‘‘Study of CC Pavement Thickness in Village Road of Expansive 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.

Keywords —Expansive soil, Swell pressure, Cement concrete pavement, Sub-grade base, Design of rigid pavement, reinforcement.

I. INTRODUCTION

Black cotton soils are inorganic clays of medium to high compressibility and form a major soil group in India. They are characterized by high shrinkage and swelling properties. This Black cotton soils occurs mostly in the central and western parts and covers approximately 20% of the total area of India. Because of its high swelling and shrinkage characteristics, the Black cotton soils (BC soils) has been a challenge to the highway engineers. The Black cotton soils is very hard when dry, but loses its strength completely when in wet condition. Most of the villages in expansive soil regions of Uttar Pradesh and Madhya Pradesh, India are connected by flexible pavements and the village streets by plain cement concrete pavements. The percentage of village link roads is much higher compared to other category roads like NH, SH, MDR, ODR, therefore village connectivity assumes a greater significance. For rigid pavements, IRC: 58-2002 is useful for highways and high volume traffic roads. The Indian Roads Congress published a manual for rural roads (IRC: SP: 20-2002) regarding planning, design and construction of rural roads. For rural roads with cement concrete pavements IRC: SP: 62-2004 has been introduced and now a days low volume roads are designed as per the guidance of IRC-62:2014. It has been observed that the life cycle cost of flexible pavement is more than the rigid pavements. As such rigid pavements are proposed for construction of new roads in villages.

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II LITERATURE SURVEY

In black cotton soil P.C.C. Pavement faces problem in dry seasons due to shrinkage and swelling in rainy season, swelling pressure and shrinkage create tension at the top of the surface and ultimately cracks develop to meet out such problems some of the observations are:

1. IRC SP: 62-2004 & IRC: SP: 62-2015 provides guidelines for design, construction and maintenance of rigid pavements for village road. There are no specific provisions for expansive soil the recommended thickness is applicable to common subgrade soil such as clay, silt and silty clay.
2. IRC SP: 62-2004 provide provisions of sub-base below the concrete pavements to prevent mud pumping & acts as capillary cut of where the pavement designed for a wheel load of 51 KN a 150 mm thick sub-base of water bound macadam provided. Some provisions need to be reinvestigated and modified.
3. The temperature variation assumed to be linear is not realistic and stresses calculated by using boundary's equations are much higher than the actual it needs rectifications.
4. For sustainable option of rigid pavement in expansive regions, the field investigations regarding the performance of existing pavements need to be carried out in detail.
5. IRC : SP : 49-2014 provide guideline for the use of dry lean concrete as subbase for rigid pavements, a thickness of minimum 150 mm is recommended for all major projects 100 mm thick for village roads case study considering (GSB + PQC), (GSB + LC + PQC) & (LC + PQC) need to be carried out in detail.
6. IRC: SP: 58-2002 and IRC SP: 58-2015 recommended reinforcement in concrete slab to counter cut the tensile stresses caused by shrinkage and contraction due to temp and moisture changes. This reinforcement in the concrete slab is not intended to contribute towards its flexural strength amount of steel used in pavement as dowel bars, tie bars and for temp steel is sufficient in quantity and affect the cost of rigid pavement but such steel has no contribution for flexural strength. Hence this reinforcement can be save when designing pavement for increasing flexural strength as per actual calculations of stresses.
7. IRC: SP: 62-2004 and IRC SP: 62-2014 provides guidelines for transverse contraction and construction joints, expansion joints, longitudinal joints, and these closely spaced joints are cause of inconvenience to the traffic. Designed reinforcement concrete pavement can increase the spacing of joints to facilitate smooth and comfortable flow of traffic.

III CALCULATIONS

The design of plain cement concrete (PCC) pavement is carried out as per IRC: SP: 62-2004. It is observed that rural roads in expansive soil regions have very low volume of traffic. The traffic usually consists of transport vehicles like tractors, buses, jeeps, cars, animal drawn vehicles, two wheelers, cycles etc.

A rigid pavement is economical when soil sub-grade is of poor strength and drainage conditions are not good. The expansive soil region has a general value of CBR 5.0 with corresponding modulus of sub-grade reaction k equal to 4.2 kg/cm2/cm for new roads and 8 kg/cm2/cm for existing WBM/BOE/GSB roads. Different parameters based on field observations to be used for design of plain cement concrete pavement. Plain cement concrete rigid pavement having width 3.0 m and 3.75 m is designed with sub-base as dry lean concrete (DLC) and also with WBM/BOE/GSB for single wheel load of 30.0 kN and 51.0 kN. Concrete of M30 grade is used as per specification. Permissible stress for M30 grade concrete is taken as 4.6 N/mm2. The stresses in the pavements due to wheel load and temperature variation are calculated using the following relations:

The stresses in the pavements due to wheel load and temperature variation are calculated using the following relations:

(a) Stresses due to wheel load:

(i) At edge

$$\sigma_{le} = \frac{0.529P}{h^2}\{(1+0.54\nu)(4\log\frac{l}{b}+\log b-0.4048)\} \quad (4.1)$$

(ii) At interior

$$\sigma_{li} = \frac{0.316P}{h^2}(\frac{4\log l+1.069}{b})$$

(iii) At corner

$$\sigma_{lc} = \frac{3P}{h^2}(1-\frac{a\sqrt{2}}{l})^{1.2}$$

(b) Stresses due to temperature:

(i) At edge

$$\sigma_{te} = \frac{E\alpha tC}{2}$$

(ii) At interior

$$\sigma_{ti} = \frac{E\alpha t}{2}(\frac{C_L+C_B}{1-\nu^2})$$

(iii) At corner

$$\sigma_{tc} = \frac{E\alpha t}{3-\nu}(\frac{a}{l})^{1/2}$$

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Where, Radius of load contact $a = \left(\frac{P}{\pi p}\right)^{1/2}$

Radius of equivalent distribution of pressure,

$b = \sqrt{1.6a^2 + h^2 - 0.675h}$

Radius of relative stiffness $l = \left(\frac{Eh^3}{12(1-\nu^2)k}\right)^{1/4}$

Here roads are designed as per existing provisions of IRC-SP-62 2014

Name of Work- Laxmi Bai Park to Rameri Marg of Distt. Hamirpur

(A)Design of Cement concrete pavement (3.0 m wide) as per IRC SP: 62-2014

Design Data

Initial CVPD=A

A:= 34

Soaked Subgrade CBR of Subgrade CBR=2.95

Modulus of subgrade reaction k MPa/m ksubgrade:=55.3

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 fck:= 30 MPa

28 day Flexural Strength=ff=0.7√30

0.7x5.4772256 =3.834 MPa

90day 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 p truck= 0.8MPa

Tyre Pressure p for dual wheel of p tractor=0.5 MPa

Spacing between centers of Dual Wheel S d=310 mm

(B) Subbase

Provide 150 mm DLC

Effective k- value for Granular

K subgrade = 52.5 MPa/m

Radius of Equivalent Circular Area (a) in mm

Table: 1 Approximate 'k' Values Corresponding to CBR Values

Soaked Subgrade CBR	2	3	4	5	7	10	15	20	50
K Value M pa/m	21	28	35	42	48	50	62	69	140

Table: 2 Effective k Values over granular and cementitious subbases

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

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

$\alpha = (P)^{1/2}/(\pi x\ P_{tractor}) = 178$

Case -2 Dual wheel of Truck with tyre pressure of 0.8 MPa (a_2)

Load on one wheel of dual wheel set P_d (N)= P_d= 25000

α =√32600.5962=180.55635 =181.00

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) =140

Joint Spacing (m) ,L=4.0

Radius of relative stiffness l (mm)

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

l = 570.00

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

For single wheel and tyre pressure p = 0.50 Mpa

σe = 0.803 x P x (4log(l / α) + .666 x (α / l) - 0.034) h²

σe = 4.490 (4.217)Hence unsafe

For dual wheel and tyre pressure p = 0.80 Mpa

σe = 0.803 x P x (4log(l / α) + .666 x (α / l) - 0.034) h²

σe = 4.45 (4.217)Hence unsafe

Trial - 2

Trial thickness of slab h (mm) = h= 150 , L= 4.0joint Spacing (m)

Radius of relative stiffness l (mm)

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

l = 601.00

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

For dual wheel and tyre pressure p = 0.80 Mpa

σe = 0.803 x P x (4log(l / α) + .666 x (α / l) - 0.034)h²

σe = 4.057 <(4.217) Hence safe

For dual wheel and tyre pressure p = 0.80 Mpa

σe = 0.803 x P x (4log(l / α) + .666 x (α / l) - 0.034)h²

σe = 4.017 (4.217)Hence safe

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Hence slab Thickness of 150 mm is Safe for the Joint Spacing of 4.00 m

Name of Work- Kalpi Madaripur to Sohrapur Marg
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 4) ksubgrade= 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 fck= 30MPa
28 day Flexural Strength= ff= 0.7√30
0.7x5.4772256= 3.834MPa
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 tractor=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 subgrade = 63
Table: 3 approximate 'k' Values Corresponding to CBR Values

Soaked Subgrade CBR	2	3	4	5	7	10	15	20	50
K Value M $_{pa}$/m	21	28	35	42	48	50	62	69	21

Table: 4 Effective k Values over granular and cementitious subbases

Soaked Subgrade CBR	2	3	4	5	7	10	15	20	50
k Value over granular subbase (thickness 150 to 250 mm), M $_{pa}$/m	25	34	42	50	58	60	74	83	170
k Value over 150 to 200 mm cementitious sub base M $_{pa}$ /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)
$\alpha = (P)^{1/2}/(\pi x\ P_{tractor}) = 178$
Case -2 Dual wheel of Truck with tyre pressure of 0.8 MPa (a2)
Load on one wheel of dual wheel set P_d (N)=P_d=25000
$\alpha = \sqrt{0.8512 \times Pd + Sd \times (Pd/ 0.5227 \times Ptruck)^2}$

$\alpha = \sqrt{32600.5962} = 180.55635 = 181.00$
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 x E x h ³/12 x (1-μ²) x k) ¼
577.72
l =578.00
For Poisson ratio = 0.15 the edge load stress equation is given by
For single wheel and tyre pressure p = 0.50Mpa
$\sigma e = 0.803 \times P \times (4\log(l / \alpha) + .666 \times (\alpha / l) - 0.034) h^2$
σe = 4.534 4.217 Hence unsafe
For dual wheel and tyre pressure p = 0.80Mpa
$\sigma e = 0.803 \times P \times (4\log(l / \alpha) + .666 \times (\alpha / l) - 0.034) h^2$
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 =608.00
For Poisson ratio = 0.15 the edge load stress equation is given by
For dual wheel and tyre pressure p = 0.80Mpa
$\sigma e = 0.803 \times P \times (4\log(l / \alpha) + .666 \times (\alpha / l) - 0.034) h^2$
1.784444444x4log 3.408x0.666x0.2934691x0.034
σe = 4.089 (4.217) Hence safe
For dual wheel and tyre pressure p = 0.80 Mpa
$\sigma e = 0.803 \times P \times (4\log(l / \alpha) + .666 \times (\alpha / l) - 0.034) h^2$
σe = 4.049 (4.217) Hence safe
Hence slab Thickness of 150.00 mm is Safe for the Joint Spacing of 4.00 m

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The field observations made for some of the roads of Uttar Pradesh and Madhya Pradesh in India that will be useful in designing the rural roads. The performance of the existing cement concrete pavements in expansive regions has been studied. The nature of sub grade and environmental conditions are also studied. The values of modulus of sub grade reaction k of the sub grade are obtained from CBR values. A detailed study of CBR values of different roads in various districts of Uttar Pradesh, India is made. Modulus of sub grade reaction. Traffic study on the different rural roads of Hamirpur and Jalaun district of Uttar Pradesh and Chhatarpur district of Madhya Pradesh India is also carried out to know the type and intensity of the traffic load conditions on the rural roads. Two number of village roads are taken for observations. As per IRC 62,2014 for traffic up to 50 CVPD and 75 mm thick compacted WBM grade –III wet mix macadam may be provided over 100 mm granular sub base.

Field Survey (Traffic Survey)

Fig: 1 Photographs of different c.c. roads which shows crocodile crack

Table: 5 Laxmi Bai Park to Rameri Marg Traffic Survey

Laxmi Bai Park to Rameri Marg of Distt. Hamirpur

Period		Motorised Vehicles					Non Motorised 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
8/2/2016	9/2/2016	42	-	-	158	200	84	178	-	42	304
9/2/2016	10/2/2016	48	-	1	184	233	78	205	-	36	319
10/2/2016	11/2/2016	62	-	-	172	234	52	212	-	28	292
11/2/2016	12/2/2016	38	-	-	184	222	68	172	2	32	274
12/2/2016	13/02/2016	44	-	1	162	207	89	168	-	35	292
13/02/2016	14/02/2016	38	-	2	158	198	74	175	3	42	294
14/02/2016	15/02/2016	30	-	-	164	194	65	156	-	21	242
Total For The Week		302	-	4	1182	1488	510	1266	5	224	2017
Average Daily Traffic For The Week		43	-	0.57	169	213	73	181	0.71	32	288

Table: 6 Kalpi Madaripur to sohrapur Marg Traffic Survey

Kalpi Madaripur marg to Sohrapur link road of Distt. Jalaun

Period		Motorised Vehicles					Non Motorised 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
6/4/2016	7/4/2016	12			120	132	176	195	-	42	413
7/4/2016	8/4/2016	10			124	134	172	202	-	45	419
8/4/2016	9/4/2016	11		3	127	141	144	208	-	43	395
9/4/2016	10/4/2016	8			118	126	142	185	-	51	378
10/4/2016	11/4/2016	11		2	126	139	124	170	-	41	335
11/4/2016	12/4/2016	13			118	131	98	162	-	39	299
12/4/2016	13/04/2016	10			124	134	99	148	-	40	287
Total For The Week		75	0	5	857	937	955	1270	-	301	2526
Average Daily Traffic For The Week		10.714285 71	0	0.7142857	122.4285 7	133.8 571	136	181	0.43	43	360.85 714

CVPD - 44 PCU -495

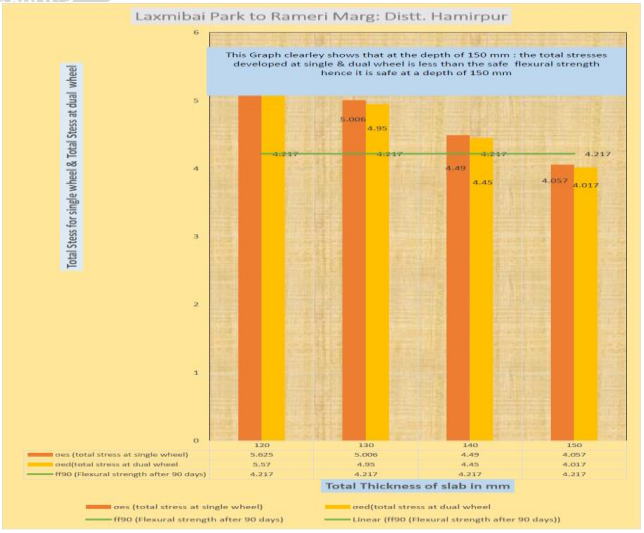

Fig: 2, Total sress for single wheel & Total Stress at dual wheel for Laxmibai Park to Rameri Marg

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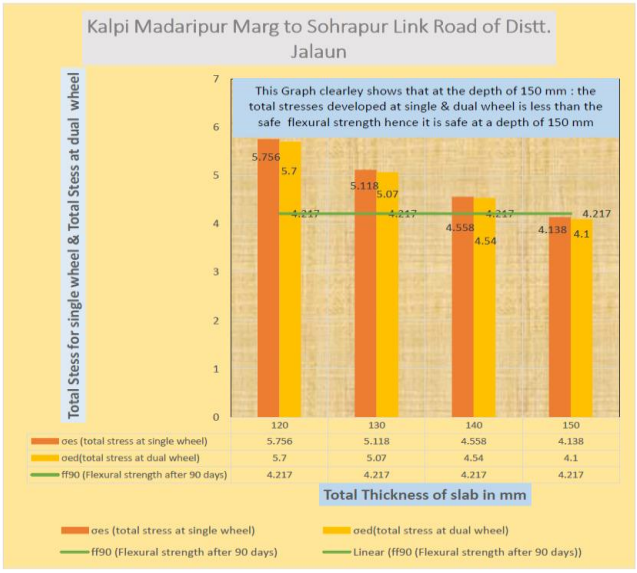

Fig: 3, Total sress for single wheel & Total Stress at dual wheel for Kalpi Madaripur Marg to Sohrapur Link Road

The Laxmi Bai Park to Rameri Marg of District Hamirpur the length and width of the road is 0.75 km and 3.0 m respectively. PQC is made of M 20 grade concrete and its thickness is 18.0 cm. The thickness of sub base with dry lean concrete is 10.0 cm. wide U type drain of size 30 X 30 cm are constructed along both side of the road in aabadi portion of the road. CBR value of sub grade is 2.95 and corresponding modulus of sub-grade reaction is 33.55 Mpa/m.

Figure 2 graph clearly shows that at the depth of 150 mm the total stresses developed at single & dual wheel is less than the safe flexural strength (4.217 mpa) hence the design is safe for "laxmibai park to rameri marg, distt. hamirpur". figure 3 graph clearly shows that at the depth of 150 mm the total stresses developed at single & dual wheel is less than the safe flexural strength (4.217 mpa) hence the design is safe for "kalpi madaripur marg to sohrapur link road of distt jalaun".

The Kalpi Madaripur marg to Sohrapur link road of District. Jalaun. The length and width of the road is 0.85 km and 3.00 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 10.0 cm dry lean concrete over 10 cm. over river bed material (RBM) 10 cm. thick. KC type are constructed along both side of the road in abadi portion. CBR value of sub grade is 2. 50 and corresponding modulus of sub-grade reaction is 29.50 Mpa/m Road has been constructed in year Oct. 2017 but Surface crocodile cracks are developed within six month after construction.As per design By IRC: SP 62 :2014 only 13 cm. thickness of PQC is sufficient for 30 KN. wheel road and 16 cm thickness is safe for 50 KN . Wheel load. Provided thickness 15 Cm. is near to designed thick, but crocodiles cracks developed within Six Month of construction .it is clear from above observation that cement concrete pavements designed as per existed codes are not sustainable in expansive soil it is due to swelling and shrinkage characteristics of expansive soil.

IV CONCLUSION

As per design By IRC: SP 62 :2014 only 13 cm. thickness of PQC is sufficient for 30 KN. wheel road and 16 cm thickness is safe for 50 KN . Wheel load. Provided thickness 15 Cm. is near to designed thick, but crocodiles cracks developed within Six Month of construction .it is clear from above observation that cement concrete pavements designed as per existed codes are not sustainable in expansive soil it is due to swelling and shrinkage characteristics of expansive soil.

From the field observations made and data collected from different sources it is concluded that the CBR value of black cotton soil of expansive soil where cement concrete road had constructed lies between 2.05 to 2.95 % and the corresponding K value are 29.50 to 34 Mpa/m. The present work the modulus of subgrade reaction k can be adopted on the basis of guideline and procedure given in IRC: SP: 62-2014 Guidelines for the Design and Construction of cement concrete pavement for low volume roads. Surface cracks (Crocodile cracks) are observed in the plain concrete pavements constructed in post. These cracks may be mainly due to shrinkage and swelling character of the expansive soil. The traffic census shows that occurrence of maximum wheel load and maximum temperature variation in the pavement simultaneously is rare. However for design critical condition of maximum wheel load and temperature occurring simultaneously is to be taken. As per IRC-SP-62:2014 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%, liqid 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 roads that is Laxmi Bai Park to Rameri Marg and Kalpi Madaripur marg to Sohrapur are constructed strictly as per provisions of IRC-SP:62 :2014 provided crust thickness 15 cm is sufficient but in field survey pavements of both the roads found cracked within one to two years of construction. It is only due to swell pressure and shrinkage property of expansive soil. Swell pressure which varies from 0-2000 KN/m2 is not considered in design of cement concrete road in expansive soil. Hence it is recommended that cement concrete pavement will designed by considering swell pressure as per expansive soil properties.

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