Engineering/Science/Technology Civil/GET/TE

Effects of Warping Stresses on Rigid Pavements – An experimental investigation

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ARTICLE HISTORY
Received: 02 Apr 2017
Revised: 10 Apr 2017
Accepted: 20 Apr 2017
Available online: 10 Jun 2017

ABSTRACT

To reduce the cost of construction of rigid pavements, alternative materials are sought for and therefore fly-ash is used as a replacement for cement in cement concrete pavements which gives increased strength, thereby reduction in thickness of pavement is achieved. This is illustrated by designing two pavements, one: conventional and other: fly-ash replaced cement concrete pavement. The rigid pavement undergoes temperature, wheel load and frictional stresses. The temperature stresses depend upon the Temperature differential between the top and bottom of the slab, which is found out using thermocouples placed in the concrete at 2.5 centimetres from top and bottom of the concrete slab.

Key words: Rigid Pavements, Flyash, Temperature stresses, Mix Design, Thickness reduction.

2455-2062 | http://dx.doi.org/xx.xxx/xxx.xxx.xxx |

I. INTRODUCTION

Transportation is a non-separable part of any society. It exhibits a very close relation to the style of life, the range and location of activities and the goods and services which will be available for consumption. Advances in transportation has made possible changes in the way of living and the way in which societies are organized and therefore have a great influence in the development of civilizations.

II. OBJECTIVES OF THE RESEARCH

The object of the project is to reduce the cost of the rigid pavement by replacing certain quantity of cement with flyash by reducing the effect of warping stresses on rigid pavement.

Out of the several factors which influence the thickness of the pavement the only factors which can be improved by a civil engineer are

a) Temperature differential

b) Concrete characteristics

c) Characteristics of sub-base and sub-grade

Of the three factors, this paper aim, is to study the temperature differential on different pavements which are made up of one with conventional concrete and other with replacing the cement with 30% of flyash, considering all other factors to be identical for both the pavements, temperature variation is observed on both the pavements and the pavement that gives good results for warping stresses is identified.

III. METHODOLOGY

- One pavement is laid with conventional concrete and other replacing 30% of cement with flyash.
- Four points are selected on these pavements that are corner, centre and two edges.
- To know the temperature difference between top and bottom at these points, thermocouples are placed at 2.5 cm from top and bottom.
- Further, warping stresses are calculated using these temperature differences as per IRC guidelines.
- Finally, economical thickness for both pavements is calculated and compared.

IV. PROPERTIES OF MATERIAL

A) Cement Concrete Materials:

Cement:

Specific gravity = 3.108

Coarse Aggregate:

Specific gravity = 2.56

Water absorption = 1.157%

Flakiness index = 14.28%

Elongation index = 53%

Fine Aggregate:

Specific gravity = 2.6

B) Sub-grade Soil:

Proctor density:

Optimum moisture content (OMC) = 9% (figure 1)

Maximum dry density @ OMC = 1.934 g/cc

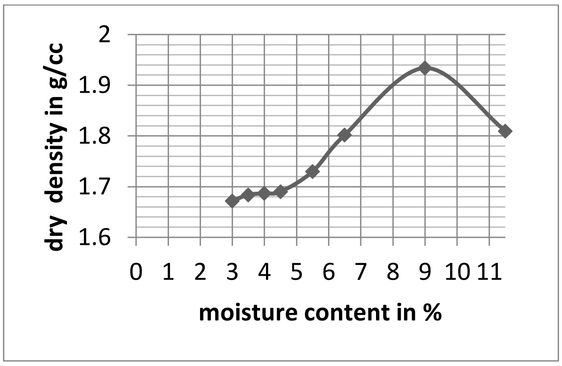

Figure 1: Optimum Moisture Content

California Bearing Ratio (CBR):

CBR value at 2.5 mm penetration = 14.2

CBR value at 5.0 mm penetration = 13.6

V. CASTING OF RIGID PAVEMENTS

After the tests on CA, FA, Cement and Water, according to the test results mix design is done for conventional concrete and mix design for concrete replacing cement with 30% flyash.

A trench of was dug up to 60cms, and sieved soil is laid in the trench and well compacted up to 30cms. According to mix design cement, coarse aggregates, fine aggregates and water are mixed in proportion and laid in the trench up to 30cms. While laying the concrete, thermocouples are inserted into the concrete at 2.5cms from bottom and at 2.5cms from top,fortwo adjacent edges, corner and centre. These thermocouples which are inserted at 2.5cms from top and bottom to know the temperature difference between top and bottom of 25cms slab.

These thermocouples are connected to digital monitors which shows temperature at a point in centigrade with accuracy of 0.1°C, this digital monitor has 8-way switch. When the switch is at particular position, it shows readings corresponding to a point as shown in table 1.

Table 1: Switch position indicating a point in the pavement

Switch at	Position indicated on pavement
Point 1	Bottom corner
Point 2	Bottom longer side edge
Point 3	Bottom interior
Point 4	Bottom shorter side edge
Point 5	Top corner
Point 6	Top longer side edge
Point 7	Top interior
Point 8	Top shorter side edge

By rotating the switch the temperature to different positions, the difference in temperature between the top and bottom at a particular point is found, thereby warping stresses are found.

Same procedure is laying of concrete is done by replacing 30% cement with flyash, and thermocouples connected to it, and temperatures and warping stresses at various positions are found.

For these pavements curing was done for 28days before readings were taken. The readings were taken six times a day at 7.00am,10.00am,12.00pm,2.00pm, 4.00pm and at 10.00pm for Seven days.

Warping stresses are calculated for both the pavements, using CBR value of the soil and flexural strength of concrete thickness of both the slabs is found.

VI. SAMPLE OBSERVATIONS

Sample observations for one day (11/04/2012) have been shown in the table 2. All readings are in degree centigrade.

Table 2 Sample observations

Time	Room Temperature	Flyash pavement				Cement pavement		
		Region	Top	Bottom	Difference	Top	Bottom	Difference
7.00 A.M.	28.5	corner	26.2	27.7	**1.5**	25.3	27.6	**2.3**
		Edge1	27.4	28.7	**1.3**	26.6	28.8	**2.2**
		Interior	27.3	29.2	**1.9**	27.6	24.8	**2.8**
		Edge 2	26.6	27.8	**1.2**	26.1	28.2	**2.1**
10.00 A.M.	38.0	corner	39.6	30.9	**8.7**	39.0	29.7	**9.3**
		Edge1	39.5	31.3	**8.2**	40.8	31	**9.8**
		Interior	41.9	31.7	**10.2**	42	30.5	**11.5**
		Edge 2	42.4	31.5	**10.9**	41.7	30.4	**11.3**
12.00 P.M.	40.0	corner	35.9	28.2	**7.7**	35.7	27.4	**8.3**
		Edge1	37.2	29.2	**8.0**	37.4	28.9	**8.5**
		Interior	40.2	30.6	**9.6**	41.7	31.5	**10.2**
		Edge 2	37.9	28.8	**9.1**	37.4	28.0	**9.4**
2.00 P.M.	41.0	corner	41.5	31.9	**9.4**	41.5	31.1	**10.4**
		Edge1	42	32.4	**9.6**	44	32.5	**12.5**
		Interior	44.4	33.1	**10.3**	43.2	30.1	**13.1**
		Edge 2	42.6	32.3	**10.3**	41.9	30	**11.9**
4.00 P.M.	39.3	corner	35.1	30.8	**4.3**	35.6	30.7	**4.9**
		Edge1	37.8	31.4	**6.4**	39.1	32.2	**6.9**
		Interior	41.3	33.9	**7.4**	41.0	33.2	**7.8**
		Edge 2	37.4	32.2	**5.2**	37.4	31.4	**6**
10.00 P.M.	36	corner	33.4	33.2	**0.2**	31.4	31.0	**0.4**
		Edge1	32.4	32.1	**0.3**	33.1	32.6	**0.5**
		Interior	33.1	32.6	**0.5**	34.4	33.8	**0.6**
		Edge 2	31.2	31.4	**0.2**	32.1	31.7	**0.4**

VII. CALULATION FOR THICKNESS

Design wheel load = 4100kg

At present traffic intensity = 200CV/day

Modulus of elasticity if concrete (E) = 2.95×10^5

Poisons ratio of concrete (ų) = 0.15

Coefficient of concrete (ά) = 10×10^{-6} per °C

Annual rate of growth of traffic (r) = 7.5%

Design life = 20years

Tyre pressure = 7.2kg/cm^2

Radius of wheel load distribution (a) = 15cm

Joint spacing (contraction joint) (L) = 4.5m

DATA FROM TESTS:

CBR of soil (soaked) = 14.2%

Modulus of sub grade reaction For CBR of 14.2% = 6.088kg/cm^2/cm

Effective modulus of sub grade reaction over 100mm DLC= 37.124kg/cm^2/cm

Flexural strength of Conventional concrete = 40.57kg/cm^2

Flexural strength of concrete with30% cement replaced by fly-ash concrete=42.19kg/cm^2

The Conventional and Fly-ash Cement Concrete pavement design calculations are shown in tables 3 and 4 respectively.

Table 3 Conventional cement concrete pavement thickness design

	Trial I	**Trial II**	**Trial III**
Assumed thickness	22 cm	21 cm	**21.6 cm**
Calculated radius of relative stiffness	51.81 cm	50.04 cm	51.11 cm
Radius of resisting section	14.20cms	14.12 cms	14.16 cms
Ratio (L/l)	8.68	8.99	8.80
Bradbury constant for ratio (L/l)	1.079	1.08	1.079
Temperature stress at edge-calculated	25.625 kg/cm^2	25.64 kg/cm^2	25.625 kg/cm^2
Residual strength available in concrete	= 40.57-25.625 = 14.95 kg/cm^2	= 40.57 – 25.64 = 14.93 kg/cm^2	= 40.57 – 25.625 = 14.95 kg/cm^2
Stress due to edge loading	14.51 kg/cm^2	15.64 kg/cm^2	14.95 kg/cm^2
Factor of Safety	1.03 (safe)	0.95 (unsafe)	1.0 (safe)
Corner load stress	16.70 kg/m^2		17.18 kg/m^2
Corner temperature stress	10.02 kg/m^2		11.12 kg/m^2
Corner stresses	26.72 kg/m^2		28.40 kg/m^2
Check	Safe		Safe
Comment	Uneconomical	Redesign	Economical

Table 4 Fly-ash replaced (30%) cement concrete pavement thickness design

	Trial I	**Trial II**	**Trial III**
Assumed thickness	18.5 cm	17.15 cm	**17.8 cm**
Calculated radius of relative stiffness	45.5 cm	43.64 cm	44.21 cm
Radius of resisting section	14.012 cms	13.99 cms	14.01cms
Ratio (L/l)	9.89	10.31	10.17
Bradbury constant for ratio (L/l)	1.076	1.068	1.071
Temperature stress at edge-calculated	22.05kg/cm^2	21.89 kg/cm^2	21.93 kg/cm^2
Residual strength available in concrete	20.14 kg/cm^2	20.3 kg/cm^2	20.26 kg/cm^2
Stress due to edge loading	19.05 kg/cm^2	20.78 kg/cm^2	20.26 kg/cm^2
Factor of Safety	1.06 (safe, uneconomical)	0.976 (unsafe)	1.0 (safe)
Corner load stress	21.54 kg/m^2		22.73 kg/m^2
Corner temperature stress	9.23 kg/m^2		9.36 kg/m^2
Corner stresses	30.77 kg/m^2		32.09 kg/m^2
Check	Safe		Safe
Comment	Uneconomical	Redesign	Economical

VIII. RATE ANALYSIS

This rate analysis is carried out for the comparison of economics of the fly-ash and conventional concrete pavement. This analysis done by assuming a two lane trail road of width=7.0m, thickness 25cm on a stretch of 1km.

The material costs are taken from present market conditions are as follows:

Sand : Rs.600/cu.m.

Coarse aggregate : Rs.1000/cu.m.

Cement : Rs.300/50kg bag

Fly-ash : Rs.60/30kg bag

And the material standards per 1 cu.m. are:0.92cu.m. of broken stone, 0.46cu.m. of sand, 440 kgs. of cement. The tables 5 and 6 show the rate analysis for conventional and fly-ash concrete pavement of 1750 cu. m. quantity

Table 5 Rate analysis for conventional concrete pavement of1750 cu. m.quantity

S. No.	**Description**	**Quantity**	**Rate**	**Per**	**Amount**
1	Cement	$\frac{440 \times 1750}{50}$	300	bag	46,20,000
2	Sand	0.46×1750	600	Cu.m.	4,83,000
3	Coarse aggregate	0.92×1750	1000	Cu.m	16,10,000

Total Rs.67,13,000/-

Adding 5% of total to include the cost of water,machinery,manpower

Therefore, total cost =6713000+335650

=Rs.70, 48, 650/-

Table 6 Rate analysis for fly-ash concrete pavement of 1750 cu. m. quantity

S. No.	Description	Quantity	Rate	Per	Amount
1	Cement	$\frac{308 \times 1750}{50}$	300	Bag of 50kg	32,34,000
2	Fly-ash	$\frac{132 \times 1750}{50}$	60	Bag of 30 kg	4,62,000
3	Sand	0.46×1750	600	Cu.m.	4,83,000
4	Coarse aggregate	0.92×1750	1000	Cu.m.	16,10,000

Total Rs.57,89,000/-

5% of the total is added, to include the cost of water,machinery andman-power.

Therefore, total cost =57,89,000+2,89,450 =Rs.60,78,450/-

IX. CONCLUSION

Analysis was performed on both pavements, one is conventional concrete and other is fly-ash concrete pavement and following observations are drawn:

•From the observations, temperature differential is more in normal concrete pavement when compared to fly-ash concrete pavement.

•Due to the replacement of 30% of cement with from the fly-ash, the reduction in the pavement thickness is 4.6cm when warping stresses are alone considered.

•From the rate analysis, the percentage of reduction in the cost due the replacement of fly-ash is about 13.7%

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