing, the bleeding water, if any, shall be removed or allowed to disappear and texturing shall be done on a firm surface. The measurement of texture depth shall be done with depth measuring gauge/device.

(a) Transverse Tining:

When the texturing is specified in transverse direction, a beam of at least 3 m length mounted with tines shall be moved in transverse direction to produce the texture. The grooves produced shall be at random spacing of grooves but uniform in width and depth. The spacing shall conform to a pattern shown below:

Random spacing in mm

10 14 16 11 10 13 15 16 11 10 21 13 10

The above pattern shall be repeated. Texturing shall be done at the right time such that the grooves after forming shall not close and they shall not get roughened. Swerving of groove patterns will not be permitted. The completed textured surface shall be uniform in appearance.

(b) Longitudinal Tining

Longitudinal tining shall be done, if specified in the Contract. The texturing bridge shall be wide enough to cover the entire width of the carriageway but within 75 mm from the pavement edge. The centre to centre spacing between the tines shall be 18 to 21 mm. The width of tine texture shall be 3 mm and depth shall be 3 to 4 mm.

10.1.14.2 Brush Texturing

Alternatively, the brush texturing may be applied. 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 normally of 3 m length are preferred. The brush shall be made of 32 gauge tape wires grouped together in tufts placed 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 long.

The texture depth shall be determined by the Sand Patch Test. This test shall be performed at least once for each day's paving and wherever the Engineer considers it necessary at times after construction 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. After the application of the brushed texture, the surface of the slab shall have a uniform appearance.

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.

Table 9 Texture Depth

Sl. No.	Time of Specified Tolerance	Number of Test Measurements	Texture Depth (mm) Required	
1.	Between 24 hours and 7 days after the construction of the slab or until the slab is first used by vehicles.	An average of 5 measurements	1.00	±0.25
2.	Not later than 6 weeks but before the road is opened to public traffic.	An average of 5 measurements	1.00	+0.25 -0.35

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

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

10.1.14.3 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 $31000/(D \times D)$ mm where D is the diameter of the patch in mm.

10.2 Semi-Mechanised Construction Technique

10.2.1 *General*

Use of very sophisticated paving machines and high capacity concrete batch mixer may not be possible in every road projects and also in remote hilly terrains or near bridge structures. The concrete roads can be constructed using semi-mechanised but the resulting quality and surface may not be the same as achieved with mechanised constructions and shall be allowed in case of exceptional circumstances.

10.2.2 *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. Fixed forms shall be at least 100-150 m length.

10.2.3 *Steel Forms*

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 of steel forms 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 3.5 m except in the case of installations along curves.

If the channel depth required is other than the standard rolled sections available, it shall be fabricated. The channel section or steel forms shall have fixing arrangement to keep them in position and enable to resist horizontal pressure of concrete.

10.2.4 The sections shall have a length of at least 3 m except on curves of less than 45 m radius, where shorter lengths 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 pickets 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.

10.2.5 The supply of forms shall be sufficient to permit their remaining in place for minimum 12 hours after the concrete has been placed. Any unevenness in the form work particularly the top will affect riding quality. After removing the form, the edge shall be protected from damage till concrete attains enough strength.

10.2.6 *Setting of Forms*

The forms shall be jointed neatly and shall be set with exactness to be required grade and alignment. Both before and after the forms are placed and set, the 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 2 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.

10.2.7 *Placement of Steel*

In placing reinforcing steel, the portion of concrete below 50-60 mm 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.

10.2.8 *Tools, Plants and Equipment*

The requirements of concrete quality in road construction being large which again is to be supplied continuously, the mixes are normally to be produced from mixers. The plants and equipment considered essential even in semi-mechanized construction are:

- (i) A couple of tilting type drums 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 days work.
- (ii) Vibrating screeds for tamping and compacting pavement surface. These are moved on the leveled fixed forms or side forms to achieve the required smoothness, grade and surface regularity.
- (iii) A couple of needle vibrators. Alternatively, fixed pavers fitted with vibrators and finisher can also be used.
- (iv) Concrete-saw-this is required for forming contraction joints in a continuously constructed lane.

- (v) Hand held sprayer for applying liquid curing compound at least 10-20 kg capacity container/tank.
- (vi) Texturing broom
- (vii) Straight edges of 3 m length.
- (viii) Appropriate tools for sealing joints.
- (ix) Stop-end and start-end made of steel or wooden sections or bulk heads. These gadgets are required for commencing and stopping paving activity.

10.2.9 *Hauling of Mix*

Transporting of concrete mix from mixer to paving site with steel pans is not permitted. Only wheel-barrows or trolleys are to be used for carrying mix to the paving site. The workability of the mix can be controlled better with the use of wheel-barrows.

10.2.10 *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 redistribution 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 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.

10.2.11 *Compaction*

Where semi-mechanized technique is adopted, compaction of the pavement shall be accomplished by a vibrating screed supplemented by plate/internal vibrators. For slabs of thickness more than 125 mm, vibrating screeds may be supplemented by 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 to the adjacent strip of un-compacted 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 and closed surface is obtained. Compaction of concrete slabs up to 125 mm thickness may be done by means of vibrating screed alone. Even in the case of

slabs of lower thickness, internal vibrators may be used with advantage of 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.

10.2.12 *Floating*

As soon as practicable after the concrete has been compacted, its surface shall be smoothed 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. This process may also be carried out in slip form or fixed form paving method.

10.2.13 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 1:4 cement and 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 up to the nearest transverse joints.

10.2.14 *Straight Edging*

After the longitudinal floating has been completed, the excess water has disappeared, and while the concrete is still plastic and before it begins to set, the slab surface shall be tested for trueness with a 3 m straight edge and graduated wedge gauge. 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 40-50 mm, 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.

10.2.15 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.

10.2.16 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.

10.2.17 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 is to be removed which has already hardened.

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

10.2.19 *Texturing*

Just before the concrete becomes non-plastic, the surface shall be textured by tining with appropriate machine.

10.2.20 *Edging*

After tining 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 arising 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.

10.3 Construction by Semi Mechanized Fixed Form Paving Train

In this case, laying of PQC is similar to semi-mechanised construction technique, however, the paving train moves on the rails fixed on both sides of the road and compaction/finishing is simultaneously carried with the equipments fitted with paving train which moves on the rails. The method of texturing, curing, joint cutting is also similar to semi mechanised construction. The fixed form paving train therefore, shall consist of separate powered machines which spread, compact and finish the concrete in a continuous operation. A fixed form paver essentially should have following features:

- It should have power arrangement for its forward movement.
- It moves either on side steel forms firmly fixed to the sub-base or on rails fixed on both sides of the forms.
- It should have augurs for spreading, needle vibrators for compacting and roller for finishing the concrete surface. The roller may also have vibration during rolling the concrete surface.

A typical fixed form paver fitted with vibrators and a roller for finishing is shown in **Fig. 17**.



Fig. 17 Fixed Form Paver with Vibrators and Roller

10.3.1 *Side Forms, Rails and Guidewires*

All side forms or rails shall be of mild steel of suitable depth so that desired depth of PQC is obtained. 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.

10.3.2 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. **Fig. 18** shows the plan and elevation of side forms laterally supported by bracings.

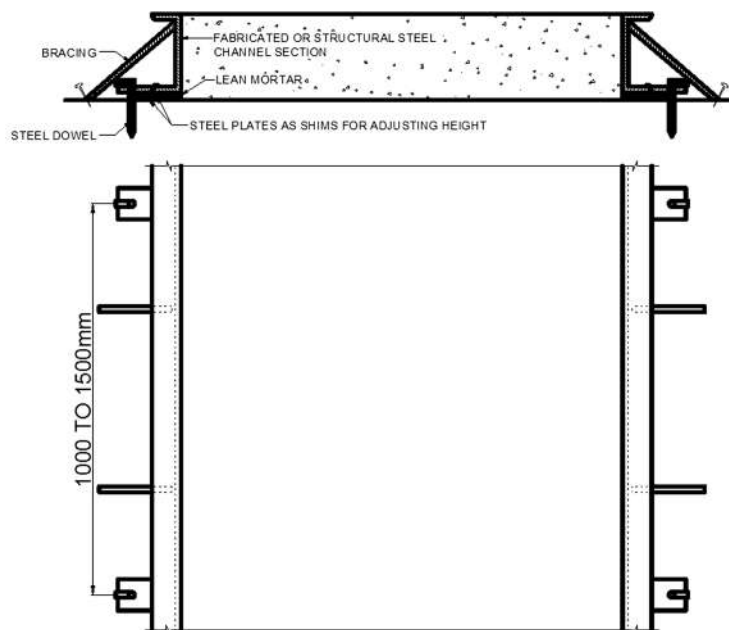


Fig. 18 Plan and Elevation of Side forms Laterally Supported by Bracings

10.3.3 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 5 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 12 hours before the construction of the slab and just prior to concreting. The form shall be removed when concrete has hardened to the extent to bear the weight of cutting machines and crew.

10.3.4 At all times, sufficient forms/rail shall be used and set to the required alignment for at least 150 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.

10.3.5 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.

10.3.6 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.

10.4 Longitudinal Joint with Shoulder

This is one of the critical areas which is generally not given proper attention. 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. In case of tied shoulder, the earth near the edge of the shoulder should be well compacted so as to minimize the entry of water. It is desirable to provide well compacted granular material in a width of 500 mm on edges of tied shoulder.

10.5 Laying of Concrete over Existing Pavement

When concrete pavement is laid over an existing bituminous pavement which is known white-topping, it shall be ensured that the existing road extends over the required width and has a minimum thickness of 150 mm and shall be laid as per IRC:SP:76. Where the general unevenness/rutting 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 details are given in IRC:SP:16/IRC:SP:76. 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.

10.6 Widening of Existing PQC

Whenever the widening of existing PQC is undertaken by the addition of lanes, the thickness of PQC, DLC, and GSB layers should be kept same as that of existing layers in order to drain off the water across the pavement surface as well as through GSB drainage layer.

Tie bars as per the design recommendations for widening PQC shall be installed all along the longitudinal joint between existing and widened PQC. Using hydraulic or electrical drilling machine with tungsten carbide bit, holes of diameter 2 mm more than the designed diameter of tie bars are drilled at mid depth of the existing PQC on its vertical face. The depth of the hole shall be half the length of the tie bar. The holes shall be cleaned properly with compressed air to remove all dust or dirt from inside the hole. Resin based epoxy shall be injected into the full depth of the hole. Afterwards, the tie bar is inserted into the hole till end with a revolving motion and held for some time to develop a grip on setting of the epoxy. The extra oozed out epoxy from the hole shall be wiped off the surface.

While laying PQC, the levels of the edge of existing PQC shall be followed for matching the longitudinal joint between the existing and freshly laid PQC.

All the transverse contraction, construction and expansion joints of the widened PQC with dowel bars provided as per the design shall be aligned exactly in line with the joints of existing PQC.

The illustrative photographs for PQC widening are given in **Appendix A**.

10.7 Transition Slab between Rigid and Flexible Pavement

10.7.1 At the interface of rigid and flexible pavement, at least 4 m long reinforced transition slab with anchor beam should be provided to give a long lasting joint at the interface. The details of transition slab are shown in **Fig. 19**. **Fig. 20** shows the sealing details of longitudinal joint between cement concrete slab and bituminous shoulder.

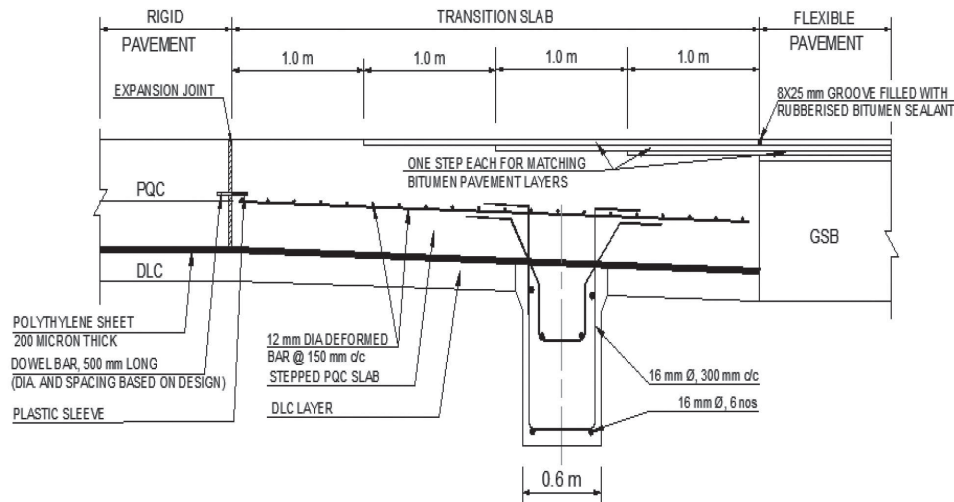


Fig. 19 Typical Details of Transition Slab Between Rigid and Flexible Pavement

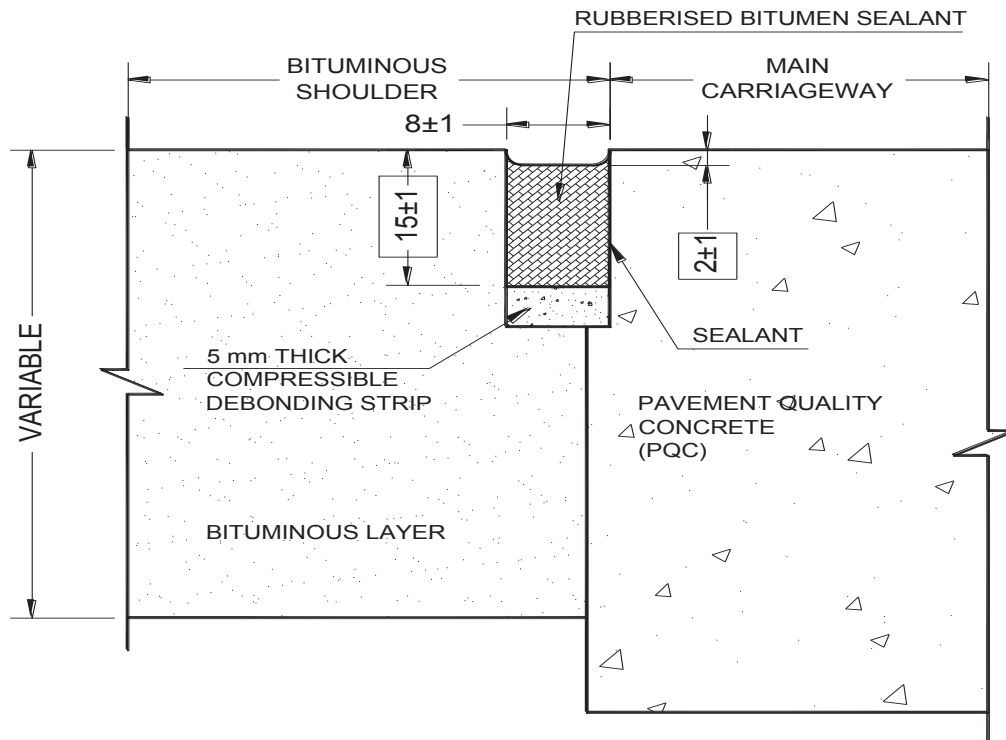


Fig. 20 Sealing Details of Longitudinal Joint between Cement Concrete Slab and Bituminous Shoulder.

10.7.2 In the curve portion of radius less than 45 m, the spacing between contraction joints shall be closer than the normal spacing. The slabs at the critical sections like curve portion, underpasses, steep gradient and the slabs having manhole cover with-in itself, slab having length/breadth ratio more than 1.5 shall be reinforced with 12 mm dia bars at spacing of 150 mm c/c at a depth of 50-75 mm from the top surface.

10.8 Curing of Concrete

10.8.1 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 with moist curing by wet hessian may be allowed. Curing compound shall be resin based aluminized reflective type.
- (ii) The curing can be done by manual methods using wet hessian which is kept moist during curing period in exception for small part of the works. Curing shall be done for a minimum period of 14 days. In case of blended cement curing shall be done for 16 days.
- (iii) 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.

10.8.2 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 aluminized reflective curing compound or white pigmented curing compound which hardens into an impervious film or membrane with the help of a mechanical sprayer.

10.8.2.1 Curing compounds shall contain sufficient flake aluminum 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. The curing compounds shall have a water retention efficiency index not less than 90 per cent in accordance with BS Specification No.7542 or as per ASTM C-309-81 Type 2B.

10.8.2.2 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 the curing compound, the fresh concrete surface shall be protected for at least 3 hours by covering the finished concrete pavement with tents supported on mobile truss during adverse weather conditions. After two or 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 14 days after which time the hessian may be removed. During the curing period, the hessian shall be kept continuously moist. All damaged/torn hessian shall be removed and replaced by new hessian on a regular basis. To check the rate of spreading of curing compound, a blank paper 1 m x 1 m can also be placed on PQC while curing compound is being sprayed, and hence the quantity of curing compound may be checked in the field.

10.8.3 *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 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 sufficiently heavy so 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. The rate of evaporation of water from the PQC shall not be more than 1 kg/sq m/hour to avoid plastic or shrinkage cracking.

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

10.8.3.2 Covering shall be placed from suitable wooden bridges (IRC:43). Walking on freshly laid concrete to facilitate placing coverings or any other use which could be otherwise done without using the freshly laid concrete at least upto 28 days will not be permitted to maintain the texture depth provided.

10.9 **Concreting during Monsoon Months**

Concreting when it is raining is not recommended. However, under unavoidable situation, when concrete is being placed during monsoon months or during the period when it may be expected to rain, sufficient supply of tarpaulins or other waterproof cloth shall be provided along the line of the 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 damage by rain shall be removed and replaced. Any damage caused to the surface or texture shall be corrected as decided by the Engineer. All other precautions recommended before for concreting in hot or cold weather shall be adhered to as far as applicable.

10.10 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 gradient. The concrete mix shall be stiffer than that used on level reaches. In case of very steep gradient, or where filled-up areas/very weak subgrade is there, reinforcement in single layer or in two layers in the PQC may be provided. Slump of concrete mix in such situations shall be about 20 mm or adjusted from field trials. On horizontal curves the separation layer in the form of polythene sheet/geotextile should be avoided to prevent the sliding outward of the slabs due to centrifugal force. On such curves, DLC should be roughened and cement slurry of proportion 1:1 cement:sand mortar should be applied over it before placing PQC to create a bond between DLC and PQC. The joints in DLC should be co-terminus with those proposed in the PQC. The joints in DLC should be sealed with bituminous sealant.

10.11 Protection of Concrete

Suitable barricades and sign boards 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 provision, 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.

10.12 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. The pavement shall be protected against all traffic usage including that of construction vehicles. Construction traffic may be allowed after 21 days of paving with written permission of the Engineer. However, it is preferable to open after 28 days of curing.

11 TRIAL LENGTH

11.1 The trial length shall be constructed at least one month in advance of the proposed start of concrete paving work. 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, texturing and curing machines etc., proposed in the construction and got approved by the Engineer before their procurement. No trials of

new materials, plant equipment or construction methods, or 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 approved trials. These trial lengths shall be constructed away from the carriageway but with at least a sub-base layer stipulated below it.

11.2 The trial length of slab shall be at least 60 m for mechanized construction and at least 30 m long for semi-mechanized construction.

11.3 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 mechanized construction and a minimum of 15 m on each day for semi-mechanized construction. The trial length shall be constructed at a similar rate to that which is proposed for the main work. Minimum of 30 beams for flexural strength 30 cubes if desired by the Engineer for the purpose of co-relation shall be cast. At the age of 28 days, 30 cores with diameter 150 mm shall be saw cut from the slab. The cores shall be saw cut in both ends to provide a specimen height of 300 mm \pm 5 mm and shall be tested for compressive strength at the age of 28 days. The test results of beam, cube and core shall conform to **Clauses 12.8.1, 12.8.2 and 12.21**.

Consolidation of concrete around the dowel should also be checked by taking few random cores above the dowel bars. If lack of proper compaction is detected by the honey-combing in the cores then the paver setting should be checked and problem be resolved to the satisfaction of the Engineer.

11.4 Transverse joints and longitudinal joints of each type (i.e contraction, construction, expansion) that are proposed for dowel-jointed unreinforced concrete slabs in the main work shall be constructed and assessed in the trial length.

11.5 Acceptance Criteria of Trial Length and Normal Construction

The trial length shall comply with the Specification in all respects, with the following additions and exceptions including strength criteria as per **Clauses 12.8.1, 12.8.2 and 12.21**. A detailed report shall be prepared and got approved by the Engineer.

11.5.1 *Surface levels and regularity*

- (i) In checking for compliance, the levels shall be taken at intervals at the locations specified in **Clause 12.14** 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 specified requirements. Shorter trial length shall be assessed pro-rata based on values for a 300 m length as per IRC:SP:16.

11.5.2 *Alignment of Dowels*

(i) Alignment of dowel bars shall be inspected at all of the transverse joints in a trial length construction by using Magnetic Pulse Induction (MPI) device as per ASTM E3013/E3013M – 15. The acceptance criteria for dowel placement shall be the following:

- Horizontal or vertical rotational alignment : ≤ 10 mm over 500 mm
- Longitudinal side shift : ≤ 50 mm over 500 mm
- Depth : Mid-depth ± 25 mm

Alignment of dowel bars may also be inspected in any two consecutive transverse joints in a trial length construction by removing the fresh concrete in a width of 0.5 m on either side of the joint. The joint pit shall be refilled with freshly prepared concrete, after inspection.

If the position or alignment of the dowel bars at one of these joints does not comply with the requirements and 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.

11.5.3 *Density*

Density shall be assessed from at least 3 cores drilled from each part of the trial length. Voids in the cores shall not be more than 3 per cent.

11.5.4 *Position of Tie Bars*

Compliance for the position and alignment of tie bars shall be checked by using Magnetic Pulse Induction (MPI) device as per ASTM E3013/E3013M – 15.

11.5.5 *Position of Dowel Bars*

11.5.5.1 Compliance for the position and alignment of dowel bars at transverse joints in normal construction work shall be checked randomly at 25 per cent of the joints by using Magnetic Pulse Induction (MPI) device as per ASTM E3013/E3013M – 15.

11.5.5.2 *Rejection Criteria*

The alignment of dowel bars should be checked using Magnetic Pulse Induction (MPI) device as per ASTM E3013/E3013M – 15. The engineer shall check the MPI report of the joints to locate the joints of possible failure due to locking of joint in advance and correct them at

the earliest. If more than half of the dowel bars at a joint do not meet any of the acceptance criteria mentioned in **Clause 11.5.2**, then the joint shall be treated as a locked joint and rejected. Such locked joints shall be reconstructed using Full Depth Repair (FDR) method as per IRC:SP:83. The joint having any bar misaligned by more than 38 mm shall be rejected.

11.5.5.3 However, if MPI device is not available then the position and alignment of dowel bars and any filler board shall be measured after carefully exposing them in one meter width 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 tolerance.

11.5.5.4 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 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 bars position and alignment are satisfactory.

11.6 Approval

11.6.1 Approval of the materials, plant, equipment and construction methods shall be given after the trial length complies with these Specifications. Normal working shall not be taken up until the trial length has been approved.

11.6.2 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, and 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.

11.6.3 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.

11.6.4 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.

11.7 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. If final set of concrete has started then within half hour of exposure, the dowels shall be inserted on both sides of the 1 m wide concrete 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. Alternatively, 20 mm holes shall be drilled on both faces of the cut to a depth of 250 mm @ 350 mm c/c. The holes shall be air cleaned. 16 mm dia deformed tie bars shall be inserted with epoxy resins. The dowel bars assembly will be reset after rectification if any and the cut shall be concreted. A regular construction joint will be cut and sealed as per IRC:57.

11.8 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 mechanized method and 6 mm for semi-mechanised construction or fixed form construction. Any spots higher than the correct surface as prescribed above, shall be ground down with an approved scabblers/grinding tool to the required level and textured by cutting grooves on the surface.

12 QUALITY CONTROL

12.1 Sampling and Testing

Samples from fresh concrete shall be taken as per IS:1199 and cube and beam specimens shall be made, cured and tested at 28 days as per IS:516.

12.2 The minimum frequency of sampling of concrete shall be one sample per 150 m³ (or part thereof) of concrete. Each sample shall comprise of 3 test specimens of beams. These shall be tested for 28 days strength. Engineer may also get cube specimens cast at the rate of 3 such specimens per sample, as in case of beam for each 150 m³ (or part thereof) of concrete for his reference, record and possible use for co-relation purposes. However, test pertaining to beams shall govern. For each day's work, number of specimens shall not be less than six beams, taken out of 2 different batches of concrete. Additional six cubes may also be got cast for reference, record and co-relation, if desired by the Engineer.

12.3 The test results of the sample shall be the average of the strength of three specimens, comprising the sample. The individual variations of any specimen (beam/cube/core) shall not be more than ± 15 per cent of the average (of the three specimen comprising the sample).

12.4 Flexural strength shall be used for quality control and for acceptance purposes. The flexural strength should be determined by modulus of rupture under third point loading as per IS:516. The preferred size of beam shall be 150 mm x 150 mm x 700 mm for the maximum size of aggregate of 31.5 mm.

12.5 It may, however, be ensured that the materials and mix proportions remain substantially unaltered during the daily concrete production. The water content shall be the minimum required to provide the agreed workability for full compaction of the concrete to the required density as determined by the trial mixes and the maximum free water cement or water cementitious material ratio shall be 0.40.

12.6 The ratio between the 7 and 28 day strength (**R**) shall be established for the mix to be used in the slab. This will be done at the time of initial design of mix. For this purpose, at least 6 specimen of beams shall be cast from each batch of concrete produced in the laboratory. Minimum 6 batches ensuring minimum 36 specimens of beams shall thus be cast cured and tested in the presence of Engineer. Out of the 6 specimens drawn from each batch, one specimen from each batch shall be cured and tested for 7 days strength and balance 5 specimen of each batch shall be cured and tested for 28 days strength. This will provide at least 30 specimens required to determine actual standard deviation of 28 days strength. The specimen of cubes may also be got cast as per procedure above if so desired for reference, record and co-relation. The value of 'R' shall be arrived by dividing the average strength of the 7 day specimens by the average strength of the 28 day specimens. The ratio 'R' shall be expressed upto three places of decimal. In case of urgency, accelerated curing methods may be adopted after approval of the Engineer-in-Charge.

12.7 If during the construction of the trial length or during some normal working, the average value of any four consecutive 7 day test results falls below the required 7 day strength as derived from the value of 'R' then the cement content of the concrete shall, without any extra payment, be increased by 5 per cent by weight. Whenever the cement content is increased, the concrete mix shall be adjusted to maintain the required workability. Cement shall be increased by 5 per cent in case of manual construction or construction in marshy/waterlogged areas.

12.8 Acceptance Criteria of Strength

12.8.1 Flexural Strength

The concrete will be said to comply with the specified flexural strength, when the following conditions are met with.

- i) The mean strength determined from any group of 4 consecutive samples (each sample containing 3 beam specimen i.e. $4 \times 3 = 12$ beam specimens) at 28 days should exceed the specified characteristic flexural strength by at least 0.3 MPa.
- ii) The strength of any sample is not less than the specified characteristic flexural strength minus 0.1 MPa.

12.8.2 Compressive Strength*

When both the following conditions are met, the concrete complies with the specified compressive strength;

- i) The mean strength determined from any group of 4 consecutive samples ($4 \times 3 = 12$ cubes specimens) at 28 days should exceed the specified characteristic compressive strength by 3 MPa.
- ii) The strength of any sample is not less than the specified characteristic compressive strength minus 1 MPa.

* Applicable for smaller projects, where design is based on compressive strength. In case of requirement, Falling Weight Deflectometer may be used for evaluation of load transfer capacity or for other parameters.

12.9 Desirable Properties of Pavement Concrete

For road work, the concrete should have sufficient workability to permit 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. The mix shall be compatible with the method of construction, equipments used and its design.

12.10 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, and difficulty in maintaining the concrete to its true profile on gradients and cross-falls, and a reduction in strength due to excessive water content. For fully mechanized construction the slump shall be 20 to 30 mm and 40 to 60 mm for semi mechanized and fixed form construction. On rising gradient slump should be around 20 mm.

12.11 Degree of Compaction

12.11.1 Particular attention should be paid in constructing concrete roads to the methods of compacting concrete. It is of the utmost importance from strength consideration that maximum compaction should be achieved without segregation and bleeding a. 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. Inadequate vibration or the compacting effort induces excess voids. The presence of 5 per cent air 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 admixtures/air entraining agents. The Engineer-in-Charge should, therefore, ensure 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 cores may be resorted to for confirming the efficacy of the vibrating effort.

12.11.2 The sides of the PQC which are honey combed/hungry surfaces shall be finished with 1:4 cement and mortar at w/c ratio 0.4.

12.11.3 *Voids in Concrete*

The voids in the concrete shall not be more than 3 per cent by volume of compacted concrete in any case.

12.11.4 The concrete represented by a core shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85 per cent of the characteristic compressive strength of the grade of concrete specified for the corresponding age as mentioned in IS:456. However, the individual core shall not have strength less than 75 per cent of the characteristic strength of concrete. Age factors shall not to be applied on cores while determining the strength.

12.12 Durability

Where soils are impregnated with deleterious salts in injurious amount, protection of concrete from direct contact with such soils may be achieved by providing a suitable capillary cut-off. 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 pozzolana or fly ash may be used. In all cases, concrete shall be well compacted, strong and dense. Pozzolanic admixtures like fly ash (upto 25 per cent) and GGBFS (up to 50 per cent) of cementitious material, Portland pozzolana cement or Portland slag cement may also be found useful in areas where alkali-reactive aggregates cannot be precluded from use in concrete road construction.

12.13 Resistance to Abrasion

The resistance of concrete to abrasion is normally very high when good quality hard aggregates are used. The use of rounded aggregates, which wear 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, use of silica fume as per IRC:114, and steel fibres as per IRC:SP:46 may reduce rapid abrasion. It has been established that with good quality concrete of compressive strength of the order of 40 MPa (corresponding flexural strength of the order of 4.5 MPa or greater as per IRC:44, good resistance to abrasion can be secured. Results would not be satisfactory when comparatively brittle materials, such as, flint are used.

12.14 Riding Quality

12.14.1 Producing regular surface of concrete for requisite riding quality 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 as well. The cement concrete mix should be of uniform consistency and such that when screeded it holds up to cross-falls and gradients without deformation, and yet is sufficiently workable at the edges of the slabs.

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

12.14.3 The surface should be checked regularly with a straight edge 3.0 m long after 6 to 12 hours of laying. Use of moving straight edge for checking surface regularity is recommended.

12.14.4 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.

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

12.14.6 All works performed shall conform to the lines, grades, cross sections and dimensions shown on the drawings or as directed by the Engineer, subject to the permitted tolerances described herein-after.

12.15 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 there from.

12.16 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 10**.

Table: 10 Tolerances in Surface Levels

Sl. No.	Layer Type	Tolerances
1	Subgrade	+ 20 mm - 25 mm
2	Granular Sub-base/WBM/WMM Layer	+ 10 mm - 10 mm
3	Dry Lean Concrete	+ 6 mm - 15 mm
4	PQC*	+ 5 mm - 6 mm

* This may not exceed – 8 mm at 0 – 300 mm from the edges

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

12.16.2 For checking compliance with the above requirements 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 out of 21 measurements (seven samples) shall be permitted to exceed the tolerance as above. This one measurement being not in excess of 5 mm greater than the permitted tolerance.

12.16.3 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.

12.17 Surface Regularity of Pavement Courses

The longitudinally profile shall be checked with a 3 meter 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 11**.

Table 11 Maximum Permitted Number of Surface Irregularities

Irregularity	Surfaces of Carriageways and Paved Shoulders			
	4 mm		7 mm	
Length (m)	300	75	300	75
No. of Surface Irregularities	20	9	2	1

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 wearing surface	5 mm in longitudinal profile and 4 mm in transverse profile. In case of transverse profile where the pavement has camber instead of unidirectional transverse slope a camber template shall be used in place of 3 m straight edge. Such situation is likely to be encountered in two lane rigid pavement.
For granular sub-base/base courses and Sub-bases under concrete pavements/DLC	10 mm

12.18 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 roll appears on the surface, and that with well-proportioned concrete; a satisfactory surface can be produced by standard methods of compaction. To remove the laitance roll, either a hollow light weight tube or long jute sheet (having high water absorption) fitted with TCM (Texturing and Curing Machine) is used. In case of tines, texture depth shall be measured with depth measuring gauge/device.

12.19 Effect of Chemical Admixtures on the Properties

12.19.1 An admixture is a material added in very small quantities to a concrete mix to improve some of its desirable properties. The types of admixtures considered here are air-entraining agents, accelerators, retarders, plasticizers and superplasticizers.

12.19.2 *Air Entraining Agent*

The use of admixtures to entrain air in concrete is permitted. The air is entrained in the form of numberless discrete and microscopic bubbles evenly distributed through the mass. 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 lowered so that the loss of strength due to air-entraining is compensated. Whilst air-entrainment is not necessary in most parts of India to increase the frost resistance of concrete in road slabs, as elsewhere. 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 cross-falls.

12.19.3 *Accelerators*

These 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). However, 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 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. When CaCl_2 is used, tie and dowel bars shall be coated with appropriate anticorrosive coatings.

12.19.4 *Retarder*

Retarders have 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.

12.19.5 *Superplasticizers/Poly Carboxylate Ether (PCE) High Range Water Reducing Admixture (HRWRA)*

These 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. 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 adsorbed on the surface of the cement particles, which gives them a negative charge, which cause 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 20 and 25 per cent in case of superplasticizers and up to 40 per cent in case of PCE based HRWRA, and depends on the cement content, aggregate type, presence of pozzolana or admixture etc. Trial mixes should be made to ensure desired workability at paving site. The water/cement ratio shall however, not be less than 0.25. The Admixture used shall conform to **Table 12.**

Table 12 Uniformity Tests and Requirement

S. No.	Property	As per IS 9103-1999
1	Chloride ion content (% by mass as Cl)	Within 10% of the value or within 0.2% whichever is greater as stated by the manufacturer and determined as per IS:6925
2	Relative Density	Within ± 0.02 of the value stated by the manufacturer
3	pH value	7-8
4	Dry Material Content (DMC) (% by mass) at 105 \pm 2°C)	0.97T < DMC < 1.03T T- manufacturer's stated value, DMC test Result
5	Ash Content (AC) (% by mass at 600 \pm 10°C)	0.99T < AC < 1.01T T- manufacturer's stated value, AC test Result

12.20 Joints and Testing of Applied Sealants

12.20.1 Arrangement of Joints

(a) Staggered Joints

It has been observed that where transverse joints have been staggered on either side of 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.

(b) Skew Joints

The use of skew joints increases the risk of cracking at the acute angled corner and may also tend to make the slab move sideways. Thus transverse joints should as far as possible, be at right angle to the edges to the pavements.

(c) Acute-angled Corner

The acute-angled corners should be avoided in the layout of the road and airfield slabs as the stresses due to loading become exceedingly high. Under the conditions of corners warping upward so that they are completely unsupported, the stresses at the corners of various angles calculated theoretically and expressed in terms of stress at a right-angled corner, are approximately be 100 per cent, 145 per cent and 210 per cent for 90°, 70° and 50° respectively.

12.20.2 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 heavy reinforcement or by both.

12.20.3 The shape 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 eyes and also permit the satisfactory compaction and finishing of the top surface.

12.20.4 Spacing of Joints

The spacing of transverse joints depends on several factors, the more important of which are the coefficient of thermal expansion of the concrete, the temperature during placing, the frictional restraint of the DLC sub-base to the movement of the slab, the thickness of the slab and the amount of reinforcement. For unreinforced concrete pavement, the spacing of joints shall be such as to obviate the formation of uncontrolled cracks which would open and give rise to spalling. For reinforced concrete slab, the spacing of joints should be related to the weight of reinforcement so that opening of hair cracks is effectively controlled.

12.20.5 Sealant

The sealant should not be more than six months old and a certificate to this effect stating that the sealant complies with the relevant standards should be obtained before approval for use.

12.20.5.1 Tests on Cold Applied, Single Component, Chemically curing Silicon Sealant for Portland Cement Concrete Pavements as per ASTM 5893, ASTM C 793 and BS/EN14187-5.

- i) **Cure Evaluation:** The sealant shall cure throughout a 12.7 mm X 12.7 mm cross section with in 21 days.
- ii) **Rheological Properties:** Sealant shall exhibit a smooth, level surface with no indication of bubbling.
- iii) **Extrusion Rate:** Not less than 50 mm/min
- iv) **Tack free time:** The sealant shall be tack free after a period of 5 Hours \pm 10 minutes when tested with draw-down of the sealant on polyethylene sheet.
- v) **Performance:** Sealant shall not develop any crack, separation or other opening in it when a hard/sharp edge stone is pressed against it after 21 days of curing.
- vi) **Hardness:** At \pm 23°C using Type 00 Durometer, the hardness shall not be less than 30.
- vii) **Flow:** There shall be no flow after 3 days of laying.
- viii) **Ultimate Elongation:** Not less than 600 per cent.
- ix) **Tensile stress at 150 per cent elongation:** Shall not exceed 3.2 kg/sq cm.
- x) **Resilience:** Shall not be less than 75 per cent.
- xi) **Hydrolysis Test:** The sealant shall pass the hydrolysis test which is a measure of performance of the sealant under water and heat simultaneously.

12.20.5.2 Field Adhesion Test for Silicon Sealant

As a check for adhesion, a simple hand pull test may be performed on the job site after the sealant is fully cured (usually within 14 to 21 days). The hand pull procedure is as follows:

- i) Make a knife cut perpendicular to the joint from one side of the joint to the other.

- ii) Make two parallel cuts approximately 50 mm long, along each side of the joint.
- iii) Place a 25 mm long mark on the sealant tab.
- iv) Grasp the 50 mm long piece of sealant firmly just beyond the 25 mm mark and pull at a 90° angle. Hold a ruler along side the sealant.
- v) If the 25 mm mark on the sealant can be pulled to the 140 mm mark on the ruler, i.e. 450 per cent elongation, without any failure of the sealant, the sealant should perform in a joint designed for +100/-50 per cent movement.

12.20.5.3 Tests on Poly-Sulphide Sealant

For poly-sulphide sealant testing and specification IS:11433 may be referred. In brief, testing procedure is given as under:

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.

- i) **Recovery:** The sealant is considered as satisfactory if it exhibits recovery of not less than 75 per cent and if tensile force required extending the specimen is not less than 25 N or greater than 300 N as per standard test.
- ii) **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.
- iii) **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 mm² per specimen when tested as per standard test.
- iv) **Test for Adhesion in Peel:** The specimen shall not fail when tested for adhesion in peel when applied to surfaces, like aluminum, stainless steel, cement mortar. Adhesion to glass after sun lamp exposure through glass and adhesion after heat ageing shall be satisfied as per standard test.
- v) **Application life:** For hand applied sealant, the application life after mixing shall be 2 hours at 25 ± 1 °C and 50 ± 5 per cent relative humidity and for machine applied sealant.
- vi) **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.
- vii) **Tack Free Time:** The sealant shall not adhere to the polythene sheet film when tested as per recommended test.
- viii) **Resistant 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 4 mm in (a) and (b) cases and the flow in the case of (c) shall not exceed 2 mm.

- ix) **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 mm². The depth of separation shall no where exceed 3 mm from the surface of the test block.
- x) **Resistant to Heat Ageing:** When tested as per 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 minimum 75 per cent and initial identification shall be not more than 2 mm.
- xi) **Test in Tension and Compression:** The specimen shall satisfy the requirement of tension and compression in a standard test.
- xii) **Resistance to Fuel Immersion:** The mass of the sealant against the standard test fuel shall not increase more than 5 per cent not decrease more than 10 per cent after 7 days cure. Also, the recovery when tested in accordance with standard test shall be atleast 75 per cent and the initial indentation shall be not more than 2.0 mm. The specimen of sealant shall also satisfy the requirement of test in tension and compression.
- xiii) **Hydrolysis Test:** The sealant shall pass the hydrolysis test which is a measure of performance of the sealant under water and heat simultaneously.

12.20.5.4 Tests on Hot Applied, Elastomeric Type Sealant as per ASTM D 3406-95

- i The sealant is elastomeric type one component, hot applied joint sealant, resistant to weathering for sealing joints and cracks in concrete pavements.
- ii 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 in-compressible materials. 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.
- iii The safe heating temperature shall be marked on all containers and shall be provided to the testing agency before 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:
 - (a) **Cone penetration, non-immersed at 25°C ± 0.1°C:** 150 g for 5 seconds shall not exceed 130 units
 - (b) **Flow:** there shall be no flow after 72 hours at 70 ± 1°C
 - (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 not immersed: No specimen shall crack; undergo separation, or results in other opening in the sealing compound and the concrete blocks.

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

- (d) **Resilience:** When tested at $25 \pm 0.1^\circ\text{C}$, the recovery shall be a minimum of 60 per cent.
- (e) **Resilience Oven Aged:** When conditioned in a forced draft oven at $70 \pm 1^\circ\text{C}$ for 24 ± 2 hours, and tested at $25 \pm 0.1^\circ\text{C}$, the recovery shall be a minimum of 60 per cent.
- (f) **Artificial Weathering:** After 160 hours 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.
- (g) **Tensile Adhesion:** The average of three test specimens shall be a minimum of 500 per cent elongation.
- (h) **Flexibility:** When conditioned in a draft oven maintained at $70 \pm 1^\circ\text{C}$ for 72 hours and bent at 90°C over 6.4 mm dia mandrel, the specimen shall have no indication of surface crazing or cracking.

12.20.5.5 The joints shall be sealed with the materials and methodology as suggested in IRC:57 “Recommended Practice for Sealing of Joins in Concrete Pavements”.

12.21 *Quality Control Chart*

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 at the rate of 2 cores for every 150 cu m. of concrete. The average of the results of crushing strength tests on these cores shall not be less than 0.8×0.85 times the corresponding characteristic compressive strength of cubes, where the height to diameter ratio of the cores is two. Where height to diameter ratio is not two, necessary corrections shall be made in calculating the crushing strength of cubes in the following manner.

12.21.1 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 correction factor obtained from the following equation:

$$f = 0.11 n + 0.78$$

where f = correction factor and
 n = height to diameter ratio

12.21.2 The corrected test results shall be analyzed 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.

12.21.3 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 area, if necessary, as assessed by additional cores and their test results.

If approved by Engineer, FWD tests may be performed for assessment of the pavement.

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

12.21.5 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.

12.21.6 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.

12.21.7 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.

12.21.8 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.

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

12.22 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.

12.23 All cores taken for density measurement in the trial section shall also be checked for thickness. The same cores shall be made use 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 and strength of concrete slab.

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

12.25 Cores removed from the main carriageway shall be reinstated with compacted concrete mix (of same design 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.

12.26 Pavement Thickness

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

12.27 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.

12.28 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 shall be considered as the specified thickness. No extra payment for the same shall be made.

12.29 Individual areas deficient by more than 20 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.

12.30 When the average thickness for the lot is deficient by the extent shown in **Table 13**, the Contract until price will be adjusted as per this **Table 13** and payment can be made for reduced thickness.

Table 13. Payment Adjustment for Deficiency in Thickness

Deficiency in the average thickness of day's work	Per cent contract unit price payable
Up to 5 mm	100
6 – 10 mm	87
11 – 15 mm	70

12.31 In the stretch where deficiency of average thickness is more than 20 mm, cores shall be cut to ascertain the deficiency as directed by the Engineer, section whose thickness is deficient by 20 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.

12.32 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) Drying shrinkage
- (b) Plastic shrinkage of concrete surface due to rapid loss of moisture
- (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.

12.33 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. Acceptance criteria for cracked concrete slabs shall be as follows:

- (i) Plastic shrinkage cracks with cumulative length of 3000 mm in a slab can be accepted after repair as per IRC:SP:83. Beyond cumulative length of 3000 mm shall be rejected.
- (ii) Slabs with cracks running transversely or longitudinally penetrating to full depth and length of the slab are to be rejected.
- (iii) Slabs with any type of cracks which are penetrating to more than half the depth shall be rejected.

12.34 Summary of Control Tests

Table 14 gives a summary of frequency of testing of pavement quality concrete.

**Table 14: Quality Control tests for Paving Quality Concrete
(Acceptance Criteria/Frequency)**

1.	Strength, Levels, Defects, Alignment and Texture	
	(i) Strength	Clause 12.8.1, 12.8.2, 12.21
	(ii) In-situ density	Clause 12.22
	(iii) Pavement thickness	Clause 12.26
	(iv) Surface levels	Clause 12.16, Table-10
	(v) Surface regularity	Clause 12.17, Table-11
	(vi) Horizontal alignment	Clause 12.15
	(vii) Acceptance criteria for cracked concrete slabs	Clause IRC:SP:83 and 12.33 clause of the present Code
	(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 as per IRC:SP:16
	(x) Alignment of dowel bars/tie bars and their accuracy	To be checked in trial length and once in every 2 km as per Clause 8.3.8 and 8.4.6, 11.5.2, 11.5.4
	(xi) Texture depth	Clause 10.1.14, 12.18
2.	Quality of Materials and Concrete	
	Control tests for materials and concrete shall be as under: (1) Cement physical and chemical test IS : 455 IS : 1489 IS : 8112 IS : 12269 IS : 12330	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) (ii) Deleterious constituents IS:2386 (Pt. 2)	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
	(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.
	Mineral Admixtures	One from each source as per IS: 3812, 12089, and 15388
	(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) (iii) Alkali aggregate reactivity IS:2386 (Pt. 7)	Before approving the aggregates and every month subsequently.
	(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	3 cubes and 3 beams per 150 cum or minimum 6 cubes and 6 beams per day's work whichever is more.
	(ii) Core strength on hardened concrete IS:516	2 cores/km.

	(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 m x 3.5 m or 6.25 m x 3.5 m. Cores may be cut in case of doubts.
	(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.

13 OPENING TO TRAFFIC

In general, traffic shall not use the newly constructed pavement for a minimum period of 28 days. The pavement shall be cleaned and the joints shall be properly sealed as per **Clauses 8.6** and **8.7** of present specification, before the pavement is opened to traffic. In any case, the pavement will not be opened to traffic before it attains the strength of 32 MPa.

Appendix-A

ILLUSTRATIVE PHOTOGRAPHS OF PQC WIDENING



Tie Bars Installed at Longitudinal Joint



Laying of PQC for Widening



Transverse Joints of Old and New PQC Aligned in Line

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)