Study of cracks on Rigid Pavement resting on Black Cotton Soil through Paithan Case Study

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Abstract- **Rigid Pavement is made up of cement concrete. Load transfer in Rigid Pavement is by slab action. Challenges arise when the pavement is on Black Cotton Soil as it has properties of Swelling and Shrinkage. Pavement at town Paithan in Maharashtra has underwent severe cracks. A study of this particular pavement has been undertaken. In this work, analysis of pavement is carried out considering swelling and shrinkage as the major concerns for the pavement. EPS Geofoam is studied and its results have been discussed as they both are options for mitigating swelling pressure. Wherever road is on high embankment Geofoam could be used. Results of analysis of cracks match with those observed during field visit.**

Index Terms— **Rigid Pavement, Slab action, Swelling, Shrinkage, EPS Geofoam.**

I. INTRODUCTION

The first concrete pavement was built in Bellefontaine, Ohio in 1893. It consists of three layers i.e. surface layer, base layer and the sub grade. Rigid pavements possess noteworthy flexural stiffness or flexural rigidity. These pavements transfer load through slab action but not grain to grain transfer as in case of flexural pavements. Rigid pavements are placed directly on the prepared sub grade or on a single layer of granular or stabilized material. In this case study, black cotton soil was brought from the site near damaged concrete pavement road in Paithan, a Taluka place in Aurangabad District of Maharashtra. The pavement had undergone longitudinal as well as lateral directional cracks and also there was relative subsidence between two slab panels. Also causes of damage and subsequent solutions were suggested in this report.

II. AIMS AND OBJECTIVES OF STUDY

1. Study the crack pattern of Rigid Pavement of Paithan Road.
2. Find out causes for the cracks it underwent.
3. Recommend remedial measures through calculations.

III. DETAILS OF CASE STUDY

In this work, case study has been taken of that of damaged cement concrete pavement at Paithan a taluka place in Aurangabad district of State of Maharashtra.

a) Road constructed in: 2013.
b) Length of road: 1.4 km.
c) Name of road: Garden Road.
d) Type of pavement: Concrete pavement.

Field Observations:

Figure No.1 GPS location of damaged concrete pavement.

Figure No.2 Crack in the direction of traffic.

Figure No.3 Crack in direction perpendicular to traffic

Figure No.4 Cracks on pavement repaired by filling them with bitumen

Figure No. 5

IV ANALYSIS WITH SWELLING AS MAIN CONCERN

The road is assumed to be simply supported. Self-weight of the pavement slab is considered. Each panel is of dimension 4.5x3.75x0.4m. In this analysis swelling pressure is given utmost priority.

Case 1: Forces acting on the beam AB are Self-weight of 36 kN/m and Swelling Pressure of 627.78 kN/m/m and they both act on transverse cross section. Cross section having dimensions as 3.75 x 0.4m.

Case 2: Forces acting on the beam AB are Self-weight of 43.2kN/m and Swelling Pressure of 627.78 kN/m/m and they both act on longitudinal cross section. Cross section having dimensions as 4.5 x 0.4m.

Case 3: Forces acting on the beam AB are Self-weight of 36kN/m, Swelling Pressure of 627.78 kN/m/m and two point loads of that of the lightest vehicle taken from the axle load spectrum in transverse cross section. Cross section having dimensions as 3.75 x 0.4m.

Case 4: Forces acting on the beam AB are Self-weight of, Swelling Pressure and two point loads of that of the heaviest vehicle taken from the axle load spectrum in transverse cross section. Cross section having dimensions as 3.75 x 0.4m.

Case 1 is solved here for sample calculations, other three cases are analysed in the same way as that of case 1.

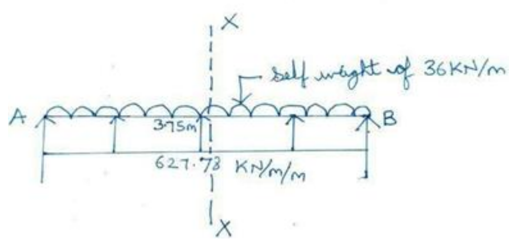

Figure No.6 Pictorial representation of Case 1.

Self weight of slab = 24BD = 36kN/m
$R_A = R_B = 1109.59kN$
Now, flexural strength of concrete= $0.7\sqrt{fck}$

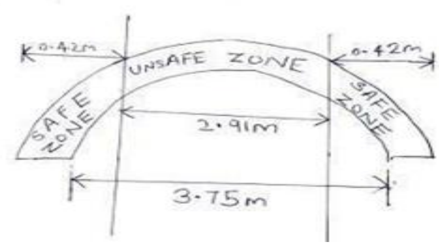

Figure No.7 Representation of Safe and Unsafe zones on road.

SAFE ZONE: It is the zone in which the bending stress is less than that of flexural strength of concrete.

UNSAFE ZONE: It is the zone in which the cracks propagate.

Bending stress generated > (flexural strength). Its unsafe, Cracks will occur.

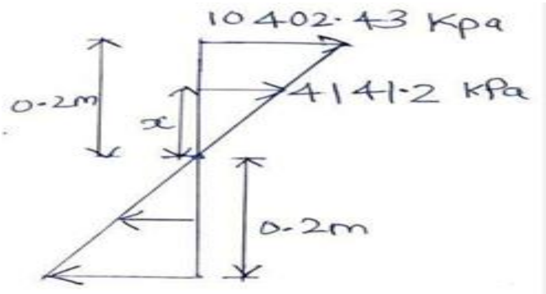

Figure No.8 Calculation of depth of crack.

Depth of crack from top surface at center

= 0.2 – 0.080= 0.120m or 120mm.

V DISCUSSION

In the four cases, Case 1, Case 3, Case 4 are the cases which are responsible for the longitudinal direction cracks, parallel to direction of traffic. Case 2 is responsible for lateral direction cracks. Case 1 and Case 2 are the governing cases. The reason behind it is that the relative maximum bending moment occurs in these cases.

VI MITIGATION OF SWELLING PRESSURE USING GEOFOAM

Table No.1 Flexural strength of various types of Geofoam.

Sr. No.	Type	Flexural Strength kPa	Size
1	EPS 12	69	2m x 0.75m x 0.75m
2	EPS 15	172	
3	EPS 19	207	
4	EPS 22	240	2m x 0.75m x 0.75m
5	EPS 29	345	
6	EPS 39	414	
7	EPS 46	517	

In the calculations, as Geofoam is lightweight material, for calculations purpose its weight is not considered.

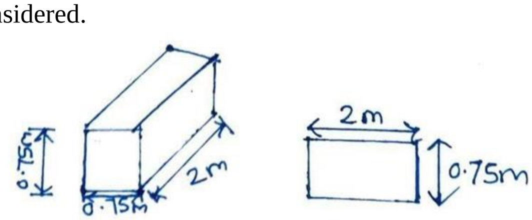

Figure No.9 Size of one Geofoam block.

Table No.2 Moment resisted by unit Geofoam block.

Type	Moment resisted by unit Geofoam block (kNm)
EPS 12	12.9375
EPS 15	32.25
EPS 19	38.81
EPS 22	45
EPS 29	64.687
EPS 39	77.625
EPS 46	96.9375

Table No. 3 Moment Resisted by one geofoamlayer acting as a combined unit.

Type	Moment resisted by one geofoam layer acting as a combined unit (kNm)
EPS 12	24.257
EPS 15	60.468
EPS 19	72.773
EPS 22	84.375
EPS 29	121.28
EPS 39	145.546
EPS 46	181.757

For Case 1:

Table No.4 Calculation of no. of blocks required for case 1.

Maximum moment (kNm)	Type of Geofoam	Optimum depth of Geofoam (m)	No. of layers needed	Total No. of blocks needed per panel	Total no. of blocks required for four lane road
1040.243	EPS 12	4.91	6.547	39.282	48885
	EPS 15	3.11	4.417	26.502	32981
	EPS 19	2.83	3.773	22.638	28172
	EPS 22	2.63	3.507	21.042	26186
	EPS 29	2.196	2.929	17.574	21870
	EPS 39	2	2.667	16.002	19914
	EPS 46	1.794	2.392	14.352	17861

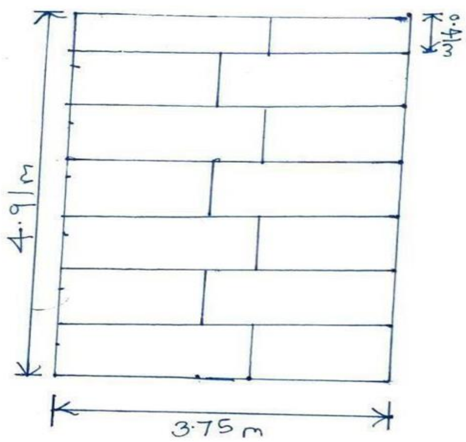

Figure No.10 Installation of Geofoam layer.

Case 2:

Table No.5 Calculation of no. of blocks required for case 2.

Maximum moment (kNm)	Type of Geofoam	Optimum depth of Geofoam(m)	No. of layers needed	Total no. of blocks needed per panel	Total no. of blocks required for four lane road
1479.718	EPS 12	5.34	7.120	35.6	44303
	EPS 15	3.387	4.516	20.780	25860
	EPS 19	3.087	4.116	20.580	25611
	EPS 22	2.867	3.823	19.115	23788
	EPS 29	2.391	3.188	15.940	19837
	EPS 39	2.183	2.911	14.555	18113
	EPS 46	1.954	2.605	13.025	16209

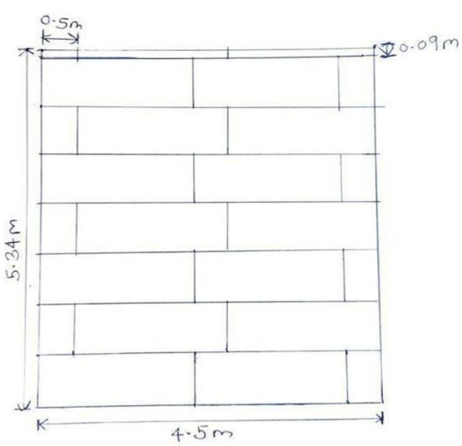

Figure No.11 Installation of Geofoam layer.

Installation of Geofoam will be same in Case 1, 3 and 4 only thing that varies is the layers of EPS Geofoam. Case 2 has different installation. Case 2 will be the governing case as it needs more flexural strength to mitigate swelling pressure.

Reason for different safe zones in different cases:

Cases 1,3 and 4 are dealt with simultaneously, while case 2 is dealt with differently. Safe zone goes on increasing from case 1 to 3 and 4 respectively because the effect of swelling pressure is minimized by the point loads of that of vehicles. But, case 1 is the governing case for longitudinal cracks because safe zone in this case is less than that of cases 3 and 4 respectively. Case 2 is the governing case for lateral or transverse cracks. Water table near the rigid pavement at Pavement is at a depth of 9.1m from ground level. From Case 2 it is seen that the optimum depth of EPS 12 Geofoam is 5.34m and as previously mentioned that water table is at depth of 9.1m from ground level, it can be concluded that there is no interference in the geofoam installation.

Shrinkage of Black Cotton soil:

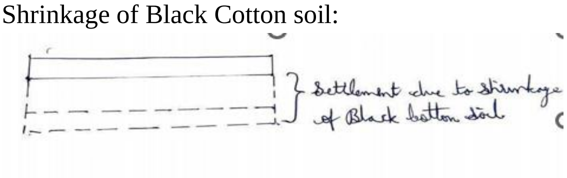

Figure No.12 Shrinkage effect

Shrinkage causes settlement or subsidence, which may be differential. This is the main reason which causes relative subsidence between slabs.

VII SOLUTIONS FOR PREVENTING DAMAGE OF CONCRETE PAVEMENT AT PAITHAN

According to classification of soil and if found expansive soil swelling pressure must be measured. Following are some remedies for preventing such type of damage in future:

- CNS layer must be provided as in these report various thicknesses of CNS layer corresponding to magnitude of swelling pressure.
- Geofoam being light in weight (1% of the weight of soil) is a dependable option to is a dependable option to mitigate swelling pressure, also it is easy in installation.
- Drains must be provided in subgrade soil so that water or moisture gets the route out of the subgrade soil.

VIII CONCLUSIONS

1. Whatever damages to the pavement at Paithan have been occurred, which maybe not only due to expansive soil (Black Cotton soil) but also due to temperature gradient. But the temperature

gradient is not the major culprit because it is failed in just one year. Apart from this, the temperature gradient at Paithan rarely crosses 10ºC. Hence it may be concluded that swelling and shrinkage are the possible reasons for the observed cracks.

2. Wherever road is on high embankment like bridge approaches or flood terrain Geofoam could be used.
3. Results of analysis of cracks match with those observed during field visit.

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