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DESIGN AND ECONOMY ASPECTS OF CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

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Abstract: Continuously Reinforced Concrete Pavement (C.R.C.P) is used for roads carrying very high volume of commercial traffic and where maintenance of road is difficult. This type of pavement is provided with main reinforcement in longitudinal direction. This pavement theoretically has no transverse joints except construction joints provided at the end of a day's job. A longitudinal joint is provided only if the road is wider than 4.5m. Approximately 0.3-0.4 percent of the sectional area of concrete slab is provided as longitudinal steel in pavements with elastic joints whereas without joints this reinforcement is 0.6-0.85 percent. Due to less number of joints smoothness and riding comfort of CRCP is better which results in low vehicle operation cost. Also CRCP road has longer life if properly constructed and care is taken while placement of steel. The demerits of CRCP is its high initial cost but merit is that it is maintenance free. This paper presents an overview of the cost of CRCP versus the conventional concrete pavement

Keywords:CRCP, transverse joints, longitudinal joint, vehicle operation cost

I. INTRODUCTION

Continuously Reinforced Concrete Pavement, CRCP is a concrete pavement in which reinforced is provided in the direction of traffic. CRCP is a durable pavement, modified version of plain concrete pavement. Reinforcement is used in CRCP, to remove the problem of concrete slab cracking, eliminate the joints, and improve the strength and life span of pavement. Maintenance is virtually eliminated in CRCP. The Bureau of Public Roads on the Columbia Pike in Arlington, Virginia first use the CRCP in 1921.

Flexible pavement is commonly used in India for pavement design. As we know that traffic volume is increasing so main focus in pavement design to improve the quality of road pavement; Continuous Reinforced Concrete Pavement (CRCP) technique is better alternative to overcome the disadvantage of other type of pavement the continuous reinforced concrete pavement it is clear from the name continuous reinforcement is provided. These reinforcement provided in longitudinal as well as transverse direction, without transverse joint(theoretically) except terminal joints and construction joints necessitated by existing conditions at the site.

Designing a CRCP involves the dimensioning of pavement thickness, longitudinal and transverse reinforcement, slab width construction joints, shoulders, climatic and foundation parameters. In CRCP, reinforcement used to keep the cracks closed and tight together. The demerits in using CRCP as a paving alternative is its high initial cost due to the large amount of reinforcing steel used in this type of pavement.

The following two basic types of concrete pavements and flexible pavement are designed and cost comparisons were made at initial direct cost and LCC basis to assess the economic benefits of

CRCP over other pavement types.

1. Jointed plain concrete pavements (JPCP)

2. Continuously reinforced concrete pavements (CRCP)

3. Flexible pavement

II. OBJECTIVES OF THE STUDY

- To determine the thickness of CRCP and JPCP according to traffic volume environmental and temperature condition
- To determine the percentage and spacing and number of longitudinal and transverse reinforcement of JPCP and CRCP with the help of MS-excel sheet
- Study the performance of CRCP and also study its failure which affect its strength
- Study the duration of maintenance required and fuel consumption cost of JPCP and CRCP

III. SCOPE OF THE STUDY

- CRCP is a maintenance free pavement so this type of pavement can be used at where the maintenance is difficult so in future these type of pavement are very helpful to use because it also reduces the delay cost(because maintenance free pavement)
- In CRCP theoretically there is no transverse joints so due to less number of joints the riding comfort is very good. In present choose of path is decided on basis of length and comfort of that road so these pavements are very helpful
- CRCP is used where heavy urban traffic corridors where traffic over the service life of the pavement can be on the order of tens of millions of equivalent load repetitions. So in future these pavement are helpful because traffic is increasing at a big rate day by day
- Fuel consumption is low in CRCP due to good riding quality. Price of petrol and vehicle service is very expensive now a days so these pavement are very helpful

IV. IMPORTANCE OF RESEARCH TOPIC

- The topic “Cost analysis of Continuously Reinforced and Conventional Concrete Pavement " has been selected for determine the demonstrate superior long-term performance of JPCP & CRCP (typical design service lives are 30-40 years) and cost-effectiveness
- In CRCP there are no numerous transverse joints and widths if transverse cracks are narrow infiltration of water to foundation is minimal
- Continuously Reinforced Concrete Pavement (C.R.C.P) is used for roads carrying very high volume of commercial traffic and where maintenance of road is difficult
- 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

V. METHODOLOGY

Steps for finding the initial cost of JPCP & CRCP are given below:

- Firstly fix the design life, grade of concrete, steel grade, traffic density, Maximumtemperaturedifferential etc.
- Then find the design traffic for 4-lane highway with the help of IRC-58 from this code we will take the value of VDF and LDF.
- Thickness of JPCP is designed on basis of graph given in Volume 7, Section 2, Part 3 of HD 26/94 of British code.
- Thickness of CRCP is designed on basis of graph given in Volume 7, Section 2, Part 3 of HD 26/94 of British code
- Make an excel sheet for finding the percentage and spacing of longitudinal bars and transverse bars with detailing
- Calculate the quantity of reinforcement required
- Calculate the quantity of concrete required

- Calculate the material cost with the help of Unit rates considered for estimation of pavement cost has been shown in **Table I**
- Calculate the labour cost
- Calculate the Interest during Construction
- Calculate initial cost
- Compare initial cost of JPCP and CRCP

VI. DESIGNSTANDARD

VI.I Design Parameters for Typical Design

Brief details of design and cost estimation of a typical 4 Lane (14 m wide) carriageway pavement has been presented below along with cost comparison of CRCP and JPCP.

The following design parameters are considered for design:

30 Years for RigidPavements

Trafficdensity	5000Vehicles/dayon4-lane
Concretegrade	M40
Gradeofsteel	Fe500
Maximumtemperaturedifferential	21 °C
Differencebetweenmean temperatures of the slab atthetime of construction andcoldestperiod	30°C

VI.II Calculation of Design Traffic in Msa

TrafficIntensity	5000Vehicles/Day
CommercialVehicles	0.75x5000=3750Vehicles/Day (Assuming 75% of theTraffic)
DesignTrafficfor4LaneDivided CarriageWay	3750x0.50=1875 Vehicles/Day
Trafficattheendof3YearConstruction Period	$1875 \times (1+0.075)^3 = 2329$
Trafficattheendof30Year ConstructionPeriod	$2329 \times 365 \times (1+0.075)^{30}/0.075$ =99245813
Design traffic	99.24 msa
Vehicle damage factor	3(for safe side)
Design traffic	99.24 x 3 = 297.72 msa

VI.III Thickness Design

FOR JPCP

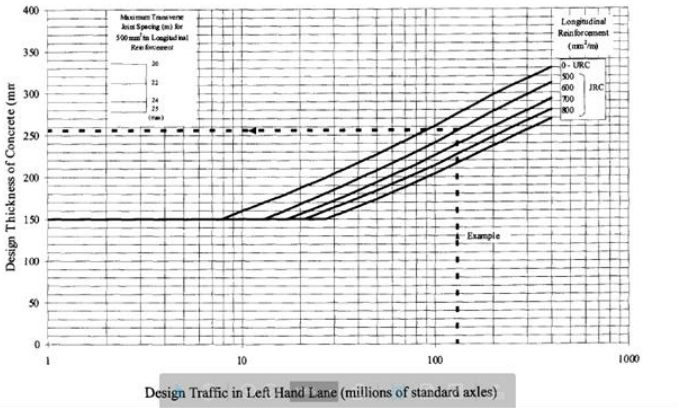

Figure I Thickness of Jpcp According to Msa

Design traffic calculated is 300 msa. For finding the design thickness for JPCP we use Volume 7, Section 2, Part 3 of HD 26/94 of British code in which Design traffic influences the thickness requirement.

Design traffic 300 msa

Longitudinal reinforcement 500 mm^2/m

From **fig I** thickness for 300 msa traffic with 500 longitudinal reinforcement is approx. 300 mm

Thickness for JPCP = 300 mm

FOR CRCP

Design traffic influences the thickness requirement

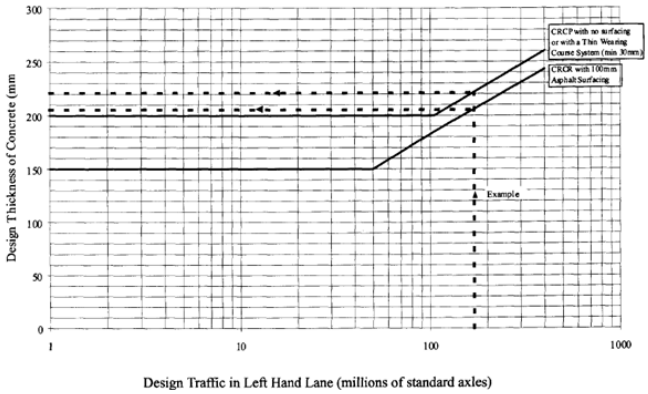

Figure II Thickness of Crcp According to Msa

Design traffic calculated is 300 msa. For finding the design thickness for CRCP we use Volume 7, Section 2, Part 3 of HD 26/94 of British code in which Design traffic influences the thickness requirement.

Design traffic 300 msa

For CRCP with no surfacing

From **fig II** thickness for 300 msa traffic without any surfacing is approx. 250 mm

Thickness for CRCP = 250 mm

VII. Calculation ofReinforcement & Concrete

VII. ICRCP

Now insert the thickness, width of pavement, dia of longitudinal bar and dia of transverse bar as an input (as shown in **fig. III**).

Given data for crcp pavement		unit
thickness	250	mm
concrete grade	40	N/mm^2
width of pavement	7	m
longitudnal steel %	0.7	
steel grade	500	N/mm^2
diameter of longitudnal bar	20	mm
leaving space for bars from edge	10	cm
diameter of transverse bar	12	mm

Figure IIIInput Data Changed Into Comfortable Units

OUTPUT

From MS-excel with the help of formulas putting in cells you can get the spacing and percentage of longitudinal and transverse reinforcement from **fig IV**

Longitudnal steel design	
steel required	61.25
no. of steel bars	20
spacing of bars	17.36842
transverse steel design	
% of transverse steel	0.02016
sapcing of bars	224.2857

Figure IV Percentage and Spacing of Longitudinal and Transverse Reinforcement

CALCULATION AND RESULTS

Percentage of longitudinal reinforcement = 0.7

Dia of longitudinal bar = 20 mm

NO.of bar = 20

Spacing = 173 mm

Percentage of transverse reinforcement = 0.02016

Dia of transverse bar = 12 mm

Spacing = 224 cm

For 1 km length of road and take a section of 3.5 m wide and 250mm thick

All values are in meter

Volume of steel = longitudinal reinforcement volume + transverse reinforcement volume

= 1000 * 3.14* (.01) ^2* 20 + 3.5 * 3.14* (0.006) ^2*45

= 6.28 + 0.0178

= 6.2978 cum

Volume of concrete = total volume of section – volume of steel

= 1000*3.5*0.25 – 6.2978

= 868.7 cum

VII. IIJPCP

Now insert the thickness, width of pavement, dia of longitudinal bar and dia of transverse bar as an input (as shown in **fig. V**) in excel sheet

INPUT

Given data for jpcp pavement		unit
thickness	250	mm
concrete grade	40	N/mm^2
width of pavement	7	m
longitudnal steel %	0.0005	
steel grade	500	N/mm^2
diameter of longitudnal bar	25	mm
diameter of transverse bar	10	mm

Figure V Give Thickness, Width of Pavement and Dia of Bars

OUTPUT

From MS-excel with the help of formulas putting in cells you can get the spacing and length of longitudinal and transverse reinforcement from **fig VI**

Longitudnal steel design		
length of bar	45	cm
spacing of bars	30	cm
transverse steel design		
length of bar	36	cm
spacing of bars	55	cm

Figure VILength and Spacing of Longitudinal and Transverse Reinforcement

CALCULATION AND RESULTS

For 1 km length of road and take a section of 3.5 m wide and 300mm thick

All values are in meter

Contraction joint is provided at 5m

So in 1 km no. of contraction joint =1000/5

= 200

No. of dowel bars in transverse direction = 3.5/0.3

= 12

No. of tie bars = 1000/0.55

= 1819

Volume of steel = longitudinal reinforcement volume + transverse reinforcement volume

= 0.45 * 3.14* (0.025) ^2* 12*20 + 3.14* (0.005) ^2 * 0.36 * 1819

= 0.529 + 0.05138

= 0.58 cum

Volume of concrete = total volume of section – volume of steel

= 1000*3.5*0.3 – 0.58

= 1049.42 cum

VIII. COSTCOMPARISON

VIII.I Initial Cost

Initial direct cost of plain concrete and continuously reinforced concrete were calculated with the help of Unit rates considered for estimation of pavement cost shown in **Table I**

Table I Unit rates considered for estimation of pavement cost

SL	Material	Units	Rate (rs.)
1	Pavement Quality Concrete (PQC)	Cum	4000
2	Reinforcement Steel – Basic cost	Tonne	21000
3	Extra for corrosion resistant property	Tonne	800
4	Reinforcement cost in RCC	Tonne	28893
5	Dry lean concrete (with & without fly ash)	Cum	2400
6	Drainage layer (DL)	Cum	1000
7	Granular sub base (GSB)	Cum	850
8	Wet mix macadam (WMM)	Cum	1400
9	Water bound macadam (WBM)	Cum	900
10	Dense bituminous macadam (DBM)	Cum	4000
11	Bituminous concrete (BC)	Cum	4500
12	Premier granular layer	Sq.m	16
13	Track coat on primed granular layer	Sq.m	10.00
14	Track coat on bituminous layer	Sq.m	5.00

Calculation for JPCP

For 1 km length of road and take a section of 3.5 m wide and 300mm thick

Density of steel = 8000 kg/cum

Steel content in 1 km section is = 0.58 cum

Mass of steel = 8000* 0.58

= 4640 kg

1 ton = 1000 kg

So, in 4640 kg steel = 4.64 ton

From **table I** reinforcement cost is = 28893 Rs/ ton

Cost of steel in JPCP = 28893* 4.64

= 134063.52 Rs

Concrete content in 1 km section is = 1049.42 cum

From **table I** concrete cost is = 4000 rs/ cum

Cost of concrete in JPCP = 1049.42* 4000

= 4197680 Rs

Material cost in JPCP = cost of steel + cost of concrete

= 134063.52 + 4197680

= 4331743.52 Rs

This is the cost for 1 lane 3.5 m section

For, 14 m 4-lane highway

Material cost = 4331743.52*4

= **173.27 lakh**

Calculation for CRCP

For 1 km length of road and take a section of 3.5 m wide and 250mm thick

Density of steel = 8000 kg/cum

Steel content in 1 km section is = 6.2978 cum

Mass of steel = 8000* 6.2978

= 50382.4 kg

1 ton = 1000 kg

So, in 4640 kg steel = 50.38 ton

From **table I** reinforcement cost is = 28893 Rs/ ton

Cost of steel in JPCP = 28893* 50.38

= 1455629.34 Rs

Concrete content in 1 km section is = 868.7 cum

From **table I** concrete cost is = 4000 rs/ cum

Cost of concrete in JPCP = 868.7* 4000

= 3474800 Rs

Material cost in JPCP = cost of steel + cost of concrete

= 1455629.34 + 3474800

= 493029.34 Rs

This is the cost for 1 lane 3.5 m section

For, 14 m 4-lane highway

Material cost = 493029.34 *4

= **197.21 lakh**

VIII.II Labour Cost

For JPCP

It is observed from standard labour requirement

Unskilled labour required = 24.2

Skilled labour = 7

According to Haryana labour wages cost per day is

Skilled labour = 393.2

Unskilled labour = 339

Total labour cost per day for JPCP = 24.2*339 + 7*339

= 10576.8

Assume approx. 100cum concrete laid by labour per day

So for 1 km long 300mm thick and 14 m wide

Volume = 1000*0.3*14

= 4200 cum

No. of days required for constructing 4200cum = 4200/100= 42 days

Take approx. 50 days for safety factor

So total labour cost for JPCP = 50*10576.8

= **5.28 lakh**

For CRCP

It is observed from standard labour requirement

Unskilled labour required = 37

Skilled labour = 15

According to Haryana labour wages cost per day is

Skilled labour = 393.2

Unskilled labour = 339

Total labour cost per day for CRCP = 37*339 + 15*339

= 17628

Assume approx. 80cum concrete laid by labour per day

So for 1 km long 250mm thick and 14 m wide

Volume = 1000*0.25*14

= 3500cum

No. of days required for constructing 3500cum = 3500/80= 44 days

Take approx. 50 days for safety factor

So total labour cost for CRCP = 50*17628

= **8.82 lakh**

VIII.III Interest during Construction

Take 4% of (material + labour) cost

So for JPCP =4% of (173.27+5.28)

= **7.142 lakh**

So for CRCP =4% of (197.21+8.82)

= **8.2412 lakh**

IX. RESULTS

From **table II**it is observed that

- The initial cost of CRCP is 15.38% more than CRCP
- More skilled labour required in CRCP
- Material cost is 11.38% more than CRCP

Table II Initial Cost Comparison between CRCP & JPCP

Pavement types **Item of cost**	**JPCP**	**CRCP**
Material	173.27	197.21
Labour	5.28	8.82
Interest during Construction	7.14	8.24
Initial Direct Cost	185.7	214.27
Extra indirect initial cost over JPCP	_	28.57
Percentage of initial direct cost	100%	115.38%

X. CONCLUSION

From the above study following conclusion can be drawn

1. CRCP saves fuel & money: The major part of the benefit
2. The initial cost of CRCP is 15.38% more than CRCP(table 2)
3. More skilled labour required in CRCP as compared to JPCP
4. Material cost is 11.38% more than CRCP due to high requirement of reinforcement
5. Thickness of CRCP is less than JPCP in JPCP we need 300 mm thick pavement but in CRCP 250 mm thick pavement is needed
6. Excellence Qualities: CRCP provides all the attributes a roadway designer seeks: Strength, Durability, Smoothness, Traction, Very Low Maintenance require, Longer Life and Low Life Cycle Cost. Further, it offers much better riding quality (smooth surface).
7. Disadvantage of CRCP is its high initial cost & difficulty in repair works required (in comparison of JPCP) to be done if not constructed properly.

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