IRC:101-1988

# GUIDELINES FOR DESIGN OF CONTINUOUSLY REINFORCED CONCRETE PAVEMENT WITH ELASTIC JOINTS

THE INDIAN ROADS CONGRESS

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Published by
THE INDIAN ROADS CONGRESS
Jamnagar House, Shahjahan Road,
New Delhi-110011

Price Rs. 80/-
(plus packing & postage)

First Published : June, 1988
Reprinted : March, 1991
Reprinted : January, 2006
Reprinted : March, 2010



Printed at Sagar Printers & Publishers, New Delhi-110003
(500 Copies)

# GUIDELINES FOR DESIGN OF CONTINUOUSLY REINFORCED CONCRETE PAVEMENT WITH ELASTIC JOINTS

## 1. INTRODUCTION

1.1. Guidelines for Design of Continuously Reinforced Concrete Pavement with Elastic Joints prepared by the Central Road Research Institute were discussed and approved by the Cement Concrete Road Surfacing Committee (personnel given below) in their meeting held at Lucknow on the 3rd February, 1985.

K.K. Nambiar -- *Convenor*
Y.R. Phull -- *Member-Secretary*

| | |
|---|---|
| H.S. Bhatia | D.G.B.R.(Maj.Gen.J.M. Rai) |
| T.A.E. D'sa | A Rep. of Cement Research |
| P.V. Kamat | Institute of India |
| G.P. Lal | Director, U.P.P.W.D.Research |
| P.J. Mehta | Institute (P.D. Agrawal) |
| V. Raghavan | City Engineer (Roads), Municipal |
| G. Raman | Corporation of Bombay |
| A. Sankaran | D.G.(RD) -- *Ex-officio* |
| N. Sivaguru | President, IRC -- *Ex-officio* |
| | Adviser, IRC -- *Ex-officio* |
| | Secretary, IRC -- *Ex-officio* |

1.2. These Guidelines were considered by the Specifications & Standards Committee in their meetings held at New Delhi on the 28th August, 1986 and 23rd April, 1987 and were returned back to the Cement Concrete Road Surfacing Committee for further consideration. These Guidelines were then finalised by Dr. M.P. Dhir, the present Convenor and Shri S.S. Seehra, the present Member-Secretary of the Committee. The document received from the Cement Concrete Road Surfacing Committee was reconsidered by the Highways Specifications & Standards Committee in their meeting held on the 25th April, 1988 at New Delhi and approved. These Guidelines received the approval of the Executive Committee and the Council in their meetings held on the 26th April and 7th May, 1988 respectively.

1.3. The technique of continuously reinforced concrete pavement (CRCP) obviates the need for expansion and contraction joints, thus permitting very long slab lengths with improved riding comfort and reduced maintenance as compared to plain concrete pavements. Conventional CRCP requires relatively high percentage of steel of the order of 0.7-1.0 per cent of concrete cross-section. The technique of CRCP construction with elastic joints (CRCP-EJ) enables significant reduction in quantity of steel required (0.4 - 0.5 per cent) and also eliminates the random cracks which occur in conventional continuously reinforced concrete pavements.

1.4. The provision of continuous reinforcement in CRCP of the conventional type results in the formation of transverse cracks in the pavement which are held tightly closed by the steel without impairment of structural strength. The closely held cracks ensure load transfer across the cracks through aggregate interlocking and also prevent the ingress of water and grit into the cracks. The width and spacing of such cracks are dependant on the amount of steel reinforcement provided. The greater the amount of steel, the closer is the spacing of the cracks and the smaller is their opening. An optimum amount of longitudinal reinforcement is called for so that the cracks are neither too widely spaced with resulting over-stressing of steel, loss in load transfer provided by aggregate interlock and accelerated corrosion of steel; nor too closely spaced so as to cause disintegration of the slab.

1.5. The elastic joints consist of dummy contraction joints with the reinforcement continuous through them. The reinforcement is painted with a bond-breaking medium over a specified design length on either side of the joint groove to provide adequate gauge length for limiting the steel strains due to joint movement. A typical elastic joint for the solved example given in *Appendix*, is shown in Fig. 1.

1.6. The use of elastic joints, apart from resulting in reduction of steel stresses by about 50 per cent and enabling the use of less quantity of steel, also preclude the random cracking associated with conventional construction, since the weakened plane provided at such joints localises the cracking. The usual spacing of such joints works out to about 4 to 5 m.

## 2. DESIGN

### 2.1. Calculation for Steel Percentage and Stresses in Steel and Concrete due to Continuity at Elastic Joints

2.1.1. The continuity of steel at elastic joints leads to restraint in

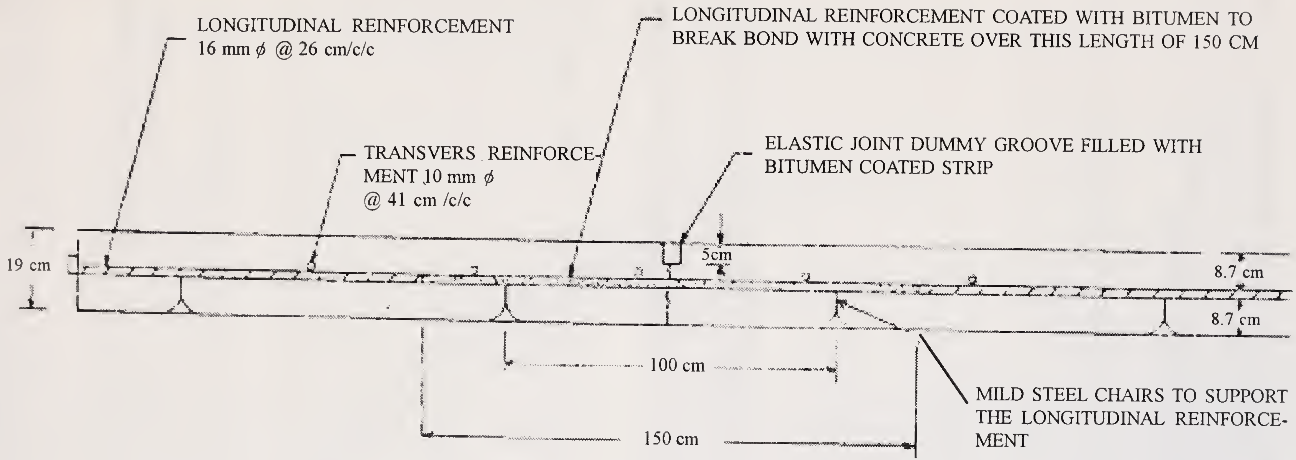


**Fig. 1. Details of elastic joint section**

the slab movement due to shrinkage and temperature change, and thus induces stresses in both steel and concrete. However, if steel is provided at mid-depth of the slab, as is the usual practice, no stress will develop in it due to wheel load and warping.

2.1.2. The stresses (due to continuity of steel at elastic joints) in steel, ($\sigma_s$), and concrete, ($\sigma_c$), in the vicinity of elastic joints may be calculated from Eisenmann equations which are given below:

$$\sigma_s = \frac{100\,(\alpha.\,\Delta_T.\,h.\,E_o.\,E_s)}{f_s.\,E_s\,(1-\lambda) + (100.h.\,E_c.\lambda)}\ \text{kg/cm}^2$$

$$\text{and } \sigma_c \quad \frac{\alpha.\,\Delta\,T.f.\,E_c.\,E_s}{f_s.\,E_s\,(1-\lambda) + 100.h.E_c.\lambda}\ \text{kg/cm}^2$$

where

$\alpha$ = Coefficient of thermal expansion of concrete per $^0$C

$\Delta_T$ = Difference between the mean temperatures of the slab at the time of construction and the coldest period in $^0$C,

$\Delta\,t$ = Maximum temperature differential between top and bottom of the slab.

*Note:* While finding out the temperature stress at the edge, IRC:58 recommends definite values of temperature differential in different states of India. This differential has been designated as $\Delta t$ in IRC:58 and is different from $\Delta_T$ which is used in this text to designate temperature difference between the minimum of minimums and the mean temperature at the time of construction. $\Delta_T$ is not a function of slab thickness whereas $\Delta t$ the temperature differential depends on the thickness of slab.

$h$ = Slab thickness in cm

$E_c$ = Modulus of elasticity of concrete in kg/cm$^2$

$E_s$ = Modulus of elasticity of steel in kg/cm$^2$

$f_s$ = Cross-section of steel in 1 m width of the slab in cm$^2$

$\lambda$ = Ratio of free, unbonded length of the steel to the slab length between two consecutive elastic joints.

2.1.3. The charts in Figs. 2 and 3 show steel and concrete stresses per $^0$C of $\Delta T$ for steel percentage range of 0.1 – 0.6 and for ratio, $\lambda$

range of 0.1–0.4. The steel stresses so determined should not exceed the permissible value of 1400 kg/cm². The concrete stresses are additive to the load and temperature warping stresses and are required to be taken into account while designing the pavement. The transverse steel may be taken as 25 per cent of longitudinal steel.

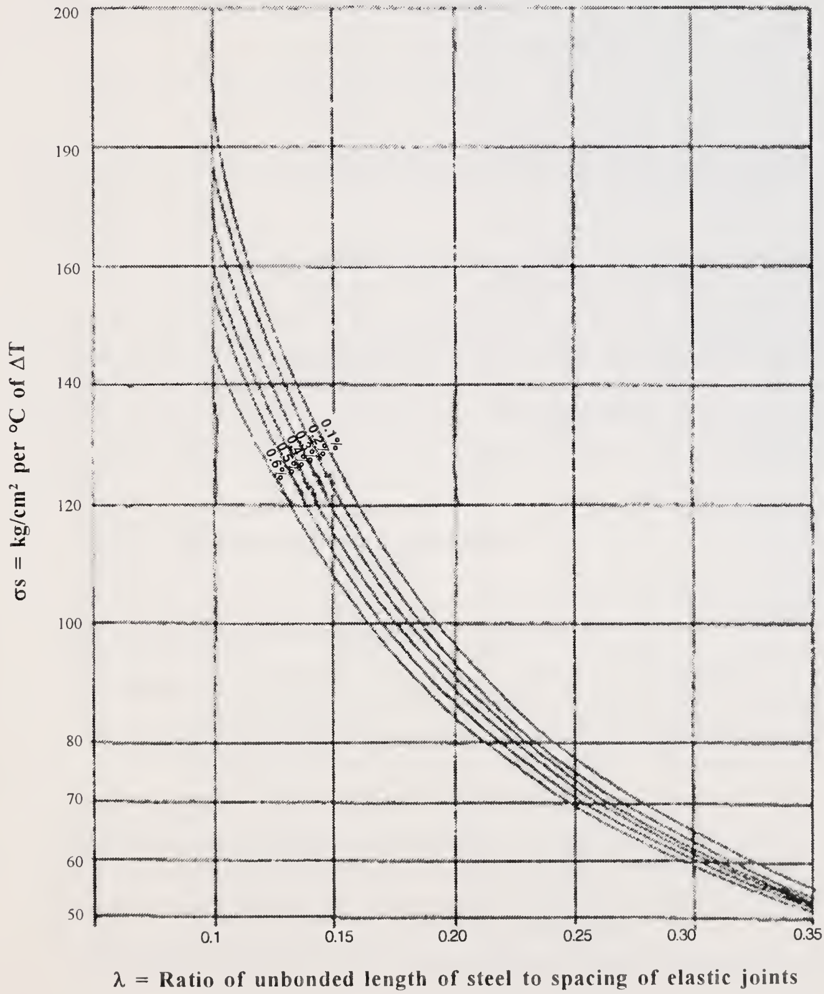


**Fig. 2. Design charts for calculation of stresses in steel**

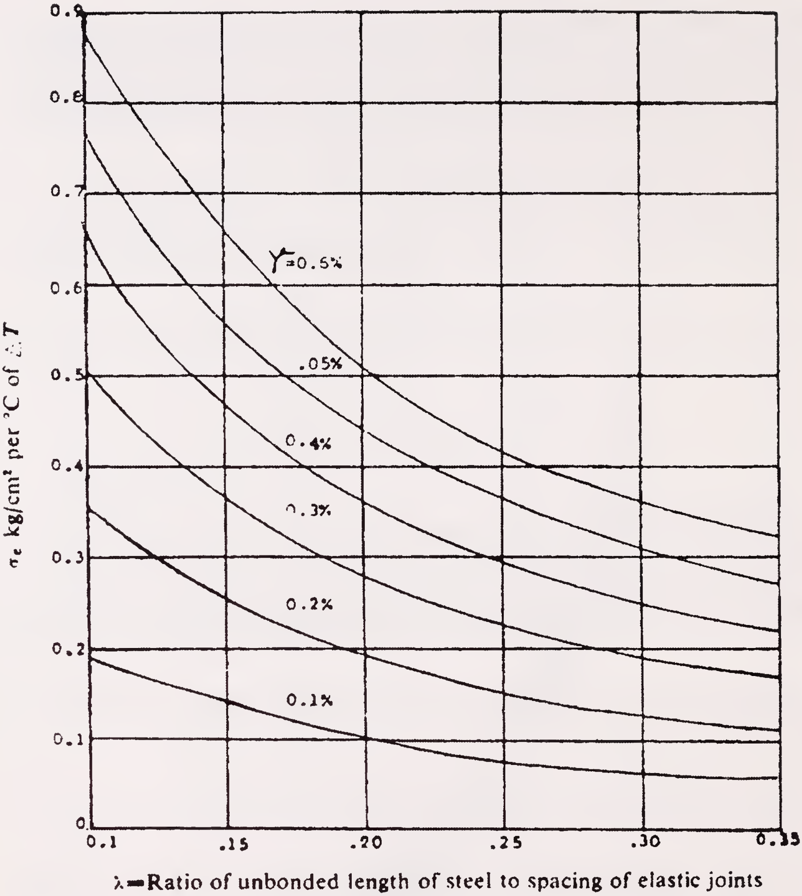


**Fig. 3. Design charts for calculation of stresses in concrete**

2.1.4. The provision of steel enables some increase in the effective slab thickness and its continuity at elastic joints provides additional load transfer over and above that provided by conventional dummy contraction joint. At the same time, the percentage of steel is small enough not to induce any restraint to bending of the slab at elastic joints due to effect of wheel load and temperature warping.

2.1.5. While in CRCP without elastic joints the permissible stress in steel in 2800 kg/cm$^2$ (i.e. the steel is allowed to be stressed upto the yield point), the permissible value in CRCP with elastic joints is restricted to 1400 kg/cm $^2$ only (i.e. normal working stress in steel used in conventional structures). The lower permissible stress in steel in CRCP with elastic joints enables taking advantage of the effective increase in concrete slab thickness due to provision of steel, while the permissible yield stress limit in steel in the case of CRCP without elastic joint precludes such increase.

### 2.2. Design of Slab Thickness

2.2.1. Initially, the thickness of plain cement concrete pavement should be worked out as per IRC:58. While working out the thickness, the additional concrete tensile stress should be accounted for as indicated in para 2.1.3.

2.2.2. The effective increase in slab thickness due to provision of steel reinforcement may be worked out by using Mallinger's chart given in Fig. 4. The equivalent CRCP slab thickness may then be calculated by reducing the thickness calculated in para 2.2.1, by the amount of the effective increase in slab thickness using Fig. 4 the average of steel in longitudinal and transverse direction may be taken.

#### 2.2.3. Outline of design procedure

Step I: Assume a thickness and examine wheel load and temperature stresses as per IRC:58.

Step II: For a proposed value, choose a steel percentage from Fig. 2 such that the steel stress is within the permissible value. Calculate the concrete stress from Fig. 3. In calculating these stresses the ordinates are to be multiplied by the corresponding value of t, as applicable to the particular location.

Step III: Add the concrete stress calculated in Step II to the value obtained in Step I and the final total stresses should be within the flexural strength of concrete. The trials may be repeated till the assumed thickness in Step I meets the requirement.

Step IV: Calculate the effective increase in slab thickness due to provision of reinforcement as per Fig. 4 (vide para 2.2.2.) and reduce the thickness obtained in Step III to account for the increase.

An illustrative example is given in *Appendix*.

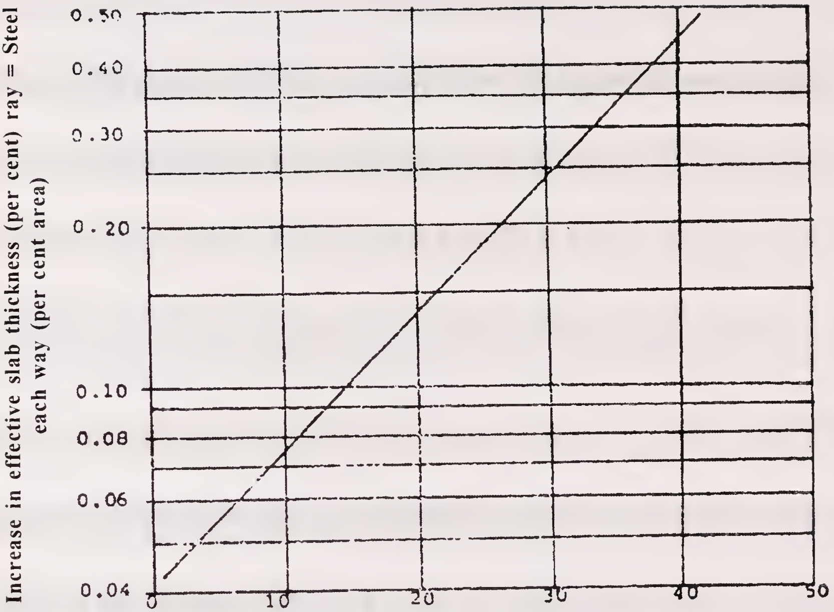


**Fig. 4. Mallinger's chart showing the effect of reinforcement on rigid pavements**

### 2.3. Cement Concrete Mix Design

The mix should be designed on the basis of absolute volume method as per IRC:44 – "Tentative Guidelines for Cement Concrete Mix Design". The flexural strength of concrete at 28 days in the field should not be less 40 kg/cm$^2$ .

## 3. MATERIALS

### 3.1. Cement

Should conform to IS : 269 or IS : 8112.

### 3.2. Coarse and Fine Aggregate

Should conform to IS : 383.

### 3.3. Steel

The diameter of steel bars should be so choosen as to keep the spacing, between bars around 25 to 35 cms. Steel should conform to IS : 432 (Part I)- Mild Steel.

### 3.4. Water

Water used for both mixing and curing should be clean and free from injurious amount of deleterious matter and should conform to IS:456. Potable water is generally considered satisfactory.

## 4. CONSTRUCTION DETAILS

### 4.1. General

The construction details are the same as in the case of plain cement concrete pavements (vide IRC:15) except the following.

### 4.2. Construction of Joints

4.2.1. **Elastic joints :** These are dummy type joints which should be induced at intervals similar to that for dummy contraction joints. The joint grooves may be formed as in the case of conventional dummy joint, and filled with sealing compound. Alternatively, bitumen-coated plywood strips of 50 mm width and 3 mm thickness may be inserted therein. On either side of the elastic joint, steel should be coated with bitumen for a length of 1/3 - 1/4 joint spacing in order to break the bond of steel with concrete and to provide greater length for elongation of the steel due to joint opening for reducing the stress in the reinforcing steel.

4.2.2. **Expansion joints :** The expansion joints are provided only at the ends of the CRCP-EJ sections and there is no need of providing these in-between. The width of such expansion joints is kept upto double that of conventional concrete pavement to accommodate the greater end movements. Details of these joints should be as shown in IRC:15.

## 5. REINFORCEMENT

The steel mats, assembled at site, are placed over suitable chairs at mid depth of the slab before concreting is done. The bars should be continuous across elastic joints and any construction joints. Where overlap of bars is required, a minimum overlap of 30 diameters should be provided. Such overlaps should be staggered. It should also be ensured that no overlap of steel bars are provided at the location of elastic joints.

*Appendix*

# AN ILLUSTRATIVE EXAMPLE OF DESIGN OF SLAB THICKNESS

1. **Design Parameters:**

| | | |
|---|---|---|
| Location of Pavement | : | Delhi |
| Design Wheel Load, $P$ | : | 5100 kg |
| Present Traffic Intensity | : | 300 veh/day |
| Design Tyre Pressure, $p$ | : | 7.2 kg/cm² |
| Foundation Strength, $k$ | : | 6 kg/cm² |
| Concrete Flexural Strength, $f_R$ | : | 40 kg/cm² |

$E_c$ = $3.0 \times 10^5$ kg/cm²

$\mu$ = 0.15

$\alpha$ = $10 \times 10^{-4} / {}^0C$

$\Delta t$ = 14.3 $^0C$ against thickness of 25 cm

2. **Design Procedure:**

Step I : Assume $h$ = 25 cm, spacing of elastic joints = 4.5 m

As per IRC:58-1988

$\sigma le$ = 18.50 kg/cm²

$\sigma te$ = 15.50 kg/cm²

$\sigma$ Total = 34.00 kg/cm²

Step II : For $\lambda = 0.33$ and $\Delta_T = 20^0C$

$r$ = 0.4 per cent (Steel reinforcement)

From Fig. 2, $\sigma_s$ = 56 x 20 = 1120 kg/cm² < 1400 kg/cm² OK

From Fig.3, $\sigma c$ = 0.235 x 20 = 4.7 kg/cm²

Step III : From Step I total $\sigma$ = 34.00 kg/cm²

From Step II $\sigma c$ = 4 .70 kg/cm²

Total $\sigma$ = 38.70 kg/cm say 39.00 kg/cm²

The total stress 39.00 kg/cm² is less than the flexural strength of concrete 40 kg/cm² and therefore the thickness of 25 cm is O.K.

Step IV : Average steel reinforcement ($r_{av}$)

$$= \frac{0.004 + 25\% \text{ of } 0.004}{2} = \frac{0.005}{2} = 0.25 \text{ per cent}$$

From Fig. 4, for $r^{\alpha}_{\upsilon}$ = 0.25%, the effective increase in slab thickness is 31%.

Reducing the thickness proportionately

$$h_r = \frac{25}{1 + 0.31} = 19.08 \text{ cm}$$

Design thickness of pavement slab = 19 cm