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IRC:118-2015

# GUIDELINES FOR DESIGN AND CONSTRUCTION OF CONTINUOUSLY REINFORCED CONCRETE PAVEMENT (CRCP)

INDIAN ROADS CONGRESS
2015

# GUIDELINES FOR DESIGN AND CONSTRUCTION OF CONTINUOUSLY REINFORCED CONCRETE PAVEMENT (CRCP)

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# GUIDELINES FOR DESIGN AND CONSTRUCTION OF CONTINOUSLY REINFORCED CONCRETE PAVEMENT (CRCP)

## 1 INTRODUCTION

Continuously Reinforced Concrete Pavement (CRCP) is intended for roads carrying very high volume of commercial traffic and where closing road often for maintenance is difficult. Unlike the jointed plain cement concrete pavement no transverse joints are provided in CRCP but longitudinal joints are necessary if the carriageway width is more than a lane-width. Longitudinal steel is provided in CRCP primarily to control transverse cracks which appear due to shrinkage taking place in fresh concrete and also hold them together. CRCP is different from jointed reinforced cement concrete pavement where steel reinforcement is terminated in each slab. USA had pioneered in CRCP work and their first pavement was constructed in Arlington in the year 1921. It is now very popular not only in USA but even in European countries like Belgium, France, Netherland etc. United Kingdom, South Africa, Australia, Germany and China have started experimenting with this technology lately. CRCP technology also has been used for construction of overlays. CRRI had taken initiative in this technology in 1980s and had produced a document for Rigid Pavement Committee entitled "Guidelines for Design of Continuously Reinforced Concrete Pavement with Elastic Joints, IRC-101-1988" (Ref. 1). This type of CRCP with numerous elastic transverse joints not only affects the riding quality but also increases the cost on account of maintenance of joints. Besides, the hardening and cracking of sealing material with age becomes a source of water infiltration. Therefore the present trend is to design CRCP without transverse joints. Difference between CRCP with and without elastic joints is explained in **Section 2**. When road width is more than 4 m there will be tied longitudinal joints between lanes. Normally shoulders are also tied to carriageway, but without joint for improved performance. CRCP construction in India is limited to small trial constructions or short road lengths in colonies or factories or Toll Plazas etc. India, therefore, has limited exposure to the construction of CRCP and have to rely on the existing international literature and state of the art for this technology.

The draft "Guidelines for Design and Construction of Continuously Reinforced Concrete Pavement" was prepared by the Sub-group comprising Shri R.K. Jain, Shri Satander Kumar, Dr L.R. Kadiyali and Shri M.C. Venkatesha. The Committee deliberated on the draft document in a series of meetings. The H-3 Committee finally approved the draft document in its meeting held on 19th June, 2014 and authorized the Convenor, H-3 Committee to send the final draft for placing before the HSS Committee.

The composition of the Rigid Pavement Committee (H-3) is given below:

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The Highways Specifications & Standards Committee (HSS) approved the draft document in its meeting held on 9th August, 2014. The Executive Committee in its meeting held on 18th August, 2014 approved the same document for placing it before the Council. The IRC Council in its 203rd meeting held at New Delhi on 19th and 20th August, 2014 approved the draft "Guidelines for Design and Construction of Continuously Reinforced Concrete Pavement" for publishing.

## 2 DIFFERENCE BETWEEN CRCP WITH ELASTIC JOINTS AND WITHOUT JOINTS

### 2.1 Continuously Reinforced Cement Concrete Pavement with Elastic Joints

**2.1.1** This pavement is similar to jointed reinforced concrete pavement except that the steel reinforcement runs through the pavement continuously. Transverse joints are formed in concrete slabs by saw cut at 4.5 m spacing for full width and sealed but without discontinuing steel. The longitudinal steel requirement in pavement with elastic joints is normally of the order of about 0.3 percent to 0.4 percent of the sectional area of concrete slab as against 0.6 to 0.85 percent (Ref 2) required for CRCP pavements without joints. Besides, the thickness of slab is reduced to compensate for the stresses relieved by steel bars introduced. Main steel deformed bars (Fe 500 as per IS:1786) are provided in the longitudinal direction at slightly above the mid depth of PQC Slab.

## 2.2 Continuously Reinforced Cement Concrete Pavement without Joints

i) It is a jointless rigid pavement with continuous reinforcement. Normally fine harmless fine transverse cracks develop on the pavement at close spacing of about 0.50 m to 2 m. A typical cracking pattern of concrete pavement can be seen in **Fig. 1**. Crack width of 1 mm and less is said to be good for controlling spalls and when crack width is less than 0.6 mm it has been found to be effective in reducing water penetration. (Ref. 2).

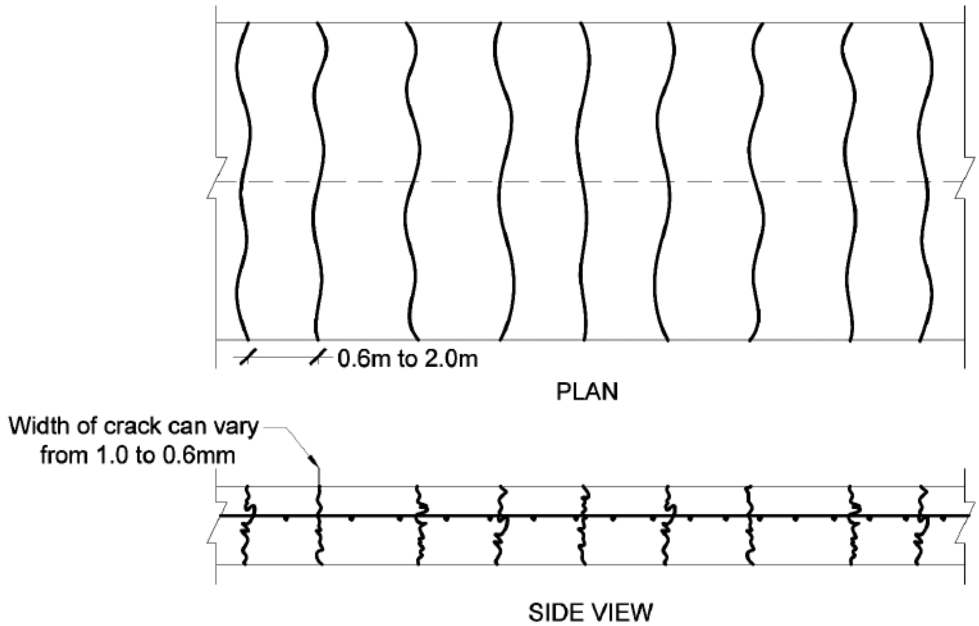



Fig. 1 The Type of Transverse Cracks which Appear on the Surface of CRCP

ii) The longitudinal joints are formed between lanes especially when pavement width is more than 4.5 m. These are generally tied joints. In addition to providing transverse bars, additional bars are provided as tie bars at longitudinal joints. And similarly concrete shoulders are tied for improved performance. Longitudinal joints are cut with concrete saw and sealed.

iii) Each country has its design method for design of rigid pavement. But in India the design method recommended in IRC:58-2011 i.e. "Guidelines for the Design of Plain Jointed Rigid Pavements for Highways" can be adopted (Ref 3). From the international experience no reduction in thickness is desirable.

iv) No anti-friction layer or separation layer in the form of polythene sheet or wax based coating is provided over base or existing bottom layer as provision of such a layer would result in formation of intermittent cracks at greater spacing but of more width. The friction offered by base is rather helpful in reducing crack spacing and also crack width. As the cracks are held tightly by steel reinforcement, the aggregate interlock comes into play to hold the cracks thus improving pavement performance.

v) Special joints and anchor beam have to be provided whenever the CRCP slab abuts with a permanent structure like bridge or culvert or any structure.

vi) Similarly special terminal slabs will be required at the transition of rigid and flexible pavement.

vii) Providing of edge support is an important aspect of the design. Concrete shoulders are normally recommended in CRCP but without longitudinal joint.

viii) Percentage of longitudinal steel reinforcement found from international experience is in the range of 0.65 to 0.80 percent of the cross-sectional area of concrete (Ref. 2). As a matter of fact it is stated that there is no requirement of transverse bars but there is a need to design transverse reinforcement for controlling longitudinal cracks and to reduce punchouts. The pavement is to be textured similar to conventional concrete pavement preferably with tine brush. A typical cross-section of continuously reinforced concrete pavement is shown in **Fig. 2**.

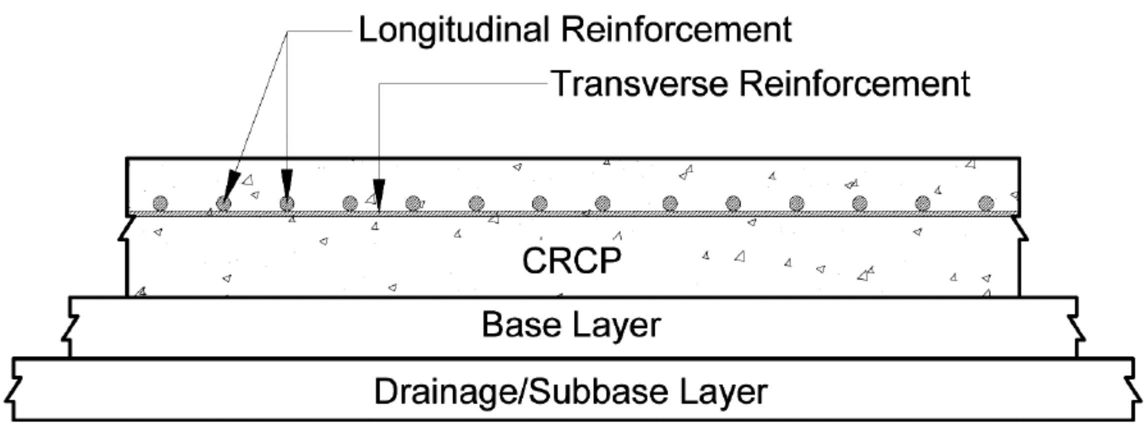



Fig. 2 A Typical Cross-Section of Continuously Reinforced Concrete Pavement

## 3 ADVANTAGES AND DISADVANTAGES OF CRCP

### 3.1 Advantages

i) These pavements are rugged and are durable especially for heavy truck corridors or expressway.

ii) As there are no transverse joints, the riding quality remains smoother but noise remains more or less similar to jointed pavement.

iii) The cost of maintenance is minimal as there is no requirement of replacement of joint seals periodically except in the case of longitudinal joints.

iv) As there are no major repairs requiring barricading or partly closing road for carrying out repairs, related losses due to traffic congestion and delay do not arise.

v) As there are no numerous transverse joints and widths of transverse cracks are narrow, infiltration of water to foundation is minimal.

vi) Life of CRC pavement is normally in the range of 30-40 years.

vii) Initial cost of CRCP is higher on account of use of steel reinforcement. But whole-life-cycle cost will be lower inspite of higher initial cost owing to lower maintenance cost especially in case of poor natural soil condition or filled-up areas. But cost of steel dowels, joint grooving, and joint sealing materials required in conventional pavement partly offsets the higher initial cost.

### 3.2 Disadvantages

CRCP roads are to be avoided in the following situations:

i) In marine climate near sea coast where the reinforcing bars are vulnerable for corrosion, CRCP should be avoided. Either epoxy coated or galvanised steel reinforcement has to be used. Where such steel bars are not available CRCP work may not be undertaken.

ii) It is not desirable to construct CRCP where there are a large number of utility lines under the pavement. It is a difficult task to cut and dismantle the CRCP to undertake repair of pipes and other utility lines located below the road.

iii) CRCP should be avoided in roads catering to light traffic like village roads, urban streets and of short length on account of increased cost of pavement.

iv) Construction of CRCP using manual method should be avoided. Construction of CRCP with manual method will be slow and would result in construction of large number of transverse construction joints which adds to the cost of construction. Fixing stop-end or bulk-head frequently at the end of day's work requires more time and resources thus increasing the cost of construction.

## 4 TYPE OF DISTRESSES

### 4.1 Punchouts

Edge punchout is a major structural distress of CRCP. It is first characterized by loss of aggregate interlock at one or two closely spaced cracks, usually less than 1.2 m apart, at the edge of the pavement. The crack or cracks begin to fault and spall slightly, causing the portion of the slab between the closely spaced cracks to act essentially as a cantilever beam. Under repetitive heavy truck loads, a short longitudinal crack forms between the two transverse cracks at about 0.6 to 1.5 m from the pavement edge. Eventually the transverse cracks break down further, the steel ruptures, and pieces of concrete punch downward under load into the subbase and subgrade. There is generally evidence of pumping near the edge of punchouts. Such punchouts may not be observed so much if non-erodable DLC subbase is used under CRCP.

### 4.2 Causes of Punchouts

- Heavy axle load
- Erosion of foundation
- Large coefficient of expansion of aggregates of concrete
- Loss of Load Transfer Efficiency (LTE) across cracks. Wider crack width has lower LTE.
- Closer transverse cracks

### 4.3 Mechanism of Punchout

The sketch showing mechanism of punchout crack is given in **Fig. 3** (Ref. 4) along with a **Photo 1**.

Photo 1 A View of a Typical Punchout Formed on CRCP

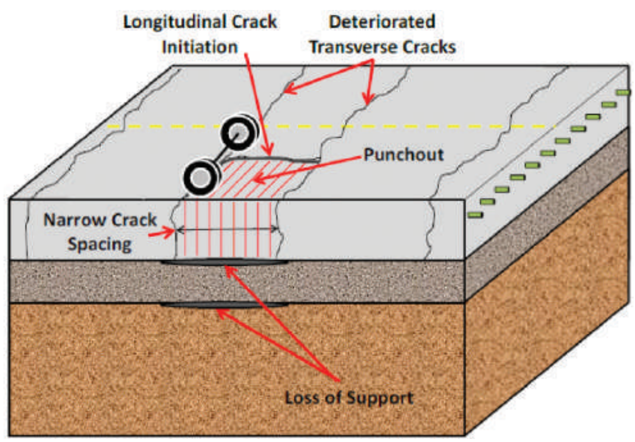
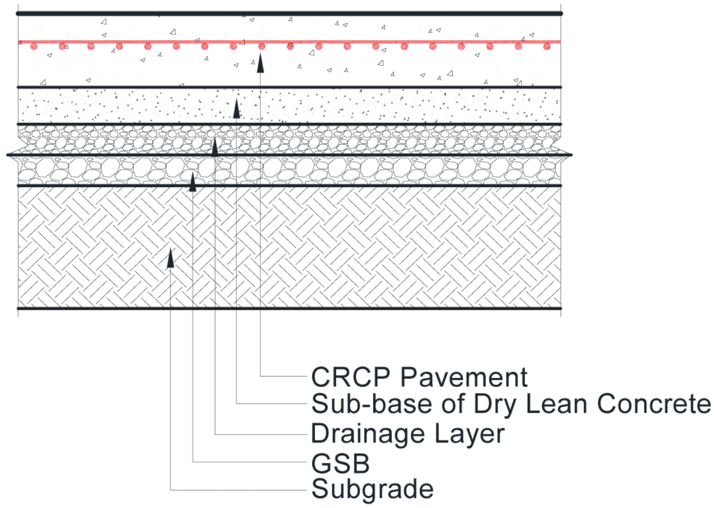



Fig. 3 The Mechanism of Formation of Punchout (Ref. 4)

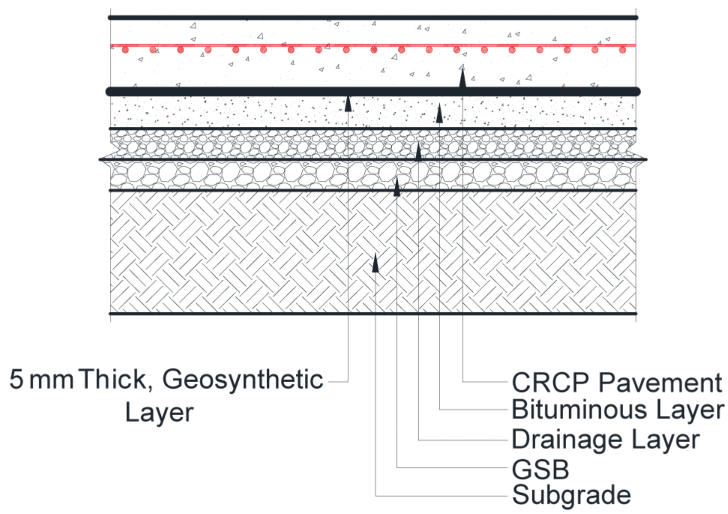
Due to formation of close cracks the load transfer efficiency also reduces with the passage of time. There has to be a balance between lower and higher percentage of steel as too low steel percentage leads to cracks at larger interval but with wider cracks whereas the higher percentage of steel results in closer cracks with narrow crack width and punchouts.

## 5 TYPICAL PAVEMENT COMPOSITION

Base and subbase layers normally provided under CRCP are not different from what is provided in the case of conventional jointed concrete pavement. This has been discussed in IRC:15-2011 (Ref. 5). Either dry lean concrete (DLC) or bituminous bases can be used under CRCP. Use of 5 mm thick geosynthetic layer on the top of bituminous layer has been used in Germany for enhancing performance. Use of cement stabilized bases has also been tried in advanced countries but on account of erosion, overlaying it with bituminous layer becomes essential. A typical pavement composition adopted in CRCP pavement is shown in **Fig. 4**.




**(a) A Typical Pavement Composition of CRCP with a Base of Dry Lean Concrete**




**(b) A Typical Pavement Composition of CRCP with a Base of Bituminous Layer**

Fig. 4 Typical Compositions of CRCP

The relative position of drainage and GSB Layers in a CRCP can be noticed in both **(a) and (b) of Fig. 4**.

## 5.1 Embankment

Non-uniform support condition is not desirable for constructing CRCP. Therefore lot of care is required in selecting soil for embankment and subgrade construction. Embankment shall not be constructed directly on expansive soil. Besides Clause 305.2.1.2 of MORTH Specifications (Ref. 6) restricts use of expansive clay as filling material below subgrade whose 'free swelling index' value is exceeding 50 percent. Even when 'free swelling index' is less than 50 percent, subgrade and top 500 mm portion of the embankment below subgrade shall be non-expansive in nature. It is desirable to remove heavy clay to a depth of 500 mm and replace it with a non-expansive soil in embankment before constructing subgrade. Adequate measures must be taken to provide sub-surface drainage under the pavement.

## 5.2 Subgrade

Subgrade of minimum 500 mm thickness is required to be provided under subbase and shall be compacted to a minimum of 97 percent of Maximum Dry Density (MDD) of heavy compaction (IS 2720-Part 8) conforming to Clause 305 of MORTH Specifications (Ref. 6). Minimum soaked CBR shall not be less than 10 percent at 97 percent of MDD of heavy compaction. Uniform support condition is essential for improved performance of concrete pavement and hence subgrade must be uniformly mixed with moisture and compacted to achieve this requirement.

## 5.3 Subbase/Drainage Layer

Subbase is a lower pavement layer which is provided above the subgrade and below the base layer. This mix is normally produced with crushed stone aggregates. As per Clause 400 of MORTH, Specifications, 2013 and IRC:37 (Ref. 7),subbase is constructed in two layers comprising of Drainage Layer (DL) and Granular Subbase Layer (GSB). Both these documents are suggesting placement of drainage layer above granular subbase layer. The relative position of these layers is shown in **Fig. 4**. Six gradings have been suggested in Table 400.1 of MORTH Specifications for granular subbase layer out of which 2 gradings i.e. gradings V and VI are suggested for use in subbase cum drainage layer (DL). The balance 4 gradings are intended for use in GSB layer. Similarly there are 6 gradings proposed for drainage layer in IRC:37-2012. The DL should satisfy the drainage requirement in terms of coefficient of permeability ‘k’ which shall be about 30 m/day for satisfactory performance. Out of these gradings,Grading-2 has ‘k’, of 35 m/day. The maximum size of aggregate proposed for drainage layer is 20 mm in Table V-1 of Annex-V of IRC-37, which is helpful in constructing a drainage layer (DL) with minimum segregation. A grading proposed below drainage layer shall be such that it can perform both as separation layer and filter layer. With more fines in the mix it will have lower permeability. Such a layer will facilitate lateral flow of water so that there will be minimum soaking of lower layers. Both drainage layer and GSB are structural layers and are normally day-lighted. Where it cannot be day-lighted, a collector pipe is provided to dispose of moisture. The free draining drainage layer may pose some difficulty for compacting in view of less percentage of fines present in it. Sometimes stabilising it with a small percentage of cement or cementitious materials or commercial material (accredited by IRC) of about 2-4 percent as per IRC:SP:89 to achieve UCS of 1.75 MPa or about 2-2.5 percent of bituminous emulsion may have to be resorted to as suggested in IRC:37. A total thickness of 250 to 300 mm of Drainage Layer (DL) and Granular Sub-Base layer (GSB) may be adopted in CRCP projects.

### 5.3.1 *Base course*

A pavement layer placed below concrete pavement is sometimes called an upper subbase or base course layer. It is referred to in this document as a base course layer. Base layer can be of either Dry Lean Concrete (DLC) layer or a bituminous layer. It is important that the base should not get eroded due to entry of moisture. Use of granular layers and cement treated or modified soil can also be constructed but such layer requires high degree of quality control in respect of uniformity in mixing cement with soil. But experience abroad suggests that a layer of bituminous layer on top of such a layer can help in controlling erosion (Ref. 2). Similarly granular base can also be constructed provided erosion is avoided with a bituminous layer on the top. In view of above factors either DLC layer or dense bituminous layer is preferable for constructing base course. In advanced countries 5 mm thick non-woven geotextile on top of bituminous base has been used for improved performance in cement concrete pavements.

## 6 THICKNESS DESIGN

In late 1980s, the pavement thickness was designed for jointed cement concrete pavement in USA and subsequently reduced by 20 percent in the case of CRCP. But the performance of such pavement was found to be not satisfactory thus requiring subsequent costly repairs (Ref. 8). Since then normally no reduction is done in thickness arrived at by the thickness worked out for jointed cement concrete pavement. Therefore for design of pavement thickness in India, IRC:58 can be adopted. An extra thickness of 10-15 mm may be provided to for compensating the wear and tear and also depth of texture. Thickness in the range of 250 mm to 300 mm is generally found to be satisfactory depending upon present traffic volume.

## 7 DESIGN OF REINFORCEMENT

### 7.1 Longitudinal Reinforcement

Due to autogenous shrinkage and drying shrinkage taking place after concreting, the CRCP tends to crack transversely. The function of the longitudinal reinforcement is to control the volumetric changes in concrete due to temperature and moisture variations and to keep the transverse cracks tightly closed. The primary reinforcement of CRCP consists of deformed bars placed in the longitudinal direction. It helps in controlling and distributing cracks in transverse direction with close spacing and minimal width. Normally transverse cracks form at a spacing of about 0.6 m to 2.0 m and their width remains at about 0.1 mm. Crack width less than 1 mm is helpful in preventing spalling whereas 0.6 mm or less is helpful in preventing water penetration (Ref. 2). The steel bars used are normally of 16 mm to 20 mm diameter and are of Grade Fe-415 (60000 psi). But in India TMT bars available now are of Fe-500 grade conforming to IS:1786 which can readily be used.

#### 7.1.1 *Design of Steel Reinforcement*

Longitudinal steel percentage of 0.65 to 0.8 percent of pavement cross-section is found to result in acceptable crack spacing and width as per CRSI Report (Ref. 2). It is found that steel less than 0.6 percent may result in large crack spacing with wider cracks and high tensile stresses in the steel. Steel percentage more than 0.8 percent may result in very short crack spacing that may result in punchout development. Longitudinal steel percentage of 0.7 percent of the cross-section of CRCP may be adopted for normal work.

#### 7.1.2 *Vertical Position of Longitudinal Steel*

Detailing of vertical position of longitudinal steel is very important on account of the following:

i) to control crack spacing and width of cracks;

ii) to provide adequate concrete cover to protect steel from corrosion;

iii) steel placed at a depth of 100 mm to 115 mm from the top for a slab thickness of 250 to 330 mm in the case of 0.7 percent of steel is found to be resulting in minimum punchouts in some study (Ref. 4).

In the light of the above statements, steel placed at about 1/3 depth of slab should be reasonable.

**7.1.3** *Longitudinal Reinforcing Steel Design*

The longitudinal steel provided in CRCP is primarily for counteracting tensile stresses caused in concrete slab on account of shrinkage and contraction due to temperature or moisture changes. An elaborate design procedure is available in AASHTO Guide for Design of Pavement Structures (Ref. 9) for determining percentage of steel satisfying the following three limiting criteria:

i) Crack spacing: To minimise crack spalling, the maximum spacing between crack should be less than 2.5 m and to minimise the potential for punchouts, the minimum spacing between cracks should be 1.07 m.

ii) To minimise spalling at cracks and water penetration, the allowable cracks width should not exceed 1 mm.

iii) Steel stress is usually taken as 75 percent of the yield stress of steel to prevent plastic deformation.

There are three equations to be solved as per AASHTO, 1993 for crack spacing, crack width and steel working stress to arrive at steel requirement and number of steel rods required.

But from the experience of agencies who have constructed large number of CRC pavement, longitudinal steel percentage of 0.65 to 0.8 percent of pavement section is found to result in acceptable crack spacing and width as per CRSI Report (Ref. 2).

**7.1.4** *Spacing of Longitudinal Reinforcement*

The clear spacing between the two adjacent bars should be at least equal to three times the dimension of the coarsest aggregate used for the concrete mix as shown in **Fig. 5** or 70 to 80 mm. Such clear gaps between steel bars are helpful for compacting concrete mix with needle vibrator. The maximum spacing, however, shall not be more than 230 mm and minimum spacing can be either 100 mm or 2.5 times the maximum size of aggregate as per Technical Advisory T5080.14 (Ref. 8).

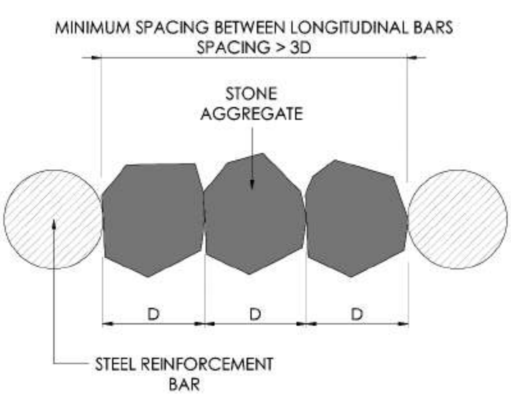



Fig. 5 A Sketch Showing Minimum Spacing Required Between Reinforcing Bars

### 7.2 Transverse Reinforcement

The traverse reinforcement is provided for the full width of the pavement and these bars are tied to the longitudinal bars which help supporting them. The transverse bars, therefore, are fixed on chair assembly first and longitudinal bars placed above them. They reduce the risk of the occurrence and opening up of random longitudinal cracks and thereby the potential punchouts. The reinforcement design is based on equilibrium of base layer restraint (friction) and concrete contraction forces.

The area of steel for the transverse reinforcement is calculated from the equation suggested in CRSI Report as under:

$$\% \text{ of transverse steel, Pt} = \frac{\gamma_c W_s F}{2_{fs}} \times 100 \qquad \text{... 1}$$

where,

Pt = transverse steel, %

$\gamma_c$ = Unit weight of concrete (kN/m$^3$)

$W_s$ = total pavement width (m)

$F_s$ = allowable working stress in steel (75% of yield strength).

As per the recommendations of Wire Research Institute (WRI, 1975), the maximum spacing between transverse bars should not be greater than 610 mm. The transverse reinforcement shall be kept at least 500 mm away from the transverse construction joints.

Friction coefficients for different base materials suggested in AASHTO Guide for Design for Pavement Structures, Washington, D.C. 1993 is given in **Table 1** (Ref. 9).

**Table 1 Friction Coefficients for Different Base Materials**

| Type of Material Beneath Slab | Friction Factor (F) |
|---|---|
| Surface treatment | 2.2 |
| Lime stabilisation | 1.8 |
| Asphalt stabilisation | 1.8 |
| Cement stabilisation | 1.8 |
| River gravel | 1.5 |
| Crushed stone | 1.5 |
| Sand stone | 1.2 |
| Natural subgrade | 0.9 |

## 8 SHOULDERS

Paved shoulders are essential for the safety of edge slabs of CRCP. Paved shoulders are helpful in preventing formation of large number of punchouts in CRCP pavement. In India in order to reduce the cost of construction not much of importance is given to the type of shoulder. Edge stress is critical in all types of rigid pavement. To reduce the edge stress, construction of full-depth shoulder is helpful. However, the following types of shoulders are also possible:

i) Full depth concrete shoulder in continuation of CRCP pavement. It is common practice in the United States to construct shoulders of same type as that of main pavement.

ii) Tied jointed plain/reinforced concrete shoulders with short transverse joint-spacings can be constructed. The use of short joint spacing will reduce potential movements of the joints that otherwise might cause cracking in the mainline CRCP. The elimination of steel reinforcement in the JPC shoulders can save some construction cost. Shoulder slabs, however, must be connected to the main CRC pavement with tie rods.

## 9 JOINTS

Although CRCP is a continuously reinforced concrete pavement, some provision of joints is unavoidable. The following types of joints are inevitable in CRCP:

i) Construction Joint

ii) Longitudinal Joint

iii) Terminal and Transition Joints

### 9.1 Construction Joint

A transverse construction joint becomes necessary at the end of each day's work or when the paving is interrupted for more than 30 minutes on account of failure of Paver or Batching Plant or non-availability of construction materials. A Stop-End should be kept ready in site for preparing a construction joint. Additional 2 m long longitudinal reinforcement shall be placed in between main longitudinal reinforcement as shown in **Fig. 6**.

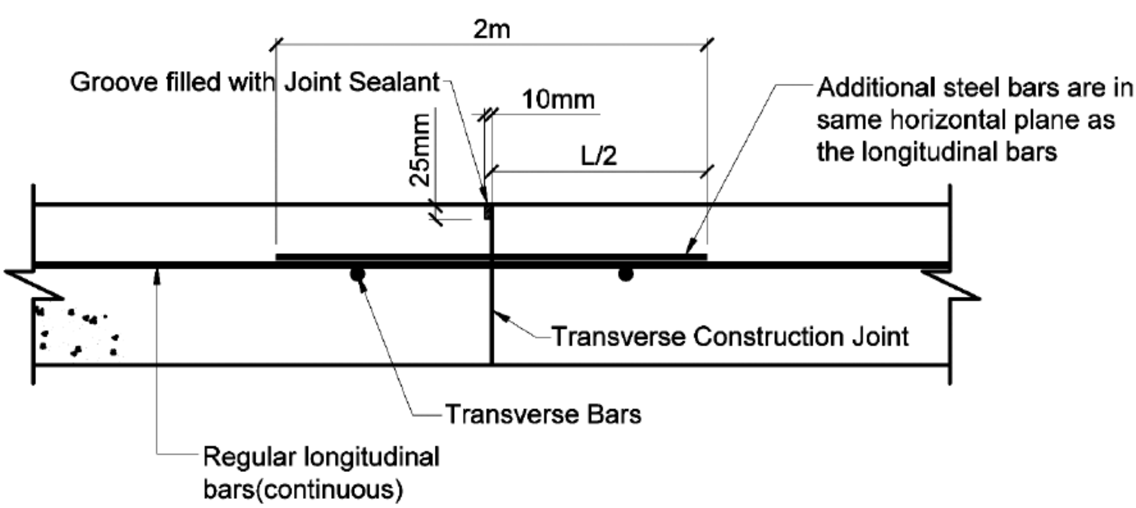



Fig. 6 Transverse Construction Joint

## 9.2 Longitudinal Joint

Longitudinal joints are provided to control longitudinal cracks due to warping, expansion and shrinkage stresses caused by temperature variations when concrete is placed in large widths. Longitudinal joints are formed normally when slabs are wider than 4.6 m (Ref. 2). These joints are formed by a joint-cutting saw to a depth of about 0.3 d, where d is the depth of the slab, and are widened and sealed with approved joint sealant. When the transverse reinforcement extends over the full width of the slab, additional tie bars are eliminated (**Fig. 7**). When road width is large and paving is done with more than one pass of paver, transverse steel arrangement may be adopted as shown in **Fig. 8**. In the case of Slipform paving, tie rods have to be inserted in old slab by drilling holes and grouting them with epoxy.

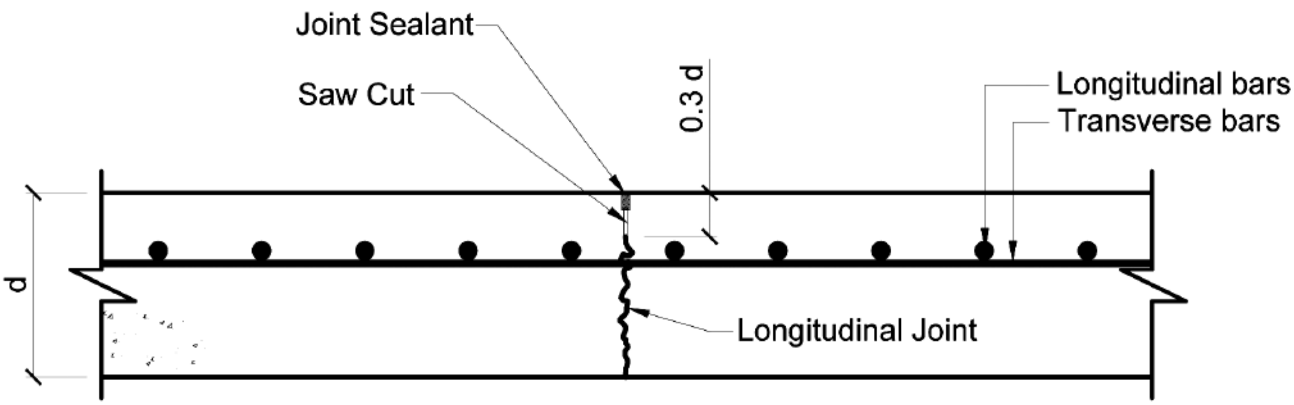



Fig. 7 Longitudinal Construction (Hinged) Joint with Transverse Bars

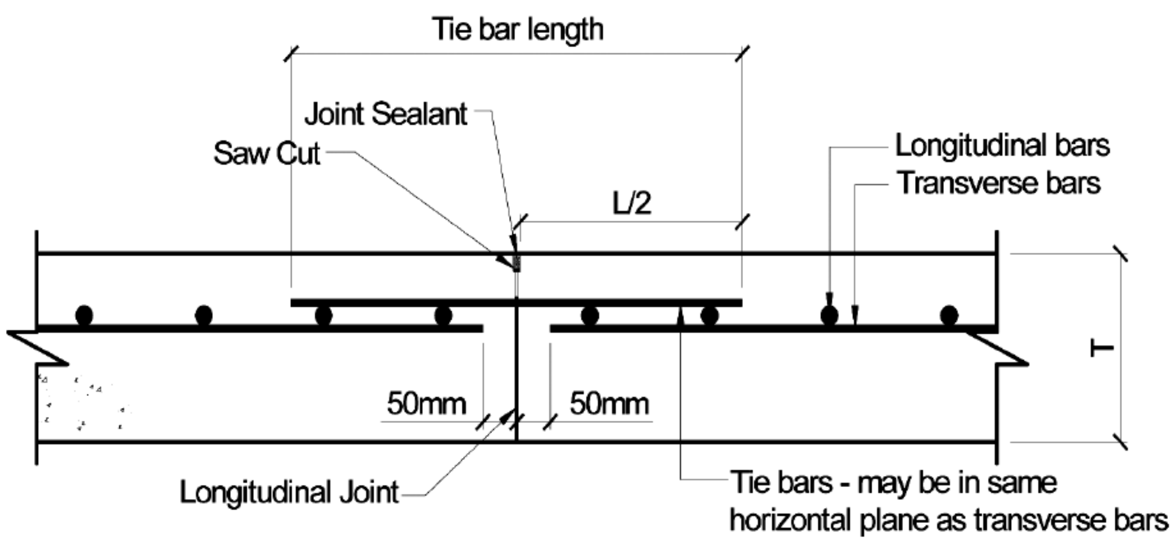



Fig. 8 Longitudinal Construction Joint with Multiple Piece Tie Bars

## 9.3 Terminal and Transition Joints

Terminal slab can be the first or last CRCP slab of a road. The terminal slab can be at a junction or middle of a road. When a CRCP terminates at any location, care has to be taken to provide a smooth change over from CRCP to other type of adjoining pavement. Besides, the expansive pressure from continuous slabs should be dissipated near the terminal slab. When a CRCP is terminated at a plain or reinforced jointed rigid pavement or a flexible pavement, the treatments differ. If a CRCP slab abuts against a bridge abutment, a different treatment is required. A deep anchor beam is normally introduced behind bridge abutments so that expansive pressure from concrete pavement can be contained and dissipated before reaching bridge abutment. Transverse construction joints should be planned in such a manner that they coincide with anchor beam or terminal joint so that construction of an extra joint is avoided. For releasing expansive pressure due to temperature changes, a few expansion joints are normally introduced near terminal slabs.

### 9.4 Transition or Terminal Joint Details

When a stretch of CRCP pavement is constructed, it normally has to be in continuation of an existing road section which will be either a flexible pavement or a rigid pavement. Expansive pressure from long length of CRCP pavement and also incompressible material entering cracks which restricts contraction has to be contained so that it does not put undue pressure on adjoining pavement/structures. The expansive pressure from central section of CRCP resting on a rough base is restrained in central section except for the last 90-120 m on both ends as per American experience. Therefore detailing of pavement at transition with adjoining pavements must be done to take care of the effect of last 90-120 m of CRCP. It may be noted that no anti-friction layer like plastic sheet is used in CRCP and the friction does not allow CRCP to expand or contract freely. All these transitions have to be specially designed so that expansive pressure is relieved and there is no blow up and at the same time the buffer slab is strong enough to withstand compressive pressure. The junctions are weak spots. A suitable sleeper slab with transition slabs has to be designed at these locations. There are primarily two types of arrangements which are adopted, viz, the use of series of anchor beams or providing transition slabs. The anchor beams are normally adopted in jointed pavements as the length increase is more in view of joints getting clogged with incompressible materials in the course of time. It is not only one anchor beam but series of them may have to be used. In softer soil like clayey soil, more such anchor beams may be required. The transition slabs are suitable at the junction of rigid and flexible pavements. The typical transition arrangements of a few cases are discussed in the following Paras:

#### 9.4.1 *Transition between CRCP and Flexible Pavement*

Provision of a transition slab will be necessary between CRCP and flexible pavement. The expansion from CRCP is restricted to the last 90-120 m as explained in Para 9.4. The transition slab is a stepped reinforced concrete slab which can be constructed to match with bituminous pavement layers. Both sleeper slab and transition slab will have dry lean concrete subbase in continuation of the subbase provided under CRCP slab. A couple of expansion joints provided at the end of CRCP will relieve expansive pressure in summer months. The details are shown in **Fig. 9**. The details of expansion joints are given in **Fig. 10**.

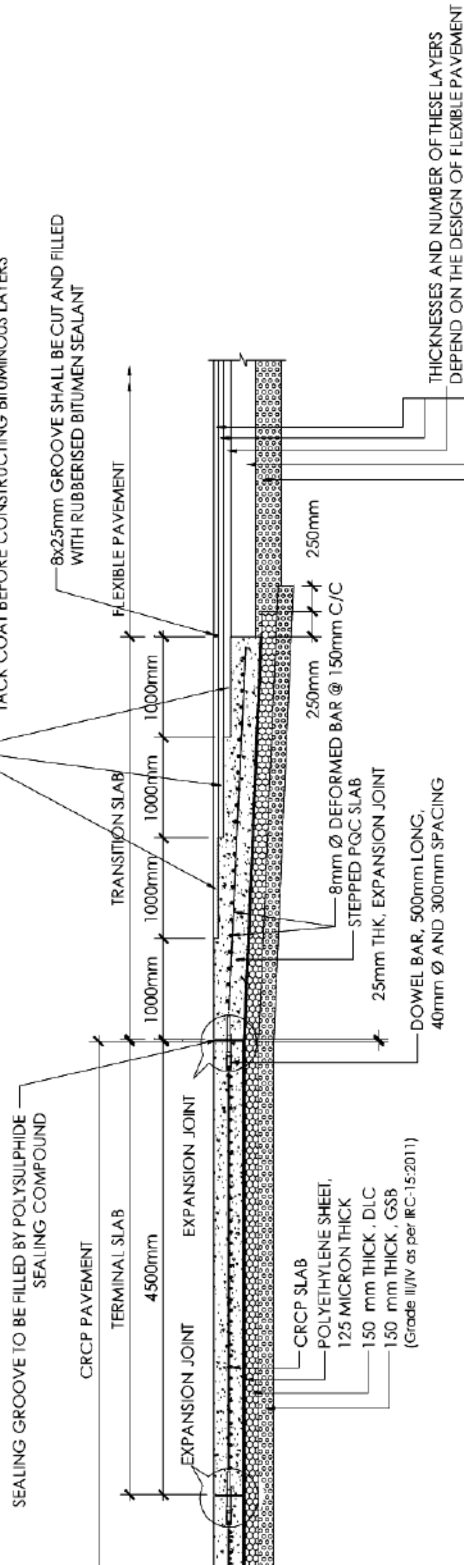



Fig. 9 A Typical Details of Stepped Concrete Transition Slab Provided between CRCP and Flexible Pavement

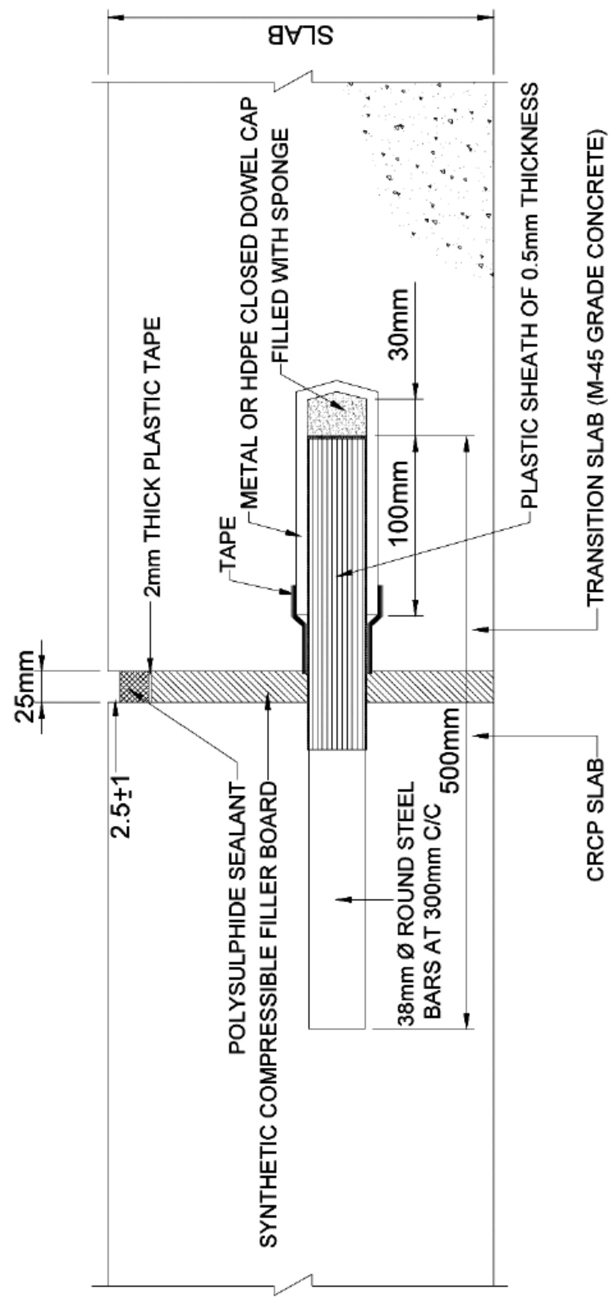
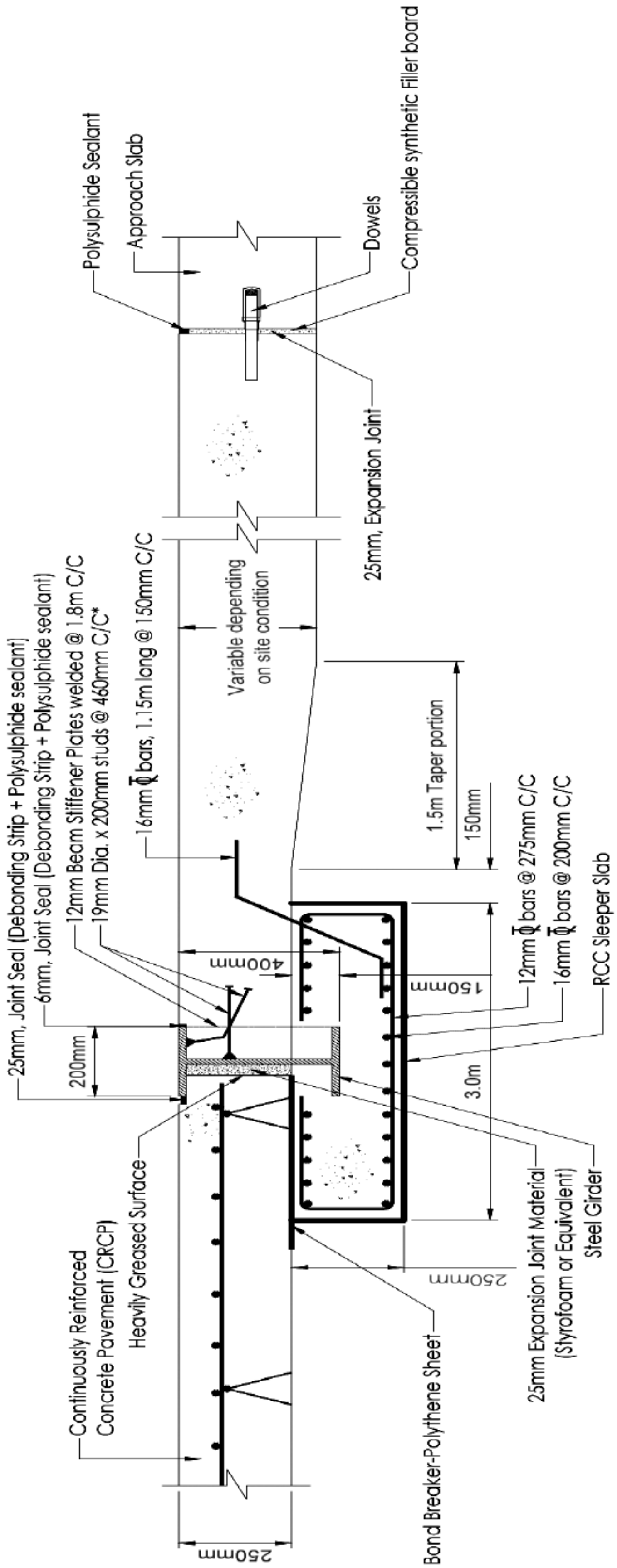



Fig. 10 Details of an Expansion Joint




Note:
* Weld shear connectors to flange and web of beam.

Fig. 11 Transition Details of a Wide Flange Beam Terminal Joint

**9.4.1.1** *Expansion joint*

At the junction of CRC pavement and flexible pavement, a stepped RCC transition slab shall be provided as shown in **Fig. 9**. Adjoining the transition slab, a terminal slab of 4.5 m length shall be provided with the same reinforcement as provided in CRC pavement. Two expansion joints may be introduced on both sides of terminal slab for relieving the expansion pressure. More number of expansion joints may be required at such places. Based on the feedback from such constructions in the country, the number of expansion joints may be increased.

**9.4.2** *Transition between CRCP and Jointed Concrete Pavement*

A Wide Flange Beam Terminal Joint shown in **Fig. 11** is proposed with two expansion joints. A sleeper slab is however provided between CRCP and jointed concrete pavement. Jointed Concrete Pavement will be in continuation of CRCP pavement with a sleeper RCC slab with a wide flange joint as shown in **Fig. 11** with expansion joints. The number of expansion joints shall depend on climate, type of stone aggregates used etc.

**9.4.3** *Transition between CRCP and Bridge Approach*

It is necessary to restrict lateral pressure exerted by expansive pressure from CRCP slabs on bridge abutment. An anchor beam will help in restraining the thrust. Details of an anchor beam are shown in **Fig. 12**. Reinforcement details of the anchor beam and the expansion joints needed are shown in **Fig. 12**. It is necessary to provide one or more expansion joints at such locations. Providing a series of anchor beams behind the approach slab can also be adopted depending upon the site situation. The details of series of anchor beams are shown in **Fig. 13**.

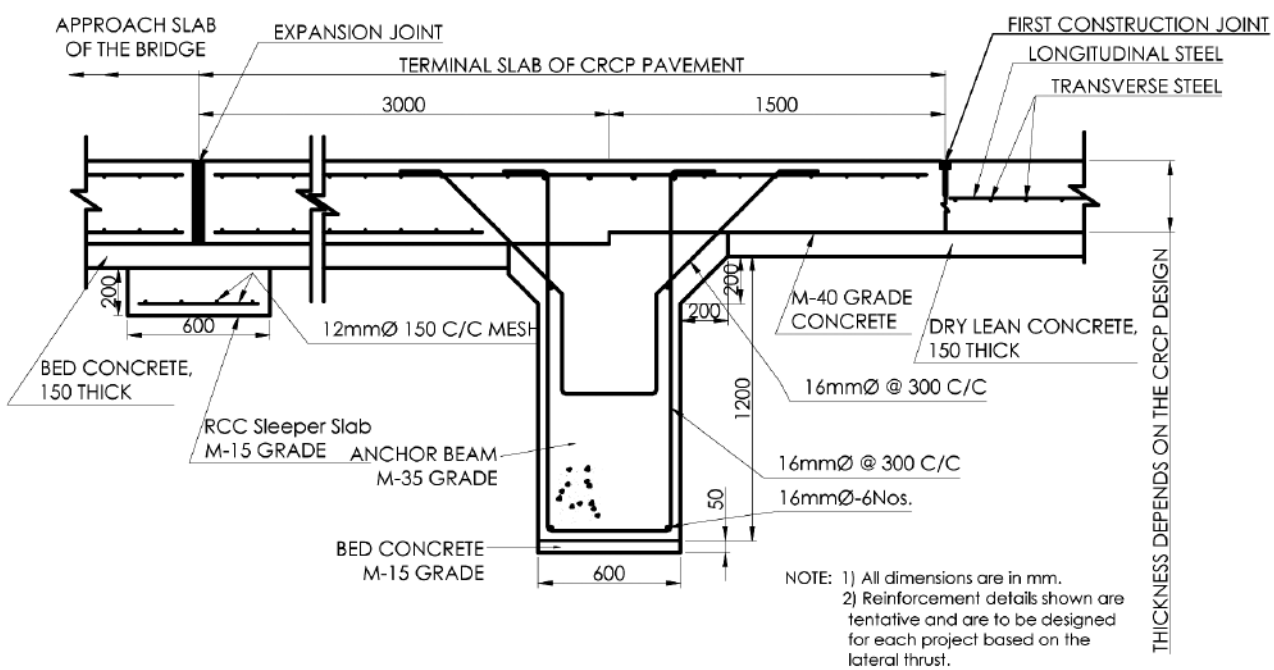



Fig. 12 Details of an Anchor Beam

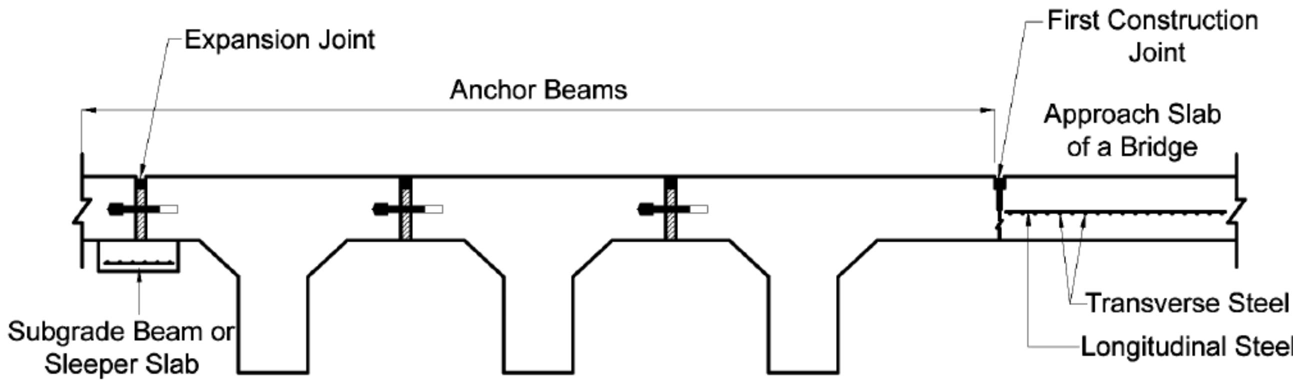



Fig. 13 Series of Anchor Beams Provided before an Approach Slab of a Bridge

## 10 LAPPING OF LONGITUDINAL REINFORCEMENT

Reinforcement bars are normally marketed upto 12 m length in India. As longitudinal bars are to be provided continuously in CRCP pavement, they have to be spliced by providing laps. The length of splicing varies from country to country, but from the studies carried out in the USA, for obtaining adequate bond strength, it is found that a length 33 times bar diameter provides good performance (Ref 2). Therefore, a lap length of 35 times the bar diameter can be adopted. These laps must be staggered so that weak spots are not concentrated in one plane. It is necessary that the laps are staggered and not more than 1/3 splicing must be in one location. A minimum distance of 1.2 m must be provided from one splice to other splice. Welding is not preferred in case of TMT bars.

## 11 CONSTRUCTION

### 11.1 Construction Machineries

The construction of the CRCP can be done as detailed out in IRC:15-2011 (Ref. 5). The paving can be done using either Slipform Paver or Fixedform Paver. Slipform Paver however will be operated on electronic sensor. But in small projects paving can be done using side shuttering using both needle vibrator and powerful modern screed vibrator. The method of paving shall be as explained in IRC:15/IRC:43.

### 11.2 Construction Joint at the End of the Day

The termination of construction at any time needs some special preparation as longitudinal steel bars have to be continued beyond the transverse construction joint. Therefore, the Bulk Head or Stop End must have provision for inserting reinforcement with ease in the holes provided. As this is a weaker location additional steel has to be provided between longitudinal reinforcement.

### 11.3 Fixing of Reinforcement on Base

Chairs made of steel or plastic are used for fixing transverse reinforcement at required height. Once transition bars are in position, it is easy to fix longitudinal bars over them. The chair assembly must be robust and should be fixed firmly to the base. The chair assembly should be able to withstand the weight of a heap of green concrete discharged over it and it should resist the lateral pressure extended by the concrete when it is being spread. A simple type of chairs which can be used is shown in **Fig 14**. There can be a welded chair assembly which can be manufactured in a factory with a transverse bar fixed for facilitating quick installation. Reinforcement in position before concreting in a road project near Pune can be seen in **Photo. 2**. As can be seen from the photograph, the chairs to support the reinforcement can also be made using 12 mm dia steel bars. The spacing of chairs may be from 0.5 m to 1.2 m and they may be staggered by 1.0 to 1.2 m.

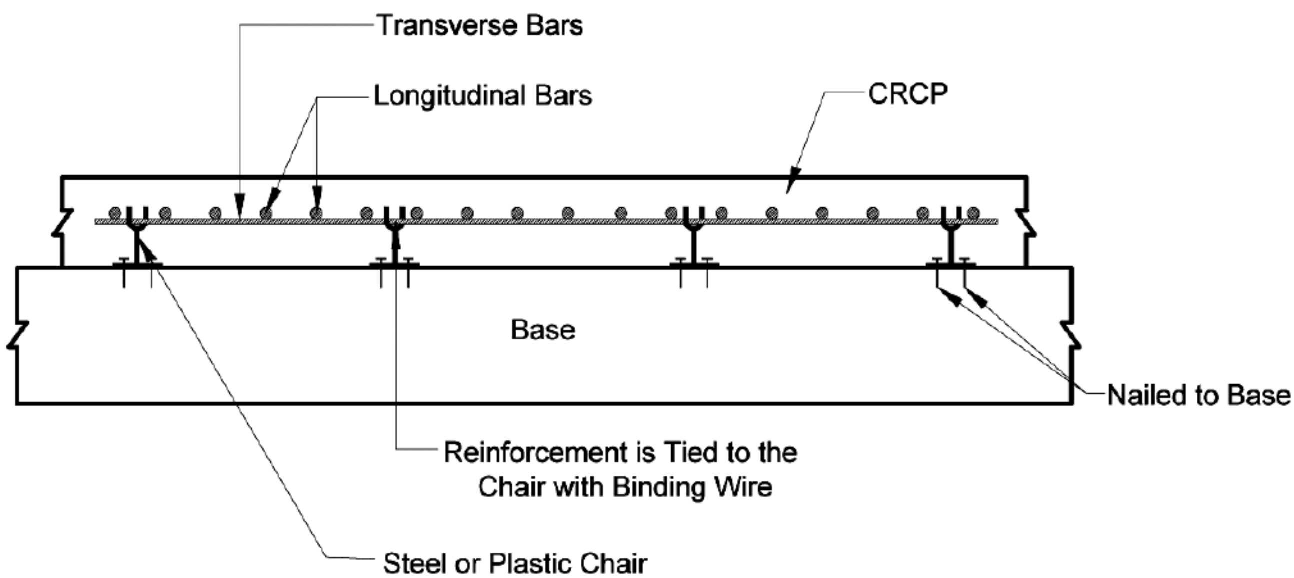



Fig. 14 Steel or Plastic Chairs used for Installing Steel Reinforcement in CRCP

Photo 2 Reinforcement in Position for Concreting

## 11.4 Construction Method

On account of steel reinforcement, dumpers or transit mixers cannot move on the base course layer. Therefore, mix has to be discharged from either from sides using conveyor belt system or with the help of large transit mixers which can load the mix from sides. If there is sufficient space on both sides, side-tipping from dumpers can be resorted to. Except for the restriction regarding the movement of dumpers/transit mixers, the paving operation is similar to the unreinforced concrete pavement. The details of paving operation can be as given in from IRC:15.

# 12 AN ILLUSTRATIVE EXAMPLE OF DESIGN OF STEEL

Let us consider that a CRCP of 300 mm thickness of M-40 grade has been designed based on IRC:58 and the reinforcement is to be calculated. The width of pavement is 7.0 m with a longitudinal joint. Longitudinal steel percentage of 0.7 percent may be considered in the design. Steel reinforcement to be used shall Fe 500 grade.

The reinforcement details are worked out as under:

## 12.1 Longitudinal Steel Design

The width of each carriageway is 3.5 m. The steel required in each lane of 350 cm will be at the rate of 0.7% will be:

Steel required = 350 x 30 x (0.7/100) = 73.5 sq cm

Considering the use of 20 mm dia rods having a cross-sectional area of 3.14 sq cm, the number of steel bars required is:

= (73.5/3.14) 1 = 23.41 Nos.     Say 24 Nos.

Leaving 10 cm from each edge, spacing of bars will be

= (350-20)/(24-1) = 14.35     say 143 mm c/c

The spacing of longitudinal deformed steel bars (TMT) of 20 mm dia shall be at 143 mm c/c.

## 12.2 Transverse Steel

Based on the CRSI Report, % of transverse steel, Pt = $\dfrac{\gamma_c W_s F}{2_{fs}} \times 100$

where,

| | | |
|---|---|---|
| Pt | = | transverse steel, % |
| $\gamma_c$ | = | Unit weight of concrete (kN/m$^3$) |
| $W_s$ | = | total pavement width (m) |
| F | = | subbase friction factor, 1.8 |
| $f_s$ | = | allowable working stress in steel (75% of yield strength). |

For Fe 500 steel yield strength is 5000 $kg/cm^2$ = 490330 $KN/m^2$

Where,

1 $Kg/cm^2$ = 98.066 $kN/m^2$

Unit weight of concrete = 2400 $Kg/m^3$ = 24 $kN/m^3$

The width of slab is 3.5 m

$$Pt = \frac{24 \times 3.5 \times 1.8 \times 100}{2 \times 490330 \times 0.75} = 0.02055\%$$

Spacing between reinforcing bars can be calculated using the following Equation as per the CRSI Report (Ref 2).

Y = As x100/Pt x D

Y = Transverse steel spacing (cm)

As = Cross sectional of steel bar ($cm^2$)

D = Slab thickness in cm

By using transverse bar of 12 mm, the area of cross-section is 1.131 sq cm.

Thickness = 30 cm

Transverse steel spacing, cm = 1.131 x 100/0.02055 x 30

Spacing = 183.45 cm

The CRSI Report suggests that it is common to provide transverse steel bars in the range of 30 cm to 90 cm. A spacing of 60 cm c/c may be adopted.

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5. IRC:15-2011, "Standard Specifications and Code of Practice for Construction of Concrete Roads (Fourth Revision), Indian Roads Congress.

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