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Sustainable option of Rigid Pavement for Less Traffic Volume Roads in Black Cotton Soil Region

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Abstract: Due to the Submergence/during rainy session, CC Pavements which are constructed on the expansive soils sub grades are getting damaged due to the sub-grade soils are expansive nature. During the submerged condition/at the time of cyclones, Swell pressure develops in the sub-grade expansive soils, If this Swell pressure is more than the combined surcharge weight of Sub base and CC Pavement, Uplift takes place. The swell pressure varies from 0 -2000 KN/sqm (for Bentonite) under the surcharge of 6.9KN/Sqm. The surcharge weight of Granular sub base is 3.0 kN/sqm and CC Pavement is 4.80 KN/sqm resulting total surcharge weight is 7.80 KN/sqm over the sub grade. Due to confined edges of both Sub base and CC Pavement with the shoulder soils, the net uplift due to Swell pressure will be more in the middle of the pavement when compared at the edges. The rate of wetting and drying of the expansive sub grade soils always starts at edges to middle of the pavement. This leads the difference in the swell pressure more in the middle than the edges. Due to the high swell pressure at the centre of the pavement and early drying of the expansive sub grade soils at the edge of the road, longitudinal cracks will be formed almost in the middle of the road. When the expansive soil dries, due to the shrinkage in the sub grade, the pavement tries to settle down. Among both CC Pavement and Sub base, the sub-base over the sub grade will settle first leaving gaps in between CC Pavement and Sub base. At this stage, during the traffic flow, transverse cracks I crocodile cracks occurs. Also, after the formation of longitudinal cracks, the length to breadth ration of CC pavement panel will be double and influence the design of CC Pavement. The failure in the CC Pavement is due rigid and also weak in tension. Based on above observations from literature and field survey it is clear that existing design are not adequate for expansive soil hence an attempt will made to design rigid pavement for village road in expansive soil with modifications in some of existing provisions, Here cement concrete pavement thickness is designed as per existing provisions of IRC SP-62:2014 which is applicable for all category of soil for low volume traffic roads. Traffic survey and present condition of pavement is also studied by considering stress developed in c.c. pavement and checked by “Finite Element Method” using ANSYS software, soil pressure is also considered in design which is the main cause of failure of c.c. pavement in expansive soil region.

Keywords: Expansive soil, Swell pressure, Cement concrete pavement, Sub-grade base, Design of rigid pavement, reinfo rcement.

Introduction:

Expensive soil are mostly found in arid and semi-arid regions and it covers very large area of the world. It covers nearly 20% of the land mass in India and includes almost the entire ocean plateau western Madhya Pradesh, Parts of Gujarat, Andhra Pradesh, Uttar Pradesh especially Bundelkhand belt, Karnatka & Maharastra the swelling soil is commonly known by the name of block cotton soils swelling to occur, these soil initially unsaturated at same water content. If the unsaturated soil gains water content, it swells on the other band it decrease in Water content occur occurs the soil shrinks the presence of mantmorllonite clay in these soil imparts them high swell – shrink potentials. study of expensive soil Expansive clay is a clay soil that have to large volume changes (swelling and shrinking) action that are directly related to changes in water content Soils with a high content of expansive minerals can form deep cracks in drier seasons or years; such soils are called vertisols. Soils with smectite clay minerals, including montmorillonite and bentonite, have the most dramatic capacity. Responsible all clays consist of mineral sheets packaged into layers, and can be classified as either 1:1 or 2:1. These ratios refer to the proportion of tetrahedral sheets to octahedral sheets. Octahedral sheets are sandwiched between two tetrahedral sheets in 2:1 clays, while 1:1 clays have sheets in matched pairs. Mitigation of the effects of expansive clay on structures built in areas with expansive clays is a major challenge in geotechnical engineering. Some areas mitigate foundation cracking by watering around the foundation with a soaker hose during dry conditions. This process can be automated by a timer, or using a soil moisture sensor controller. Admixtures can be added to expansive clays to reduce the shrinkage and swelling characteristic.

Important features of black soil:

1. Regur means cotton – best soil for cotton cultivation.
2. Most of the Deccan is occupied by Black soil.
3. Mature soil.
4. High water absorption capacity.
5. Swells and will become sticky when wet and shrink when dried during summer.
6. Self-ploughing is a characteristic of the black soil as it develops wide cracks when dried.
7. Rich in: Iron, lime, calcium, potassium, aluminum and magnesium.
8. Deficient in: Nitrogen, Phosphorous and organic matter.
9. Colour: Deep black to light black.
10. Texture: Clayey.

RIGID PAVEMENTS:

Considerable work has been carried out for the analysis, design and construction of rigid pavements by various researchers and design engineers. The guidelines have been developed by Indian Roads Congress for the design and construction of cement concrete pavements for village roads in year 2004, named as IRC: SP: 62-2004 which is further revised on 2014. For low traffic volume roads, i.e. village roads and streets, a rural road manual has been introduced by IRC, wherein it is mentioned to prefer cement concrete roads in populated areas/streets to meet out the problems of maintenance due to poor drainage etc. Cement Manufacturer Association of India and Prasad (2007) have shown that cement concrete rigid pavements are cheaper in terms of life cycle cost than flexible pavements. However, the initial construction cost of rigid pavements is much higher than the flexible pavements. Prasad (2007) carried out life cycle cost analysis of the two types of pavements and concluded that the cost

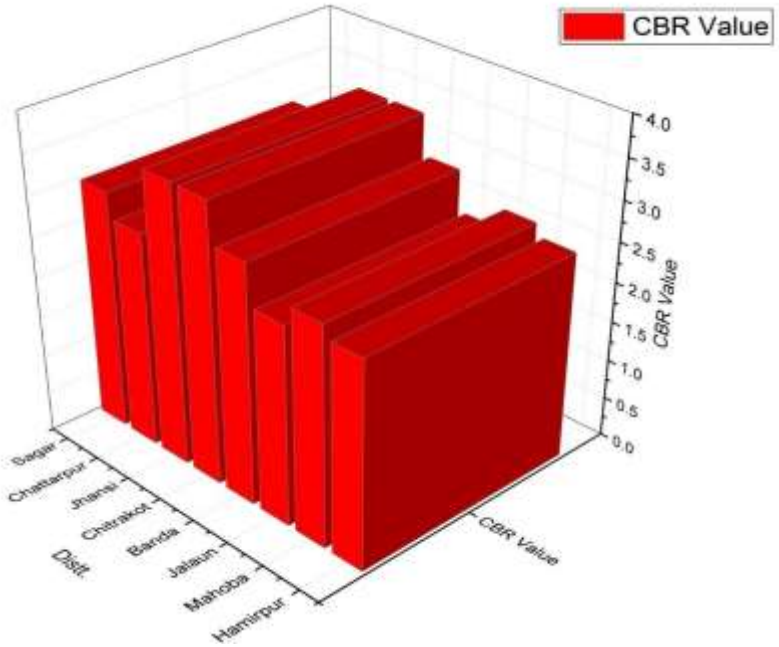
difference between flexible and rigid pavement is negligible considering the savings for the cost of maintenance, vehicle operating cost and fuel. Further, rigid pavement is a better option from climatic and environmental considerations. Also, cement concrete pavement is the best option for locations having cement and fly ash in close proximity when sub-grade soils have low CBR values. A number of joints are provided in rigid pavements to reduce the stress due to change in temperature. Kadiyali and Dandvate (1984) made a comparative study of economics of rigid and flexible pavements and observed that the rigid pavement is far more economical than flexible one based on overall economic consideration. This generalization is valid for all zones of the country and is independent of the sub-grade characteristics. Due to the Submergence/during the cyclones, CC Pavements which are constructed on the expansive soils sub grades are getting damaged due to the sub-grade soils are expansive nature. During the submerged condition/at the time of cyclones, Swell pressure develops in the sub-grade expansive soils, If this Swell pressure is more than the combined surcharge weight of Sub base and CC Pavement, Uplift takes place. The swell pressure varies from 0 -2000 KN/sqm (for Bentonite) under the surcharge of 6.9KN/Sqm. The surcharge weight of Granular sub base is 3.0 kN/sqm and CC Pavement is 4.80 KN/sqm resulting total surcharge weight is 7.80 KN/sqm over the sub grade. Due to confined edges of both Sub base and CC Pavement with the shoulder soils, the net uplift due to Swell pressure will be more in the middle of the pavement when compared at the edges. The rate of wetting and drying of the expansive sub grade soils always starts at edges to middle of the pavement. This leads the difference in the swell pressure more in the middle than the edges. Due to the high swell pressure at the centre of the pavement and early drying of the expansive sub grade soils at the edge of the road, longitudinal cracks will be formed almost in the middle of the road. When the expansive soil dries, due to the shrinkage in the sub grade, the pavement tries to settle down. Among both CC Pavement and Sub base, the sub-base over the sub grade will settle first leaving gaps in between CC Pavement and Sub base. At this stage, during the traffic flow, transverse cracks I crocodile cracks occurs. Also, after the formation of longitudinal cracks, the length to breadth ration of CC pavement panel will be double and influence the design of CC Pavement. The failure in the CC Pavement is due rigid and also weak in tension.

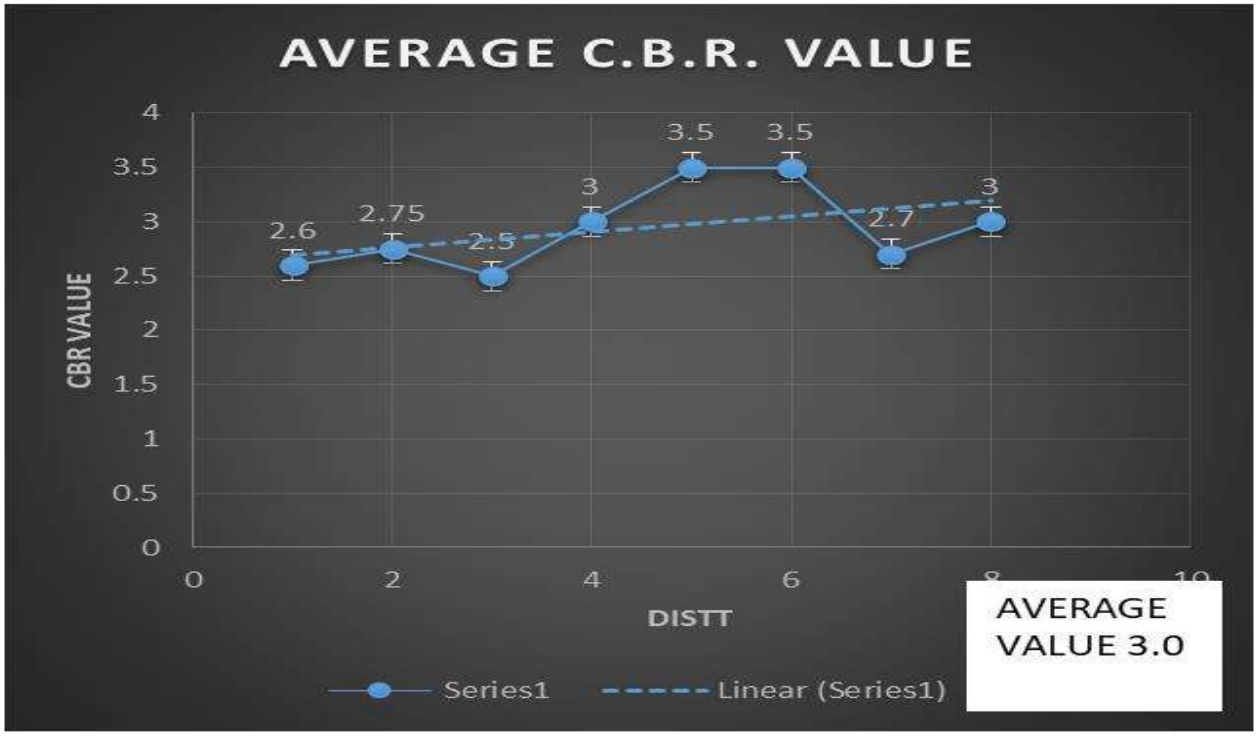
CBR Value in Expansive soil region –

In Expansive soil region no of cement concrete roads are visited to know the performance of existing pavements .CBR value of various roods are collected for further study and it is found that the CBR value of distt like Hamirpur, Mahoba,Jalaun , Banda , Chitrakoot , Chhatarpur , Jhansi and Sagar etc are found between 2.0 to 3.0 . Such subgrade
are very poor in nature and modulus of subgrade reaction K value of soil is between 21 to 28 mpa/M **Average**

Value of CBR of Different Roads for Different Districts Falls in Expansive soil Region

Sr.no.	District	CBR
1.	Hamirpur	2.60
2.	Mahoba	2.75
3.	Jalaun	2.50
4.	Banda	3.00
5.	Chitrakoot	3.50
6.	Jhansi	3.50
7.	Chattarpur	2.70
8.	Sagar	3.00





The Average CBR Value of Black cotton soil area is 3 in average.

Study of performance of existing Plain Cement Concrete Roads:

Performance of ten existing rigid pavement of plain cement concrete (PCC) constructed 2 to 4 years back like ; Laxmi Bai Park to Rameri Marg of Hamirpur , Bidokhar link road in district Hamirpur And Kalpi Madaripur marg to Sohrapur link road of Jalaun , Konch-paretha pahargaon road, Jalaun , Rampura thana gohan marg Jalaun , Rampura thana gohan marg Jalaun , Kalpi-Madaripur to Dahelkhand link road Jalaun , Hamirpur-Kalpi marg to basrehi link road , Jalaun (U.P.) Shahpur link road of Tehsil Chandla Chhatarpur , Sijai Link Road of tehsil lauri distt. Chhatarpur (M.P.) has been taken for the study. The width of the road are 3.0 m. to 3.75 M PQC is made of M30 grade concrete and its thickness varies from 15.0 cm. The thickness of base of lean concrete is 15.0 cm. CBR value of sub grade is 2.05 to 2.95 and corresponding modulus of sub-grade reaction is 25.45 Mpa/m to 33.55 Mpa/m. Length and width of road , provisions in sub base and in base coarse , road side drainage type and year of construction are shown in following table.

Fig. 1 (Plain C.C. pavement sowing surface Crakes)

Fig. 2

S.N.	Name of Road	Length in Km	Width In mtr.	Sub base	Base	CBR	Road Side drainage	Year of Construction
1	Sumerpur - Banki - Dharampur marg distt- Hamirpur (U.P.)	3.55 (1.55 CC + 2.0 PC)	3.75	13 cm WBM / DLC (10 cm) River bed material (RBM) – 10 CM	PQC (1:2:4) 15 cm	2.75%	U Type drain (60x60 cm) in Abadi portion	Oct-17
2	Nadehara Link Road Distt. Hamirpur	5.00 (1.0 CC + 4.0 PC)	3.00	12.5 Cm WBM/DLC (1:4:8) 10 cm	PQC (1:2:4) 15 cm	2.60%	U Type drain (30 X 45 cm) in Abadi portion	May-17

Surface cracks observed are shown in Fig. 1 & 2. In all above ten no's of road constructed in expansive soil region. Crocodile cracks are found in the top of the surface with in the two to three year of the construction which causes failure of the road. The detail study was carried out on cement concrete road in Sumerpur - Banki - Dharampur marg distt- Hamirpur (U.P.) , Nadehra Link Rioad Distt. Hamirpur details of two roads taken for study are as follows.

Sumerpur - Banki - Dharampur marg distt Hamirpur- The length and width of the road is 3.55 km and 3.75 m. respectively. PQC is made of M 30 grade concrete and its thickness is 15.0 cm. The thickness of sub base with dry lean concrete is 13 cm WBM and 15.0 cm dry lean concrete over 10 cm. river bed material (RBM).wide U type drain of size 60 X 60 cm are constructed along both side of the road in abadi portion of the road. CBR value of sub grade is 2.95 and corresponding modulus of sub-grade reaction is 33.55 Mpa/m Road has been constructed in year Oct. 2017 but Surface crocodile cracks are developed within six month after construction. Cracks are clearly visible in Fig. 1 **Nadhera Link road Distt. Hamirpur**- The length and width of the road is 1.55 km and 3.75 m. respectively. PQC is made of M 20 grade concrete and its thickness is 15.0 cm. The thickness of sub base with dry lean concrete is 10 cm over 12.5 cm thick WBM. River bed material (RBM) wide U type drain of size 30 X 45 cm are constructed along both side of the road in abadi portion of the road. CBR value of sub grade is 2.60 and corresponding modulus of sub-grade reaction is 30.40 Mpa/m Road has been constructed in year May. 2017 but Surface crocodial cracks are developed within One year after construction. Cracks are clearly visible in Fig. 2.

TRAFFIC SURVEY OF PLAIN CEMENT CONCRETE ROADS TO KNOW THE TRAFFIC DENSITY

Sumerpur - Banki - Dharampur marg distt- Hamirpur (U.P.)											
Period		**Motorized Vehicles**						**Non-Motorized Vehicles**			
From Date	To Date	Car, Jeep, Van, Three Wheelers	Buses	Trucks	Moter Cycles /Scooters	Total Fast	Animal Drawn Vehicle	Cycles	Riksha	Tractor Trolley Unit	Total Slow
1	2	3	4	5	6	7	8	9	10	11	12
18/2/2019	19/2/2019	42	0	3	210	255	105	279	6	40	430
19/2/2019	20/2/2019	48	0	4	232	284	96	282	9	42	429
20/2/2019	21/2/2019	62	0	2	198	262	99	262	11	42	414
21/2/2019	22/2/2019	38	0	3	212	253	102	276	8	41	427
22/2/2019	23/2/2019	44	0	3	222	269	111	296	10	43	460
23/2/2019	24/2/2019	38	0	2	212	252	115	291	9	43	458
24/2/2019	25/2/2019	30	0	3	205	238	109	299	8	43	459
Total For The Week		302	0	20	1401	1813	737	1985	61	294	3077
Average Daily Traffic For The Week		43	0	2.85	213	259	105.28	283.57	8.71	42	439.56
CVPD-45		**PCU-777**									

NADEHARA LINK ROAD DISTT. HAMIRPUR (UP)

Period		Motorised Vehicles					Non Motorised Vehicles			
From	To	Car, Jeep, Van, Three Wheelers	Buses	Trucks	Moter Cycles /Scooters	Total Fast	Animal Drawn Vehicle	Cycles	Riksha	Tractor Trolley Un
Date	Date									
1	2	3	4	5	6	7	8	9	10	11
6/8/2018	7/8/2018	52	0	0	79	131	184	153	-	28
7/8/2018	8/8/2018	58	0	1	92	151	178	172	-	20
8/8/2018	9/8/2018	72	0	0	86	158	152	184	-	22
9/8/2018	10/8/2018	48	0	0	92	140	148	143	2	19
10/8/2018	11/8/2018	54	0	1	81	136	146	138	-	21
11/8/2018	12/8/2018	48	0	2	79	129	112	142	3	20
12/8/2018	13/8/2018	36	0	0	82	118	108	132	-	22
Total For The Week		368	0	4	591	963	1028	1064	5	152
Average Daily Traffic For The Week		52.57142857	0	0.5714286	169	137.5714286	147	152	0.71	21.7142857
CVPD - 23		PCU - 469								

Nadehara link road Distt. Hamirpur (U

Detail traffic survey shows that the traffic density is within the limit of low volume traffic roads (village roads) but Surface cracks (Crocodile cracks) are observed in both the above plain cement concrete pavements. These cracks may be mainly due to shrinkage and swelling character of the expansive soil and these cracks are not due to excessive traffic volume.

As per IS: SP 62 – 2014 Pavement Thickness for Traffic up to 50 CVPD:

A sub-base of 75 mm WBM over 100 mm GSB is considered. The sub grade soil has a CBR value of 4 Percent. The effective k value over WBM is taken as 42 MPa (35 + 20 percent of 35 MPa). Thickness values for a dual wheel load of 60 kN are 150 mm for all the joint spacing of 2.50 m, 3.25 m and 4.00 m since temperature stresses are not considered. For other k values, excel sheet can be used to get the thickness.

A minimum thickness of 150 mm is recommended even for higher modulus of sub grade reaction. Design of above both roads found adequate as per provisions of IRC: SP 62 -2014, Traffic is also with in the limit of village roads, River Bed Material (R.B.M.) layer is also provided in both of the roads. Surface cracks are observed in both of the roads constructed in expansive soil region. Longitudinal and crocodile cracks are found in the top of the surface with in the two to three year of the construction which causes failure of the road. In Bundel khand region maximum cement concrete roads found cracked due to Expansive soil Sub grade. Hence design of rigid pavement is carried out by providing reinforcement taking advantages of flexure. Stresses developed in pavement due to swell pressure are checked by finite element method modeling by using ANSYS Software.

Rechecking of C.C. Pavement Design as per provision of IRC SP 62-2014

Name of Work - Sumerpur - Banki - Dharampur marg distt - Hamirpur (U.P.)

Design of Cement concrete pavement (3.75 m wide) as per IRC SP :62-2014

(A) Design Data

Initial CVPD=A **A:= 45**

Soaked Subgrade CBR of Subgrade **CBR:= 2.75**

modulus of subgrade reaction k MPa/m (Table 3.1) **$k^{subgrade}$:= 52.5**

Modulus of Elasticity of Concrete, E in MPa **E:=** 30000

Poisson's ratio **μ:=** 0.15

Coefficient of Thermal Expansion of Concrete **α:=** 0.00001

Characteristic 28 day Compressive Strength of Concrete **f^{ck}:=** 30 MPa

28 day Flexural Strength= ff= 0.7 √30

0.7 5.4772256 3.834 MPa

90 day Flexural Strength= ff90= 1.1xff = 4.2174637 4.217 MPa

P = 50000

Single or dual wheel load P (N) =

Tyre Pressure p for dual wheel of truck ptruck:= 0.8 MPa

Tyre Pressure p for dual wheel of truck ptractor:= 0.5 MPa

Spacing between centers of Dual Wheel $Sd := 310$ mm

(B) Subbase

Provide 150 mm DLC

Effective k- value for Granular subbase (MPa/m) is 20% more than k value of subgrade $k := 1.2 \cdot k_{subgrade} =$ 63

Table 3.1 Approximate' k' Values Corresponding to CBR Values

Sosked Subgrade CBR	**2**	**3**	**4**	**5**	**7**	**10**	**15**	**20**	**50**
k Value Mpa/m	21	28	35	42	48	50	62	69	140

Table 3.2 Effective k Values over granular and cementitious subbases

Sosked CBR	**2**	**3**	**4**	**5**	**7**	**10**	**15**	**20**	**50**
k Value over granular subbase (thickness 150 to 250 mm), Mpa/m	25	34	42	50	58	60	74	83	170
k Value over 150 to 200 mm cememtations sub base Mpa/m	42	56	70	84	96	100	124	138	280

Radius of Equivalent Circular Area (a) in mm

Case -1 Single wheel of Tractor with tyre pressure of 0.5 MPa (a1)

$$a = \frac{(P)^{1/2}}{(\pi * p_{tractor})} = 178$$

Case -2 Dual wheel of Truck with tyre pressure of 0.8 MPa (a2)

Load on one wheel of dual wheel set Pd (N)= $P^d := 25000$

$$a := \sqrt{\frac{0.8512 \times Pd}{Ptruck \times \pi} + \frac{Sd}{\pi} \times (Pd/0.5227 \times Ptruck)}$$

$$a := \sqrt{32600.5962} := 180.5563519 = 181.56$$

DESIGN

As per IRC SP: 62-2014 if the traffic is between 50 and 150 cvpd thickness evaluation should be done on the basis of total stresses resulting from wheel load of 50 kN and temperature differential.

Trial

1

Trial thickness of slab h (mm)= h:= **140**

Joint Spacing (m) L:= **3.5**

Radius of relative stiffness l (mm)

$l := (1000 \times E \times h^3/12 \times (1-\mu^2) \times k)^{1/4}$

$l := 8.232E+13 / 738.99$

$1.114E+11$

$l := 577.72$

578.00

For Poisson ratio = 0.15 the edge load stess equation is given by

For single wheel and tyre pressure p

= 0.50 Mpa

$e = h^2$

σ

$e = h^2$

σe = 4.534 **4.217 Hence unsafe**

For dual wheel and tyre pressure p = 0.80 Mpa

$0.803 \times P \times (4\log(l / a) + .666 \times (a / l) - 0.034)$

σ 0.803 x P x (4log(l / a) + .666 x (a / l) - 0.034)

σe = 4.49 **4.217** **Hence unsafe**

Trial - 2

Trial thickness of slab h (mm)= h **150**

L:= 4.0

Joint Spacing (m)

Radius of relative stiffness l (mm)

l := (1000 x E x h ³/12 x (1-μ²) x k)¼

l := 1.013E+14 / 738.99

1.37011E+11

608.40

l **608.00**

$\sigma^{e} =$ h²

For Poisson ratio = 0.15 the edge load stess equation is given by

σe = 4.049 **4.217** **Hence safe**

For dual wheel and tyre pressure p = 0.80 Mpa

0.803 x P x (4log(l / a) + .666 x (a / l) - 0.034)

σe = h²

1.784444444 x 4log 3.408 0.666 0.2934691 0.034

1.784444444 2.130 0.195 0.034

1.784444444 2.291200643

σe = 4.089 **4.217** **Hence safe**

For dual wheel and tyre pressure p = 0.80 Mpa

0.803 x P x (4log(l / a) + .666 x (a / l) - 0.034)

Hence slab Thickness of 150.00 mm is Safe for the Joint Spacing of 4.00 m

As per IRC-62, 2014 , Cement concrete pavement of thickness 150mm is safe for low volume traffic road and this the most common provisions adopted now a days for design of cement concrete pavement. Although traffic volume is within the range of low volume traffic road as explained above and design is strictly as per existing provisions of IRC62, 2014 but this cement concrete pavement is not sustainable in expansive soil region.

Hence an attempt is made here by considering swell pressure in design of cement concrete pavement with consideration of flexure.

Swell Pressure:

In expansive soil shrinkage in summer and swelling in winter or rainy seasons may developed tension on the top surface of the pavement ultimately cause the cracks . Hence it is important to consider swell pressure during design and it is compulsory to check the stresses developed due to swell pressure to know the effect of swell pressure in cement concrete pavement.

Determination of Swelling Pressure of Black Cotton Soil – A Method

When buildings or road are founded on black cotton soil, it is generally found that they suffer damage, unless special precautions are taken. The causes for such damage are the excessive swelling and shrinkage of the soil that take place when moisture finds its way into the subsoil under the foundations and subsequently dries up during the hot period.

Damage to structures due to these reasons may be avoided if the following methods are adopted:

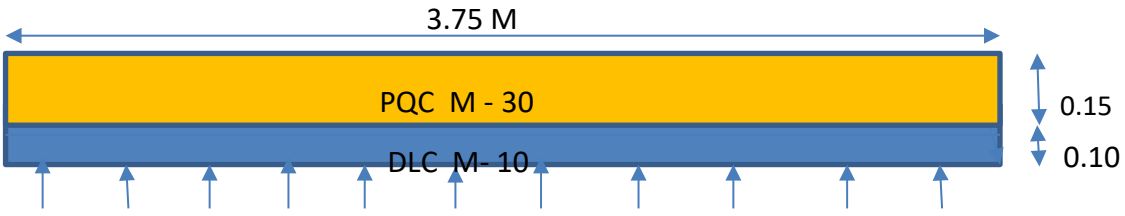
(a) The foundation is carried down to a depth, not affected by seasonal moisture variations.

(b) The foundation load is such that the pressure on the soil under dead load itself equals or exceeds the swelling pressure of the soil.

The former method as in (a) may not be always practicable especially in case of roads and runways, and a knowledge of the value of the swelling pressure of soil would be considered a necessary pre-requisite wherever the second method is to be adopted. It is obvious that the amount of swelling pressure of a soil will depend on the type and percentage of clay it contains, the initial density and moisture content, the final degree of saturation attained and the depth of the soil layer. This paper describes a laboratory method of test by which swelling pressure of an undisturbed or remolded sample of soil can be determined, and an apparatus to carry out such tests. The presentation also includes results of experiments carried out with a representative sample of black cotton soil remolded in the laboratory. In Black cotton or expansive soil swell pressure varies form 0 – 2000 KN/m^2. District like Hamirpur , Mahoba and Jalaun swell pressure is considered around 500 KN/m2 and as per IS:62- 2007 & 2015 , 100 mm Thick CNS layer is provided to counteract the swell pressure . Although this concept is not successful in Bundelkhand due to poor of RDM material and inadequate focus, care of contractor during laying of this layer.

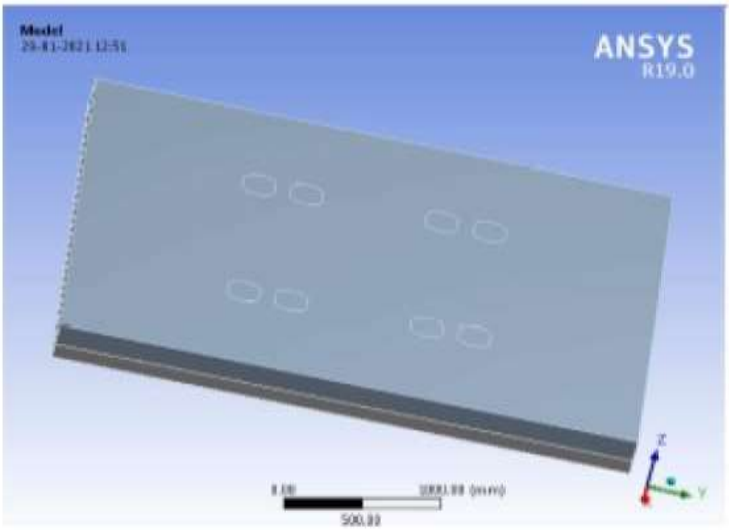
Data Provided for FEM modeling through ANSYS Software

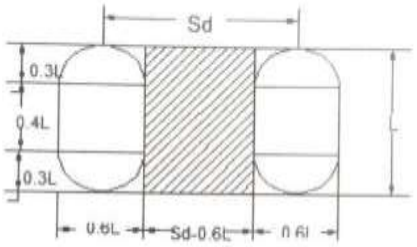
- 100 mm D.L.C. of M10 (1:3:6) is considered below the PQC. Of M-30 Grade Concrete of thickness 150 mm Swell Pressure of expansive soil is taken as 500 KN/m2.
- As per IRC-SP-62-2014 temperature differentials for concrete slab as taken 12.5 degree for 150 mm thick slab. Modulus of elasticity of concrete 30,000 MPa.
- Poisson's Ratio taken as 0.15
- Effective K value over granular and cementitious subbases taken as 56 Mpa/m for CBR 3
- CBR value taken as 3
- Flexural strength for 90 days taken as 4.217 MPa for M30 Grade of concrete. Size of plate considered for FEM Modeling - 4.5M X 3.75 M
- 10 mm dia mtr. Bar is considered as a main reinforcement and 8 mm dia bar as a distribution steel at top and bottom of the pavement



SWELL PRESSURE 500 KN/M2

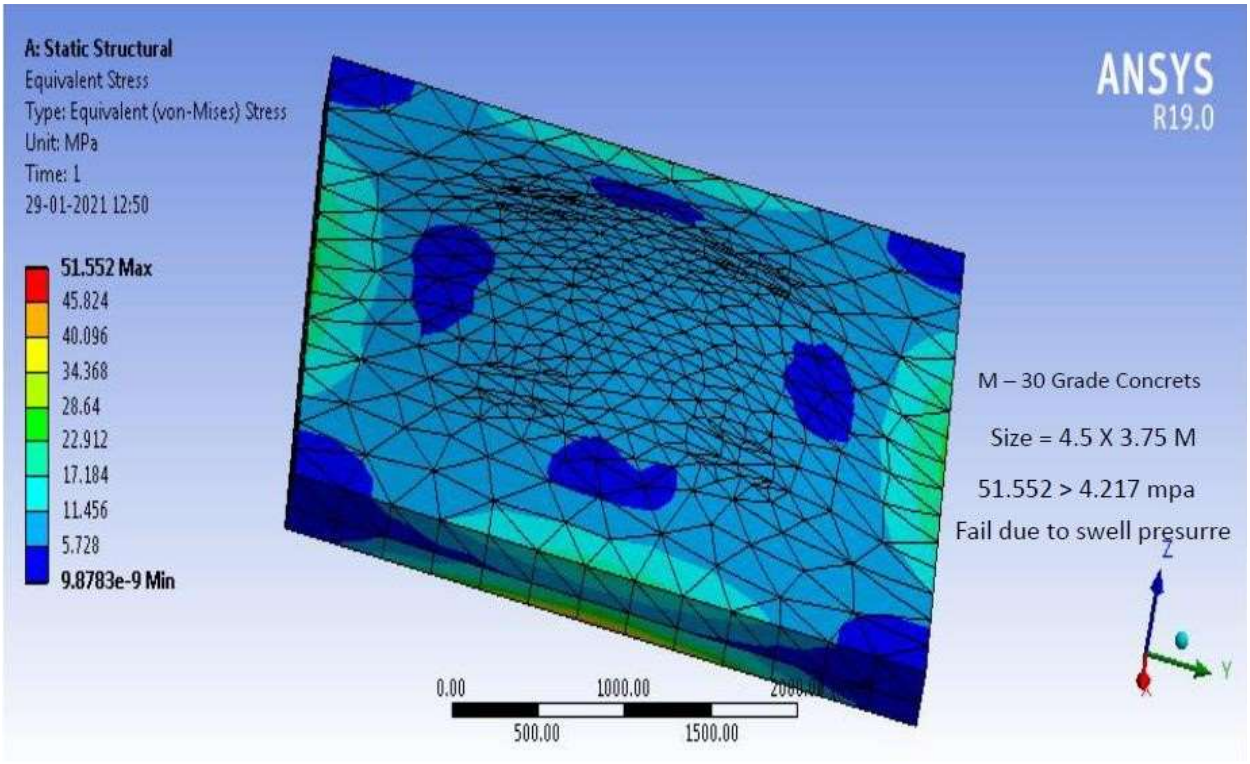
FEM MODELLING (ANSYS SOFTWARE)





Contact areas of two wheels as per IRC :SP:62-2014

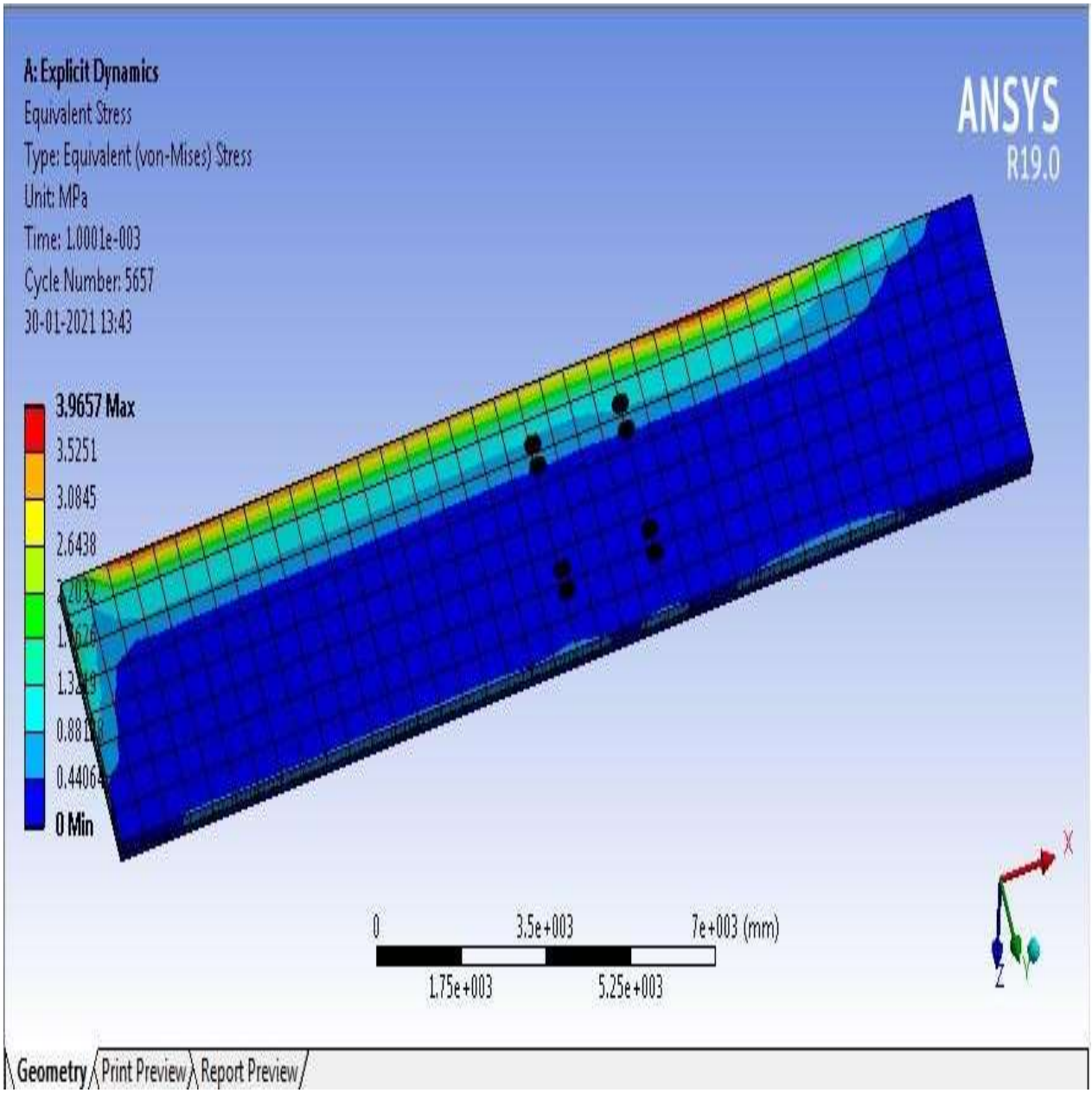
Object Name	Line Body	Line Body	Line Body	Line Body
State	Meshed			
Graphics Properties				
Visible	Yes			
Transparency	1			
Definition				
Suppressed	No			
Stiffness Behavior	Flexible			
Coordinate System	Default Coordinate System			
Reference Temperature	By Environment			
Offset Mode	Refresh on Update			
Offset Type	Centroid			
Material				
Assignment	Structural Steel			
Bounding Box				
Length X	20010 mm			
Length Y	0. mm			
Length Z	0. mm			
Properties				
Volume	4.023e+006 mm³			
Mass	31.581 kg			
Length	20010 mm			
Cross Section Area	201.05 mm²			
Cross Section IYY	3216.6 mm²·mm²			
Cross Section IZZ	3216.6 mm²·mm²			
Statistics				
Nodes	81			
Elements	40			
Mesh Metric	None			



The stresses developed due to 500 KN/m^2 swell pressure varies from 5.728 to 51.552 MPa in cement concrete pavement while 90 days flexural strength of M30 grade concrete is 4.217 Mpa hence this is a main cause of development of cracks and failure of cement concrete pavement in expansive soil region within 1-2 year of the construction, to prevent this failure reinforcement is provided in the top and bottom of pavement with a different spacing and developed stress is checked by FEM (ANSYS SOFTWARE).In this above Ansys analysis 4.5 M X 3.75 meter plate is considered for FEM modeling 100 mm D.LC provided below PQC of M-30 grade concrete having 150 mm thick .This is a most common existing design in UPPWD for low volume traffic roads as per IRC:SP-62:2014 .

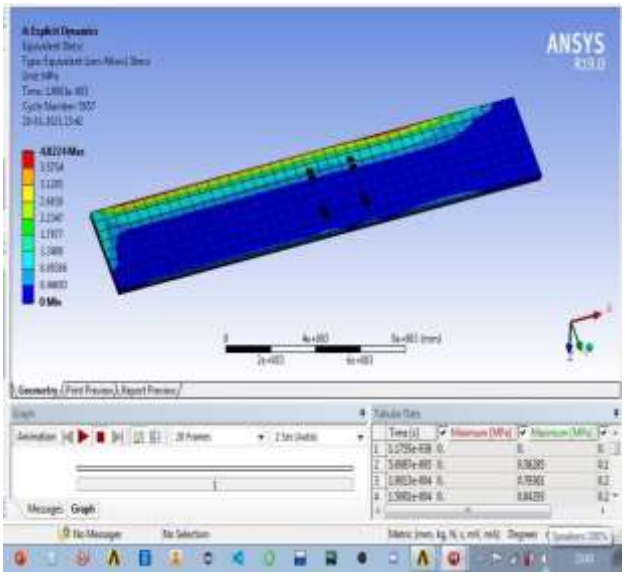
90 Days Flexural strength of M-30 Grade Concrete in Mpa	Stress developed due to swell pressure in cement Concrete Pavement of Thickness 150 mm. in Mpa
1.1 X 0.7 $\sqrt{fck}$ 1 X 1 X 0.7 $\sqrt{30}$ 4.217 Mpa.	5.278 11.456 17.184 22.912 28.64 34.368 40.096 45.824 51.552

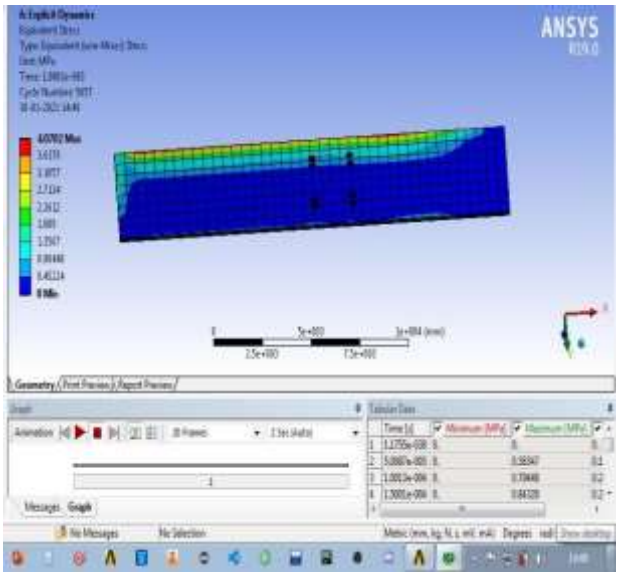
The flexural strength of M-30 concrete is 4.27 Mpa but the stress developed due to swell pressure are up to 52.Mpa greater than the flexural strength of concrete. This is a main course of formation of crocodile and linear cracks in cement concrete pavement constructed in expansive soil region. **Hence it is recommended that cement concrete pavement should be design by considering swell pressure which is a main factor to damage cement concrete pavement in expansive soil region.**



M 30 WITH REINFORCEMENT 0.3% (Spacing 10 cm x 25 cm) Spacing of 10 mm dia bars in top and bottom:

Top & Bottom 10 cm x 25 cm Total Flexure strength at 90 days is 4.217 Mpa
Here total max strength generated is 3.96 Mpa **Hence Design is safe**





M 30 WITH REINFORCEMENT (15 CM X25 CM) & REINFORCEMENT 0.2%

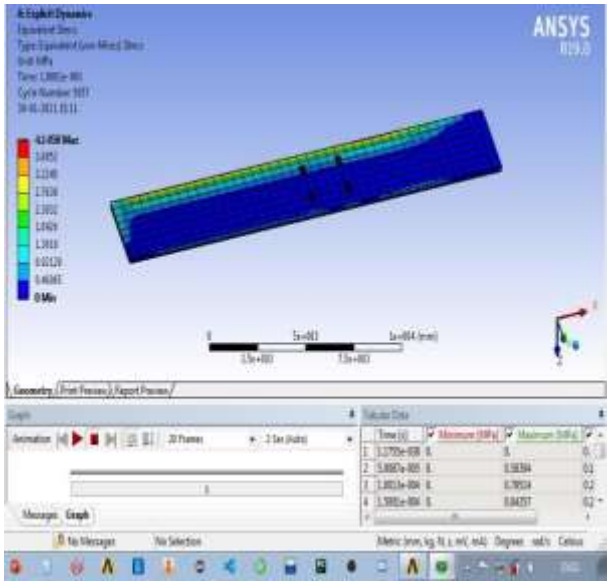
Total Flexure strength at 90 days is 4.217 Mpa
Here total max strength generated is 4.07702 Mpa
Hence Design is safe

M 30 WITH REINFORCEMENT 0.15% (20 cmx 25 cm)

Total Flexure strength at 90 days is 4.217 Mpa
Here total max strength generated is 4.0224 Mpa
Hence Design is safe

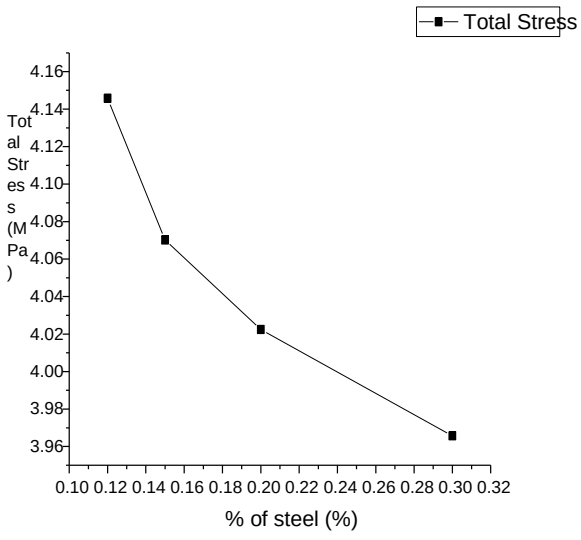
M 30 WITH REINFORCEMENT 0.12% %REINFORCEMENT AND TOTAL STRESSES DEVELOPED (M30)

Spacing 25 cm x 25 cm



Total Flexure strength at 90 days is 4.217 Mpa
Here total max strength generated is 4.1458 Mpa
Hence Design is safe

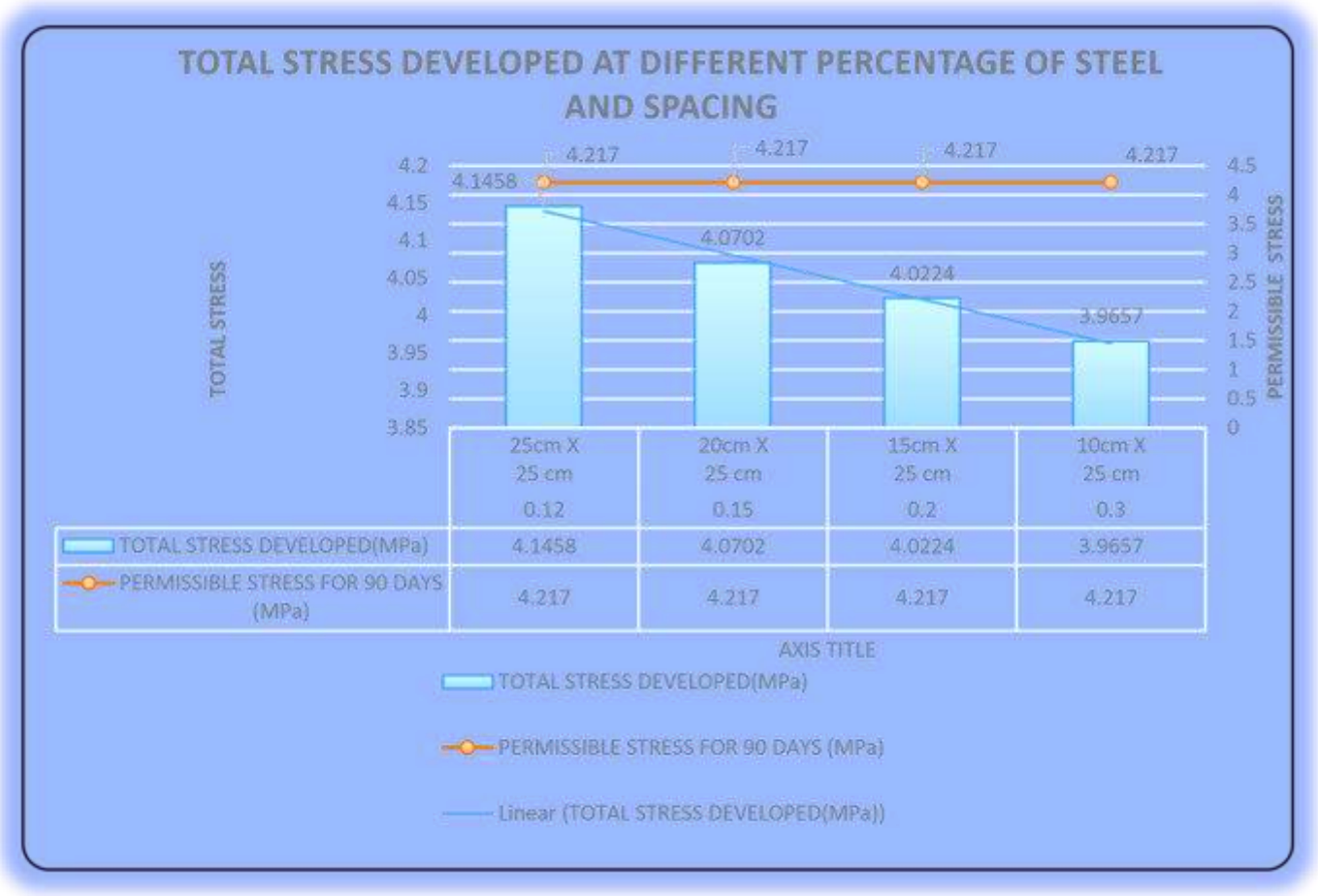
COMPERATIVE CHART FOR DIFFERENT



TABULAR REPRESENTATION OF RESULT FOR M30 GRADE OF CONCRETE VS % STEEL

PERCENTAGE OF STEEL (%)	SPACING OF 10 MM DIA STEEL	TOTAL STRESS DEVELOPED(MPa)	PERMISSIBLE STRESS FOR 90 DAYS (MPa)	SAFE/UNSAFE
0.12	25cm X 25 cm	4.1458	4.217	SAFE
0.15	20cm X 25 cm	4.0702	4.217	SAFE
0.20	15cm X 25 cm	4.0224	4.217	SAFE
0.30	10cm X 25 cm	3.9657	4.217	SAFE

10 mm diameter bar are used as a main bar and 8 mm diameter bar is used as a distribution steel at top and bottom of the pavement, as per above table it is clearly found that spacing of 25 cm x25 cm of steel at top and bottom is a most suitable and economical section for sustainable reinforced cement concrete pavement.

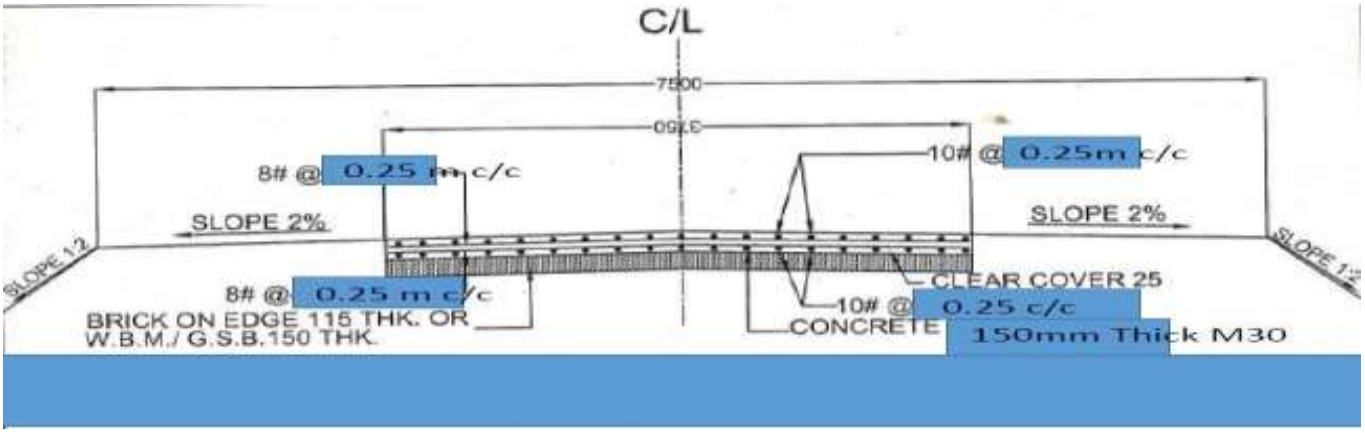


Here clearly see that the calculated permissible stress for 90 days is 4.217 MPa for M30 grade of concrete and after considering different percentage of steel as per design specifications and according to that different spacing is provided. As per minimum percentage of steel as per design specifications the total stress developed is less than the calculated permissible stress for M30 grade of concrete.

Per Km Cost Comparison Of Plain & Reinforced Concrete Pavement (Pavement width 3.75 M wheel load 50kN) (Using M 30 concrete)

S.No.	Plain Cement Concrete Pavements					Reinforced Cement Concrete Pavements			
	Item	Measurement	Qty	Rate (in Rs)	Amount (in Rs.)	Measurement	Qty	Rate (in Rs)	Amount (in Rs.)
1	2	3	4	5	6	7	8	9	10
1	M 30 Cement concrete Rate of PCC are inclusive with 125 micron polythene sheet and for RCC without polythene sheet .	1x1000x3.75x0.15	562.5 M3	5934 Per M3	3337875	1x1000x3.75x0.15	562.5 M^3	5858 Per M3	3295125
2	.23 M wide Brick Boxing on both side of the road	2x 1000x.23 x.15	69 M^3	5500 Per M3	379500	-	-	-	-
3	Number of Joints	1000	223	4000	892000	1000	50	4000	200000
		4.5	No.	Per Joint		20	No.	Per Joint	
4	Reinforcement								
	10 mm in longitudinal direction	-	-		-	2x50 x 15x20.0x0.62=31000	18600		
	8mm in transverse direction	-	-		-	2x50 x 80x3.75x0.39=11700	11700		
							30300	56	1696800
							Kg	per kg.	
	Total				4609375				5191925

Sustainable RCC pavement for black cotton soil having reinforcement at top and bottom



The cost of existing cement concrete pavement and proposed R.C.C. Pavement is nearly same. In expansive soil region existing cement concrete pavement designed as per provisions of IRC SP:622014 are not a sustainable option because they get damaged within the very short span of time and after that the maintenance or repair of these pavements are very costly, generally one more layer of cement concrete (M30) is suggested to repair these damaged pavements which is very costly affair. In proposed R.C.C. pavement stress developed due to swell pressure is counterbalance by providing steel in top and bottom and due to less number of joints there is no need of brick boxing on both side of the R.C.C. pavement and after estimating the construction cost the cost of proposed R.C.C. pavement is roughly same and it is a sustainable and durable option for construction of village road in expansive soil region.

Conclusion:

As per design By IRC: SP 2:2014 only 15 cm. thickness of PQC is sufficient for 50 KN. Wheel load. Provided thickness 15 Cm. but crocodiles cracks developed within Six Month of construction and road get damaged with in one to two year of construction .it is clear from above observation that cement concrete pavements designed as per existing codes are not sustainable in expansive soil it is due to swelling and shrinkage characteristics of expansive soil. It is concluded from field observations made and data collected from different sources that the CBR value of expansive soil where cement concrete road had constructed lies between 2 to 3 % and the corresponding K value are 21 to 28 MPa/m. Surface cracks (Crocodile and linear cracks) are observed in the plain concrete pavements constructed in the past. These cracks may be mainly due to shrinkage and swelling character of the expansive soil. As per IRC-SP62:2014 for traffic up to 50 CVPD 75 mm thick compacted WBM GR-III provided over 100 mm thick granular sub base made up of gravel or RBM with CBR not less than 30%, liquid limit less than 25% and plasticity index less than 6 or 150 mm of cement/lime /lime fly ash of unconfined compressive strength 3 MPa at 7 days and 150mm thick PQC of M30 is recommended for village roads. Both the road taken in example are constructed strictly as per provisions of LRC –SP 62 -2014 but get damaged with in one to two year. Several roads of Bundelkhand region are studied and in detail survey all the roads are found cracked. Design of all existing roads found adequate as per provisions of IRC: SP 62 -2014, Traffic is also with in the limit of village roads, quality of few roads may be inferior but not in all the roads, in field survey all the roads got damaged. It is due to swelling pressure. In present work found that the stress developed due to swelling pressure are checked by FEM using software ANSYS 2019 from which it is clear that stress due to swell pressure is more than the flexural strength of M-30 Concrete to prevent these cracks reinforcement is provided in top and the bottom of the pavement.

Hence design of rigid pavement is carried out by providing reinforcement by taking advantages of flexure. Stresses developed in pavement are checked by finite element method modelling by using ANSYS Software and to nullify this Stress developed in c.c. pavement due to swell pressure and wheel load 10mm and 8mm diameter for steel is provided in top and bottom of the section with 250mm X
250 mm spacing Centre to Centre, which is a sustainable option for cement concrete pavement in village road construction in expansive soil region? The cost of ordinary CC road considering with their life span and proposed R.C.C. Pavement as a sustainable option for expansive soil region is almost equal.

REFERENCES

[1] IRC: SP: 20-2002, “Rural Road Manual”.

[2] IRC: SP: 42-1994, “Guidelines of Road Drainage”.

[3] IRC: SP: 62-2014, “Guidelines for Design and Construction of Cement Concrete Pavement for Low Volume Roads (First Revision).

[4] Dr. R. Kumar, Scientist, Rigid Pavements Division, CRRI, “Design and Construction of Rigid Pavements/Cement Concrete.

[5] Pandey, B.B., “Warping Stresses in Concrete Pavements- A Re-Examination”, HRB No. 73, 2005, Indian Roads Congress, 49-58.

[6] Westergaard, H. M. (1948), "New Formulas for Stresses in Concrete Pavements of Airfield", ASCE Transactions, vol. 113, 425444.

[7] Srinivas, T., Suresh, K. and Pandey, B.B., "Wheel Load and Temperature Stresses in Concrete Pavement", Highway Research Bulletin No. 77, 2007, 11-24.

[8] Bradbury, R. D. (1938), "Reinforced Concrete Pavements", Wire Reinforcement Inst., Washington, D.C.

[9] B. Kumar, Scientist, Rigid Pavements Division, CRRI, "Design Construction & Quality Control Aspects in Concrete Road (ppt)".

[10]IRC: 15-2011, "Standard Specifications and Code of Practice for Construction of Concrete Roads (Fourth Revision)".

[11]IRC: 58-2011, "Guidelines for Design of Plain Jointed Rigid Pavement for Highways (Third Revision)". [12]IRC: 57-2006, "Recommended Practice for Sealing of Joints in Concrete Pavements (First Revision)".