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EXPERIMENTAL INVESTIGATION ON FLEXIBLE PAVEMENTS, WITH VARIOUS SOILS

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ABSTRACT

The demand for the improved transportation facilities, for the growing population requires proper design of pavement. The idea behind this design is to lower the cost of construction, increase in life span, to meet all the demand of vehicular population and less maintenance cost. The choice of an adequate foundation soil is one of the problems in any construction project. So, soils are considered as the oldest and most complex construction materials by engineers. The main aim of this project is to design the flexible pavements on Moorum and black cotton soil, and the Design of Rural Roads and National Highways as per Indian Road Congress (IRC) specifications. The thickness of the pavement is obtained from design curves by conducting California Bearing Ratio test for soils of worst condition. The soil collected is tested in the laboratory for the index properties and designing is done which results in cracking of the surface therefore sand with different percentages namely 10%, 20%, 30% and 40% by the total weight, which reduces the cracks and increases the load bearing capacity. Comparisons are made in the pavement thickness with and without stabilizing the soil. It has been found out the effective utilization of the soils can be done by stabilization with some admixtures i.e., either by mechanical or chemical stabilization, there by resulting in decrease of the pavement thickness and making the construction cost economical.

KEYWORDS: Specific Gravity, Sieve Analysis, Atterberg Limits, Differential Free Swell Index, Compaction, California Bearing Ratio Test

INTRODUCTION

A pavement is hard crust placed on the soil (sub- grade) for the purpose of providing a smooth and strong surface on which the vehicles can move. The surface of the road way should be stable and non- yielding, to allow the heavy wheel loads of road traffic to move with least possible resistance. Hence soil is very essential highway material because of the under mentioned reasons: i) Soil sub-grade is part of the pavement structure; further the design and behaviour of pavement, especially the flexible pavements, depend on the great extent on the sub grade soil. ii) Soil is one of the principle materials of construction in soil embankments and in stabilized soil base and sub-base courses. There are many tests for measuring soil strength; some of them give strength parameters of the soil, other methods are empirical and gibe only arbitrary strength values. The types of the strength tests may be classified as shear test, bearing and penetration tests. There are several soils which are unsuitable as highway material, since they cannot be used as such in the base course, sub-base or the sub grade. The strength and durability characteristics of these soils can be improved to the desired extent by adopting a stabilization technique.

One of the widely used methods of stabilization is soil-cement which is applicable to wide range of soil types. The cement stabilized soil can be used in sub-base and base course layers of pavements [1].

The design of flexible pavement involves the interplay if variables like the wheel loads, traffic, climate, and terrain and sub-grade condition [2]. It is difficult to evolve an analytical method for the evaluation of the above parameters. Because of this a universally accepted method for the design of flexible pavement has not been evolved yet. The methods being used are, therefore, based partly on the experience of highway study, mostly on practical experience [3]. The methods adopted for design are therefore mostly economical [4].

The Indian Road Congress set up a flexible pavement design Sub-committee, and the recommendation of this committee, accepted by the parent organization (IRC) have come up as guidelines for the design of flexible pavement (IRC:37-1970) [5]. The flexible pavement does not only include the usual granular type Water Bound Macadam construction but also all such pavement which may be classified as semi-rigid in view of their comparatively high modulus of elasticity [6]. Some of the semi-rigid bases are below:

Stabilized soil bases formed by the addition of sand, lime, cement etc [7]. Lean concrete bases [8]. Bitumen-bound stone layer of varying concrete gradation [9]. The methods of design which are being adopted at the moment are at compromise between pure theory and pure empirical by using evaluation of the strength of the grade soil as well as the materials used in various layers of the pavement [10]. and then working out the required total thickness from a pre-knowledge of the performances of the pavement supporting different traffic loads. The objective of the project is to design the suitable pavement having more load bearing capacity, design life (reducing the cracks on surface), reducing the pavement thickness and making the cost of construction economical.

For this purpose, mechanical Stabilization is done i.e., soil is mixed with sand in different proportions and design is done which results in decreasing pavement thicknesses which is economical and reducing the cracks on the surface which increases the design life.

METHODOLOGY

CLASSIFICATION OF PAVEMENTS

The different types of pavements available are: Flexible pavement, Rigid pavement.

- Composite pavement with semi-rigid base with suitable bituminous surfacing.
- Semi-rigid base with surfacing of inter connected concrete paving blocks.
- Roller compacted concrete.

In India, most of the roads are with flexible pavement, however, the recent trend is of concrete pavement, especially for high density traffic corridors and expressways. Hence the design must follow standard procedure based on material property, traffic and design life. There are many associated factors like rainfall, ground water table etc., which are to be taken into account for evolving durable pavement design. In all designs, economies in the initial cost as well as in life cycle cost are crucial and very important. These aspects assume extra emphasis in case of rural roads.

FLEXIBLE PAVEMENTS

Flexible pavements are those, which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads. The flexible pavement layers reflect the deformation of the lower layers on-to the surface of the layer.

Thus, if the lower layer of the pavement or soil sub grade is undulated, the flexible pavement surface also gets undulated. A typical flexible pavement consists of four components:

Sub grade, subbase, base, surface These layers transmit the vertical or compressive stresses to the lower layers by grain to grain transfer through the points of contact in the granular structure.

RIGID PAVEMENTS

Rigid pavements are those which posses note worthy flexural strength or flexural rigidity. These stresses are not transferred from grain to grain to the lower layers as in the case of flexible layers. The rigid pavements are made of Portland cement concrete-either plain, reinforced or pre-stressed concrete. The plain cement concrete slabs are expected to take-up about 40 Kg/cm 2 flexural stresses.

TESTING METHODS OF SOILS

SPECIFIC GRAVITY

The specific gravity of solids for most natural soil falls in the general range of 2.65 to 2.80. The smaller the values are for the coarse-grained soils. The table gives the average values for different soils.

Table1: Density Bottle Method

S.No	Soil Type	Specific Gravity
1.	Gravel	2.65-2.68
2.	Sand	2.65-2.68
3.	Silty Sands	2.66-2.70
4.	Silt	2.66-2.70
5.	Inorganic	2.68-2.80
	Clays	
6.		Variable, may
	Organic Clays	fall below
		2.00

DENSITY BOTTLE METHOD

It is suitable for fine-grained soils, which more than 90% passing 2mm sieve. However, the method can also be used for medium and coarse-grained soils; with more than 90% passing 2mm IS Sieve.

Table 2

S. No	Particulars	G1	G2	G3
1	Weight of density bottle(w1) gms	16.94	16.94	16.4
2	Weight of bottle + dry soil(w2) gms	31.6	30.6	32.1
3	Weight of bottle + soil + water(w3) gms	84.67	83.7	84.81
4	Weight of bottle+water (w4)gm s	75.62	75.5	77.01
5	Specific Gravity	2.61	2.59	2.58
6	Average G, (G1+G2+G3)/3	2.59		

Specimen calculations: G= (W2-W1)/((W2-W1) - (W3-W4))

AVERAGE G=2.59 3.

PYCNOMETER METHOD

The method is similar to the density bottle method. As the capacity of the Pycnometer is larger, about 200 to 300 gms of oven-dry soil is required for the test. The method can be used for all types of soils, with more than 90% passing through 20mm IS sieve and for coarse-grained soils with more than 90% passing a 40mm sieve.

$$\text{Specific Gravity of solids} = \frac{\text{Macc of dry coiS}}{\text{Macc of equivaSent voSume of water}}$$

$$G = \frac{M2 - M1}{(M4 - M1) - (M3 - M2)}$$

M_1 = Mass of empty density bottle or Pycnometer, in gms, M_2 = Mass of density bottle or Pycnometer + Dry soil, in gms, M_3 = Mass of density bottle or Pycnometer + Dry soil + Water, in gms, M_4 = Mass of density bottle or Pycnometer with water, in gms

Table 3

Test No.	1	2	3	4
Type of Soil	clay		silt	
M1	30.26	29.83	28.10	28.36
M2	40.26	39.83	38.10	38.36
M3	79.53	79.43	78.22	78.24
M4	73.05	73.05	72.03	72.03
Mass of soil (m2-m1)	10	10	10	10
Mass of water contained(m4-m1)	42.79	43.22	43.93	43.67
Mass of water Occupying the volume(m3-m2)	39.27	39.60	40.12	39.88
(m4-m1) -(m3-m2)	3.52	3.62	3.81	3.79
$Gs = \frac{M2 - M1}{(M4 - M1) - (M3 - M2)}$	2.8	2.76	2.6	2.6
Average sp.gravity	**2.78**			

Figure 1

SIEVE ANALYSIS

The dried sample is taken in a tray and soaked with water. The sample is stirred and left for a soaking period of at least one hour. The slurry is then sieved through 75μ sieve and washed with a jet of water. The material retained on the sieve is taken and dried in an oven. It is then sieved through the set of fine sieves of the size 10mm, 4.75mm, 2.36mm, 1.18mm, 600μ, 425μ, 300μ, 150μ, 90μ, 75μ. The material retained on each sieve is collected and weighted. Coefficient of Uniformity

$$Cu = \frac{D60}{D10}$$

$$\text{Coefficient of Uniformity Cu} = \frac{D30^2}{D10 \times D60}$$

Table 4

Sieve No.	4	10	20	40	60	140	200	pan
diameter	4.75	2	0.80	0.425	0.25	0.106	0.075	--
Mass of empty sieve(g)	116.23	99.27	97.58	98.96	91.46	93.15	90.92	70.1
Mass of Sieve + Soil retained	166.13	135.77	139.68	138.96	114.46	184.15	101.12	301.19
Soil retained(g)	9.9	36.5	42.1	40	23	91	10.2	231.0
% retained	9.5	7	8	7.6	4.4	17.4	19	44.1
% passing	90.5	83.5	75.5	67.8	63.4	46.1	44.1	0.0

Total weight of Soil retained=523.7

Percent passing=100-cumulative percent retained.

% gravel=9.5, %sand=46.4, % fines=44.1 D10=0.002mm, D30=0.017mm, D60=0.25mm Cu=0.25/0.02=125, Cc=0.017^2/(0o25x0.002)=0.58

Figure 2

COMPACTION

The dry pulverized sample is sieved through 4.75mm sieve and the portion passing this sieve is only used for this test. About 16kg of dry soil in total may be necessary for the compaction test if the 1000cc mould is used and about 35kg if the 2250cc mould is used. For compacting the soil in the mould every time the required quantity will depend on the soil type, size of the mould, moisture content and amount of compaction. As a rough guidance, for each test 2.5kg of soil may be taken for light compaction and 2.8kg for heavy compaction, and then the required is added in the case of 1000cc mould in the case of 2250cc mould then weights may be 6.3 and 7.0kg respectively. The estimated weight of water to be added to the soil every time may be measured in a jet graduated in cc.

Table 5

Type of Compaction	No. of layers	Magnitude of blows		
		Weight of hammer	Fall cm	No. of blows
Light compaction	3	2.6	31	56
Heavy compaction	5	4.89	45	56

CALIFORNIA BEARRING RATIO

The test consists of causing a cylindrical plunger of 50mm diameter to penetrate a pavement component material at 1.25 mm/minute. The loads for 2.5 mm and 5 mm are recorded. This load is expressed as a percentage of standard load value at a respective deformation level to obtain CBR value. The standard load values were obtained from the average of a large number of tests on different crushed stones is given in the table below:

Table 6

Penetration, mm	Standard load, kg	Unit standard load, kg/cm^2
2.5	1370	70
5.0	2055	105
7.5	2630	134
10.5	3180	162
12.5	3600	183

Table 7: CBR Values

Penetration	Proving Ring Dial Reading	Piston load(lb)	are a	penetration
0	0	0	3	0
0.025	14.25	290.83	3	96.94
0.05	39.5	808.2	3	269.4
0.075	68.2	1391.9	3	463.97
0.1	98.06	2001.31	3	667.1
0.125	117.8	2404.18	3	801.39
0.15	129.4	2640.32	3	880.11
0.175	139.6	2849.1	3	949.7
0.2	148.7	3034.82	3	1011.61
0.3	170.7	3483.82	3	1161.27
0.4	183.8	3751.18	3	1250.39
0-5	202.2	4126.71	3	1375.57

Swell after 4 days=0.395mm

Height of specimen=116.43mm% swell

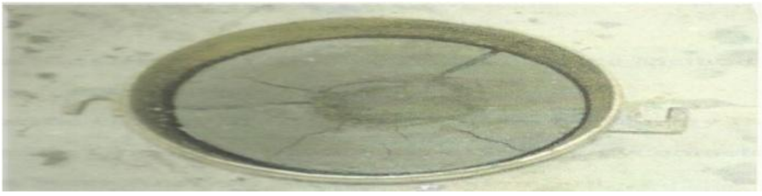
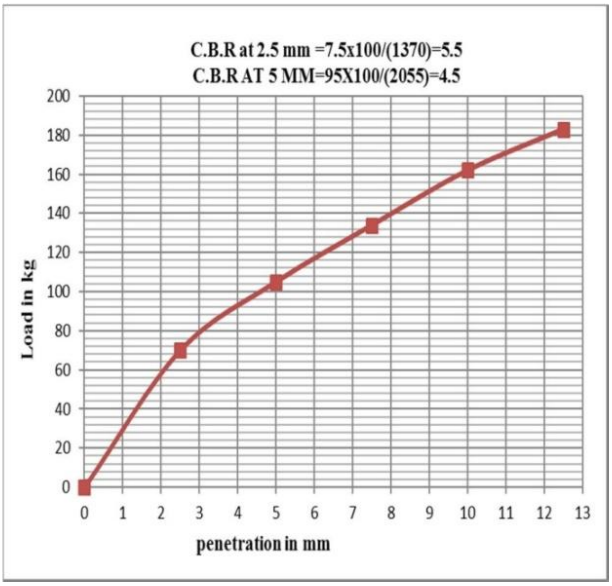
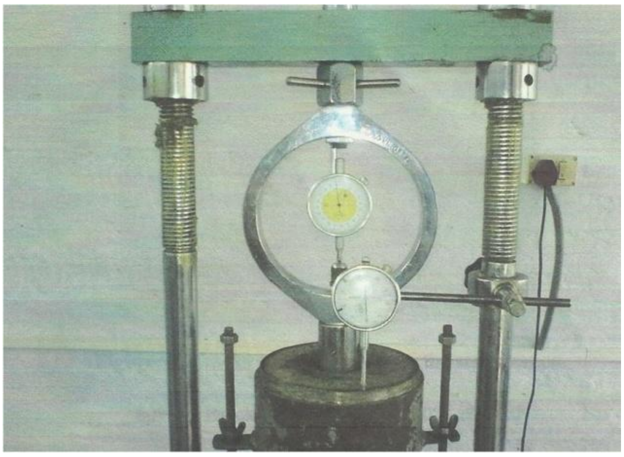


Figure 3: Cracks are reduced Due to Stabilization



Typical Load Penetration Curve for a CBR Test



Arrangement of Mould & Proving Ring

PAVEMENT DESIGN CATALOGUES

The recommended designs for traffic range 1 msa to 10 msa and 10 msa to 150 msa are given. In some cases, the total pavement thickness given in the recommended designs, is slightly more than the thickness obtained from the design charts. This is in order to: i) Provide the minimum prescribed thickness of sub-base. ii) Adapt the design to stage construction which necessitated some adjustment and increase in sub-base thickness.

RECOMMENDED FOR TRAFFIC RANGE 10 – 150 ms

Soil is stabilized with sand to increase its compaction characteristics since cracks are occurred during the compaction due to its swelling and shrinkage character. Tests are conducted for mixing the soil with sand with different percentages of sand (10, 20, 30, & 40 by weight). The high Optimum Moisture Content (O.M.C) and Maximum Dry Density (M.D.D) for different percentages.

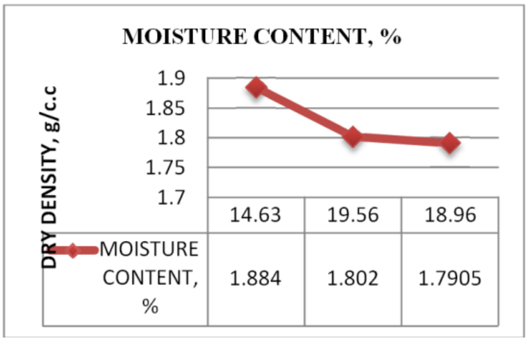


Figure 4: 60 % B.C.S and 40 % SAND, HEAVY COMPACTION

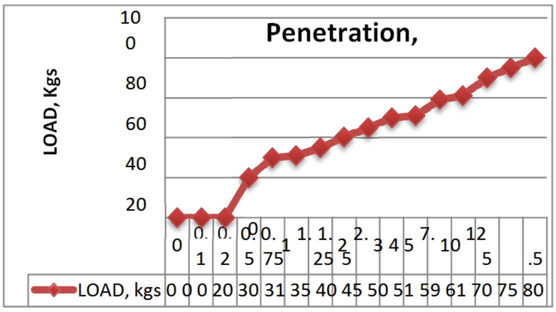


Figure 5: CBR For Black Cotton Soil (Light Compaction) 70% of MOORUM & 30% of SAND

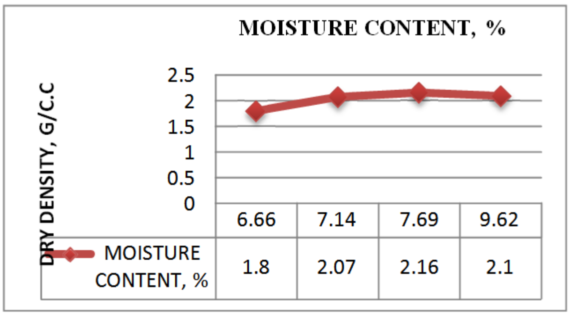


Figure 6: MOORUM SOIL 60 % MOORUM and 40 % SAND, HEAVY COMPACTION

Table 8

CBR2%				
Cumulative Traffic(msa)	**Total Pavement Thickness**	**Pavement Composition**		
Cumulative traffic(msa)	**Total pavement thickness(mm)**	**Bituminous Surfacing**		**Granular base & sub base(mm)**
		BC (mm)	**DBM (mm)**	
10	850	40	100	Base=250 Sub-base=460
20	880	40	130	
30	900	40	150	
50	925	40	175	
100	955	50	195	
150	975	50	215	

Table 9

CBR3%				
Cumulative Traffic(msa)	**Total Pavement Thickness**	**Pavement Composition**		
Cumulative traffic(msa)	**Total pavement thickness(mm)**	**Bituminous Surfacing**		**Granular Base & Sub Base(mm)**
		BC (mm)	**DBM (mm)**	
10	760	40	90	Base=250 Sub- base=380
20	790	40	120	
30	810	40	140	
50	830	40	160	
100	860	50	180	
150	890	50	210	

Table 10

CBR4%				
Cumulative Traffic(msa)	**Pavement Thickness**			
Cumulative Traffic(msa)	**Total Pavement Thickness(mm)**	**Bituminous Surfacing**		**Granular Base & Sub Base(mm)**
		BC (mm)	**DBM (mm)**	
10	700	40	80	Base=250 Sub-base=330
20	730	40	110	
30	750	40	130	
50	780	40	160	
100	800	50	170	
150	820	50	190	

STABILIZATION

Stabilization is the process of improving the engineering properties of the soil and thus making it more stable. It is required when the soil available for construction is not suitable for the intended purpose. In its broadest census, stabilization includes compaction, pre-consolidation, drainage and many other such processes. However, the term stabilization is generally restricted to the processes, which alter the soil material itself for improvement of its properties. The objectives of the project are summarized as follows: i) To improve compaction characteristics of black cotton soil. ii) To reduce the cracks of black cotton soil. iii) To decrease the settlement in pavement structure.

CONCLUSIONS

When the soil used for design without stabilization the thickness of pavement is increased. whereas on stabilization with 60% of soil & 40% of sand, 70% soil & 30% sand, it is found that the mix proportion of 70%-30% is economical than 60%-40% because of the decrease in the optimum moisture content. The following advantages:

- Strength of soil is increased.
- Thickness of pavement is reduced.
- Cost of construction is reduced.

Table 11

S. No		1	2	3	4	5	6
Type of Soil		Black Cotton Soil	Black Cotton Soil	Black Cotton Soil	Moorum	Moorum	Moorum
Condition		Soaked(H. C)	Stabilization (70% of soil-30% sand)	Soaked Stabilization (60% soil-40% sand)	Soaked	Soaked(70% Soil-30% Sand)	Soaked(60% Soil-40% Sand)
C.B.R		2	8	3	4	8	5
Traffic		20	20	20	20	20	20
Total thickness		880	575	790	730	575	690
thickness	SDBC	40	40	40	40	40	40
	DBM	130	85	120	110	85	100
	Road base	250	250	250	250	250	250
	subbas	460	200	380	330	200	300

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