

## Optimizing Performance: Continuously Reinforced Concrete Pavement Design

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ABSTRACT “Continuously reinforced concrete pavement” as the title suggests this type of pavement is reinforced throughout in longitudinal direction. This type of pavement has no transverse joints unless and until there is end of pavement or the pavement comes in contact with some other pavement or bridge. A longitudinal joint exists only if the road is wider than 14 feet. Due to reduction of joints smooth and continuous riding is possible resulting in fuel saving. Also CRCP roads are maintenance free if properly constructed and care is taken while placement of steel. Once CRCP roads are constructed they need not to be taken care of for the next 50-60 years.

The principal behind this roads is that “Let the road crack”, exactly opposite as in case of other type of roads where we avoid crack formation at any cost. CRCP is allowed to crack due to which stresses in the pavement are released. The cracks formed are held tightly by the reinforcement, due to which widening and deepening of cracks is restricted. Hence we can conclude that in CRCP controlled cracking is permitted. The initial cost of CRCP is high, but as it is maintenance free, and lasts for decades, overall cost of CRCP is less as compared to other type of reinforced concrete pavements. Study and observations have shown that this type of roads are alarmingly successful,

hence CRCP is widely used in USA, GERMANY, BRITAN, and several other developed and developing nations. Use of CRCP will enhance the cement, and steel industries; it will reduce the fuel consumption by vehicles, and will save lots of money required for frequent construction and repairs of other type of pavements. Keywords: CRCP, , concrete pavement design, concrete pavement construction.

## 1. INTRODUCTION

Transport is a vital infrastructure for rapid economic growth of the country. Speedy transportation of natural resources (such as raw materials), finished goods and perishable materials to all parts of the country including the points of export outlets are basic inputs to economic growth. Recently there has been a major shift in transportation mode from Railways towards the Road sector. Now a day's about 60% of freight and 80% of passenger transport is met by Road transport in India, which demonstrates the need for development of a good road network. In India flexible pavement (bitumen) is most common for both national and state highways. Majority

of roads are also built with conventional bitumen pavements considering its lower initial cost, though the life cycle cost of these pavements are very high compared to rigid pavements due to frequent repairs and also need for complete resurfacing at interval of 4-5 years. Further fuel consumption of vehicles is much higher on this type of pavement than that on rigid pavement. In advanced countries rigid pavement is increasingly being used due to large number of benefits it offers.

What is CRCP? In concrete pavement the longitudinal reinforcing steel is continuous throughout the pavement length. It is a joint less concrete pavement sufficiently reinforced to control cracking, without the aid of weakened transverse joints such as are used in ordinary or conventional type of jointed concrete pavement. Reinforced bars in the concrete are lapped to form continuous reinforcement holding the pavement together in all kinds of weather and preventing formation of large cracks that would otherwise reduce the service life of the pavement. CRCP has all the good features of concrete pavements such as

durability, high structural strength, nonskid surface and good visibility at night, wet or dry—features which make concrete, and especially continuously reinforced concrete, a permanent road surfacing material. In CRCP reinforcement steel is an important element and it offers the following functions:

1. Holds crack tight
2. Facilitates load transfer across cracks
3. Provides stiffness by restraining end movement

**Definitions and Characteristics of CRCP**  
Continuously reinforced concrete pavement (CRCP) is concrete pavement reinforced with continuous steel bars throughout its length. Its design eliminates the need for transverse joints (other than at bridges and other structures) and keep cracks tight, resulting in a continuous, smooth-riding surface that is virtually maintenance-free. The whole idea of CRCP is based essentially

on the “so-let-it-crack” philosophy rather than the difficult concept of avoiding cracks at any price. The principle in CRCP is to confine random cracking to acceptable spacing and crack widths so that the slab performs the same as if no crack exists, i.e. equal deflection at cracks and the mid span of the slab. In an unreinforced slab, cracks which occur will normally widen and get progressively worse under the effects of traffic and climatic conditions. During the contraction of the concrete fine dirt enters the wide cracks, leading to faulting, spalling and cracking and blow-ups develop, requiring extensive repairs and early surfacing to restore the smooth surface. The amount of reinforcement required to control the cracking is relatively smaller for shorter spans. As length of the slab increases amount of steel needed also increases.

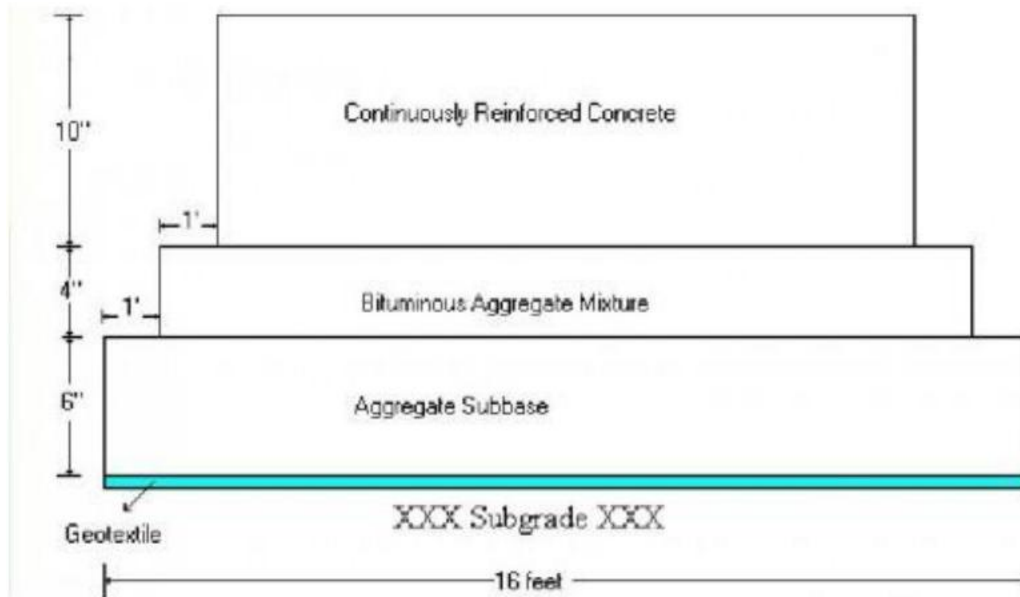


Fig 1.1 cross section of CRCP

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## 2. DESIGN CONSIDERATIONS

### 2.1 Design Aspects

The volume changes stresses in CRCP will be taken care by providing sufficient reinforcement to keep the cracks tightly closed while maintaining adequate pavement thickness to counteract the stresses produced by wheel loads. CRCP allows the concrete to develop very fine transverse cracks that seem to be uncontrolled and random. The spacing's of transverse cracks that occur in CRCP is an important variable that directly affect the behavior of the pavement.

Relatively large distances between cracks result in high steel stresses at the crack and in excessive crack widths. A decrease in crack spacing reduces the steel stresses and crack widths.

### 2.2 Crack Spacing

The limits on crack spacing are based on the possibility of spalling and punch outs. Based on experience, the maximum spacing between consecutive cracks should be limited to 2.4m to minimize spalling. To minimize the potential of punch outs, the minimum desirable crack spacing is about 1.1m.

### 2.3 Crack

Width The limit on crack width is based on a consideration of spalling and water infiltration. The crack width should be reduced as much as possible through the selection of higher steel percentage or smaller diameter reinforcing bars. As per AASHTO stipulation the allowable crack width should not exceed 1.0mm.

### 2.4 Steel Stress

The limiting stress of 75% of the ultimate tensile strength is recommended. AASHTO Design Nomographs and Equation are available for determining the percentage of longitudinal reinforcement to satisfy the criteria of crack spacing, crack width and steel stress respectively. The optimum amount of steel reinforcement is selected in CRCP so that crack spacing lies between 1.1m to 2.4m, the crack width is less than 1.0mm and steel stress does not exceed 75% of the ultimate tensile strength. CRCP allows the use of slightly smaller load transfer co-efficient compared to JPCP. And hence the

thickness requirement is less compared to JPCP. The maximum desirable crack spacing is derived from a correlation between crack spacing and incidence of spalling. Maximum crack spacing is derived from consideration of effect of slab length on the formation of punch-out.

### 2.5 Steel Reinforcement

The amount and depth of longitudinal reinforcing steel are the most important aspects of steel reinforcement in CRCP as it affects transverse crack spacing and the width of the cracks. The longitudinal reinforcement in CRCP is used to control the fine transverse cracks that form due to volume changes in the concrete. The function of steel is to hold the random cracks tightly closed, to provide structural continuity and to minimize the penetration of potentially damaging surface water and in-compressible. 2.6 Longitudinal Reinforcing Bars

These are the main reinforcement in CRCP. The total area of longitudinal reinforcing bars required usually is stated as a

percentage of the cross-sectional area of the pavement. The amount of longitudinal reinforcing bars is generally between 0.5% and 0.7% and it may be more where weather conditions are severe and also the temperature differentials are more. Transverse reinforcements are useful to support the longitudinal steel when the steel is preset prior to concrete placement. Transverse reinforcement may be lesser grade.

### 2.6 Transverse Reinforcing Bars

The function of the bars is as follows: 1. To support the longitudinal bars and hold them at the specified spacing. When used for this purpose, the longitudinal bars are tied or clipped to the transverse steel at specified locations. 2. To hold unplanned longitudinal cracks that may occur tightly closed.

### 3. METHODOLOGY

CRCP is characterized by the presence of a continuous steel reinforcement set into the cement and by the omission of transverse joints other than construction and terminal joints. Instead of being concentrated in the contraction joints as is the case with JPCP,

volumetric changes (due to temperature and moisture) result in the development of a large number of evenly distributed hairline cracks appearing at random. The amount of longitudinal reinforcement is determined so as to control cracking and to ensure structural continuity of the pavement. The aim sought is a great number of cracks fine enough to limit the penetration of de-icing salts and to ensure proper aggregate interlock which leads to a higher load transfer efficiency. One of the main arguments for the use of this type of slab is that it requires little or no maintenance. This represents savings in maintenance costs but also direct savings for users. Initial costs are heftier due to the reinforcement but these costs are similar to those for a conventional pavement after 10 to 15 years according to the World Road Association (PIARC), or after 15 to 18 years according to Belgian experts. Other favorable factors are a better long-term performance and longevity of pavement smoothness. The use of CRCP is recommended for urban and rural-area highways, especially where there is high-volume traffic and great number of trucks. Use of CRCP is widespread in the world,

especially in the United States and Europe. • The United States first used this concrete pavement in 1921. Several road tests were conducted during the 1940s and 1950s. Today, over 50 000 kilometers of highway lanes have been built in CRCP. • Belgium built its first CRCP section in 1950. This country has made extensive use of this type of concrete pavement since 1970. Several projects were conducted since then to arrive at the current design. It is interesting to note that this country uses CRCP not only on its highways but also on its country roads and national highways. The participants of the 2001 Québec Tour in Belgium had the opportunity to witness first-hand this country's know how in the area of concrete pavement. • France has used CRCP since 1983 and, to date, it has over 600 lane-kilometers, as well as, several rehabilitation projects underway.

#### 4. CONSTRUCTION OF CRCP

Construction of CRCP is similar to that of other concrete pavement types. Planning and execution are crucial since errors made during these stages can be detrimental to the overall success of the project. It is important

to pay special attention to certain details such as the selection and installation of the reinforcement, the carrying out of the construction joints, and so forth. As with any other type of pavement, the base must be finished to ensure a uniform roadbed for the reinforcement supports and construction equipment, as well as, to provide a uniform slab thickness. The base must ensure proper drainage to the slab base interface and be non-erodible to limit the potential of punch-outs. A permeable base fully satisfies these criteria. First, the transverse reinforcement bars are manually placed on metal supports by teams of steel fixers. A sufficient amount of supports will prevent any collapsing under a 250-kg load. Their design must be in accordance with the concrete cover specifications. Longitudinal reinforcement bars are placed on the transverse ones and then tied to the latter. Generally, it is recommended that longitudinal reinforcement be placed on the upper third section of the slab to limit crack openings. A sufficient amount of concrete cover above the reinforcement is necessary to prevent any corrosion. A minimum spacing of 150 mm between the reinforcement bars is

recommended to ensure adequate steel cover. The longitudinal bars may be welded to one another or tied. If tied, the recommended overlap is 25 to 35 bar diameters. The overlaps are usually offset from one lane to the next to ensure they are not all in the same cross section. The free ends of CRCP are exposed to movements mainly caused by temperature differentials. Systems are installed at each end to restrict the movements from the last 100 meters of the slab. Surveys conducted in certain American states concluded that a wide-flange beam provides a cost-effective method for accommodating end movements. In Belgium, anchors made of fixed beams embedded in the base are used. The use of bridge expansion joints is also acceptable. Figure 3 shows the plan of work and a picture of an anchorage beam. Concrete placement for the CRCP is similar to that of the conventional pavement. Desirable results are dependent on the following factors: vibrator adjustment to avoid contact with the reinforcement bars and concrete workability to ensure adequate steel cover. Figure 4 shows pavement placement achieved with a slip form paver. Tie-bars should be placed in longitudinal

construction joints to keep slab edges together on either side the joint. Special attention must be paid when forming the transverse construction joints when concrete placement is completed at the end of the day. The Belgians noted incidents of slab blow-ups (9) at construction joint mainly due to the poorer quality of concrete resulting from a delayed or inadequate vibratory compaction on one or both sides of the joint.

## 5. CONCLUSION

Compared to flexible pavement, CRCP gives additional design life of at least 10 years. Further, it offers much better riding quality, less dislocations to traffic movement and substantial saving in vehicle operating cost comprising reduced consumption of fuel, lubricants etc. Considering durability and maintenance free service of CRCP it is desirable to construct all these concrete roads with CRCP. Thermo mechanically treated, TMT, bars are desirable for CRCP pavement. Corrosion resistant TMT bars may be used in corrosion prone areas. The demerit of CRCP is its high initial cost & difficulty in repair works required to be done if not constructed properly. Joint less



concrete pavement, CRCP offers excellent smooth Riding surface for the vehicles that maximizes the comfort for the passengers. It needs minimum cost of maintenance and rehabilitation. It minimizes the detrimental dynamic loads that are applied to the vehicles and pavement. Air and noise environment improve along the thickly populated existing corridor. Concentrations of CO and NOX are expected to reduce by around 70 % and 45% respectively. The noise level would reduce substantially. Concrete can withstand even the heaviest traffic loads. There's no need to worry about ruts, shoving effects common with asphalt pavement. Concrete's hard surface makes it easier for rolling wheels. Studies have even shown that this can increase truck fuel efficiency. Savings in fuel to the extent of 20%, may be considered ultimately reducing the vehicle operating cost. Concrete roads facilitate increased speed and thereby savings in time and money. Almost maintenance free service reduces traffic disturbances and thus reduces man-hour loss to the road users. Use of CRCP drastically can reduce import of bitumen there by leading to saving of foreign currency.

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