Soil stabilization on the design of flexible pavement

R.Vinod Kumar[1], B.Hari Krishna[2], C.V.Swapna [3] U.Mahesh[4]

Department Civil engineering, Sree Vidhyanikethan Engineering College, Tirupati (A.P), India.

Email[1]: vinodkumar.teja@gmail.com Email[2]: hari222civil@gmail.com

Abstract: *Highway engineering is an engineering discipline branching from civil engineering that involves the planning design, construction, operation and maintenance of roads, bridges to ensure safe and effective transportation of people and goods. Standards of highway engineering are being continuously improved. These days construction of pavements on expansive soils expand while wet and contract when dry. This may cause potholes and cracks on the surface of pavement and life of the pavement decreases and cost of construction increases. In order to overcome this problem different additives are used to stabilize the soil. In this project iron oxide is used to stabilize the soil different percentages of Iron oxide and fly ash is added to soil sample and CBR values are found. Using CBR values pavement thickness is found for each percentage of iron oxide.*

Keywords: **Iron oxide, California Bearing Ratio, fly ash, soaked condition, flexible pavement**.

1. Introduction

Generally during construction of roads we may face many problems due to poor soil sub-grade. Cohesive soils can creep over time under constant load, especially when the shear stress is approaching its shear strength, making them prone to sliding. Especially in case of clayey soils the problems may be high because of its low shear strength. They are plastic and compressible and they expand when it is wet and shrink when it is dry. This is an undesirable feature and these types of soils are generally poor for foundations. In case of pavements it causes ruts and potholes on surface of pavement. The presence of potholes may cause problems to the vehicles moving on the road. To overcome the problem civil engineers started stabilizing soil in order to construct pavements on any types of soil. Soil stabilization not only decreases structural failures of roads but also it helps in reducing pavement thickness, which reduces the cost of construction

The main objective of this project is to stabilize soil using fly-ash and iron oxide. Fly-ash is a by-product formed during combustion of coal. Fly-ash is very effective in stabilizing expansive soils. The engineering properties of soil are improved by adding fly-ash by 10% of soil weight. In addition to fly-ash, iron oxide is added to improve the properties of soil. Iron oxide is inexpensive and used in paints, coatings and colored concretes. It increases load bearing capacity of soil and helps in decreasing pavement thickness.

Most of the Indian highways system consists of flexible pavement; there are different methods of design of flexible pavement. The California Bearing Ratio (CBR) test is an empirical method of design of flexible pavement design. It is a load test applied to the surface and used in soil investigations as an aid to the design of pavements. The design for new construction should be based on the strength of the samples prepared at optimum moisture content (OMC) corresponding to the Proctor Compaction and soaked in water for a period of four days before testing. In case of existing road requiring strengthening, the soil should be molded at the field moisture content and soaked for four days before testing. It has been reported that, soaking for four days may be very severe and may be discarded in some cases, Bindra 1991. This test method is used to evaluate the potential strength of subgrade, sub-base and base course material for use in road and airfield pavements. Bindra 1991 reported that design curves (based on the curve evolved by Road Research Laboratory, U.K) are adopted by Indian Road Congress (IRC: 37-1970). As per IRC, CBR test should be performed on remolded soil in the laboratory. In-situ tests are not recommended for design purpose Bindra, 1991. The design of the pavement layers to be laid over subgrade soil starts off with the estimation of subgrade strength and the volume of traffic to be carried. The Indian Road Congress (IRC) encodes the exact design strategies of the pavement layers based upon the subgrade strength which is most commonly expressed in terms of the California Bearing Ratio (CBR). For the design of pavement CBR value is invariably considered as one of the important parameter. With the CBR value of the soil known, the appropriate thickness of construction required above the soil for different traffic conditions is determined using the design charts, proposed by IRC. CBR value can be measured directly in the laboratory test in accordance with IS: 2720 (Part-XVI) on soil sample procured from the work site. Laboratory test takes at least 4 days to measure the CBR value for each soil sample under soaked condition. In addition, the test requires large quantity of the soil sample and the test requires skill and experience without which the results may be inaccurate and misleading.

2. Experimental program

For checking the properties of the soil, reported different properties like Grain Size Analysis, maximum dry density (MDD), optimum moisture content (OMC), liquid limit (LL), plastic limit (PL), plasticity index (PI), etc.

3. Materials and Methodology

Loose red earth was obtained from Sree Vidyanikethan Engineering College, Tirupati, soil Sample were collected at a depth of 1 meter, soil passing 4.75 mm sieve is used in tests, all tests are conducted based on IS: 1498 – 1970 and The material which is collected for testing is different in quality and property, so that the material was separately tested in the laboratory so as to design the soil sub grade.

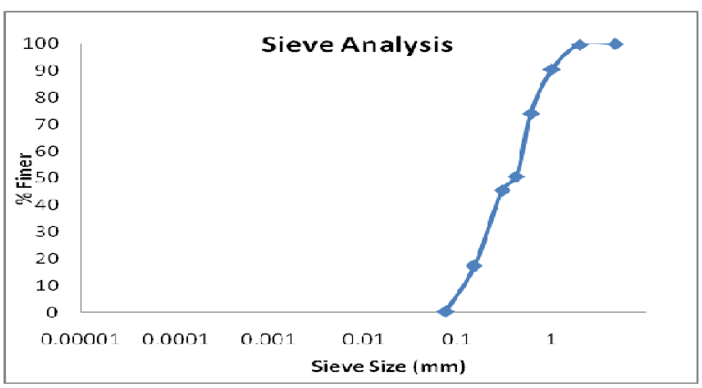
Sieve analysis

Grain size analysis is carried out to determine the relative percentages of different sizes of particles in the sample. These sizes control the mechanical behavior of coarse grained soil. Dry method of sieving is used for coarser fractions (retained on 4.75 mm sieve) and wet method is used for finer fractions (retained on 75micron sieve) and pipette method is used for fractions passing 75 micron sieve.

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for to determine suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are more generally used.

IS Sieve Size (mm)	Weight Retained (gm)	Percentage Weight Retained (gm)	Cumulative Percentage Retained (%)	Cumulative Percentage finer (%)
4.75	-	0	0	100
2	2.61	2.61	0.37	99.63
1	64.3	66.91	9.5	90.5
600	116.2	183.37	26.12	73.88
425	163.2	346.57	49.37	50.63
300	36.24	382.81	54.53	45.47
150	197.66	580.47	82.69	17.31
75	119.28	699.75	99.68	0.32
Pan	2.2	701.95	100	0

Table No 1: Sieve Analysis of Soil



Graph 1: Sieve analysis Test curve

Summary of Results

Percentage of Gravel in soil sample = Nil

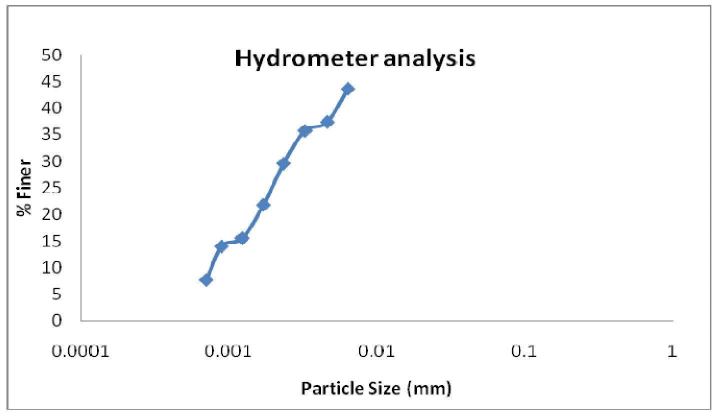
Hydrometer Analysis (IS 2720 - Part 4)

Purpose

Hydrometer analysis is used to find percentage of various soil grains finer than 0.075mm.

Elapsed Time, t min	Actual Hydrometer reading, R_h	Corrected hydrometer reading, $R_{cl}=R_h+C_m$	H	He	Particle size, D(mm)	Percentage of fines
30	1.014	14.0	5.5	12.19	6.37x10-3	43.55
1	1.012	12.0	6	12.69	4.59x10-3	37.33
2	1.0115	11.5	6.2	12.89	3.27x10-3	35.7
4	1.0095	9.5	6.5	13.19	2.34x10-3	29.55
8	1.007	7.0	7.2	13.89	1.70x10-3	21.77
16	1.005	5.0	7.6	14.29	1.22x10-3	15.55
30	1.0045	4.5	7.7	14.39	0.89x10-3	14
50	1.0025	2.5	8.2	14.89	0.70x10-3	7.7

Table No 2: Hydrometer analysis



Graph 2: Hydrometer analysis.

Percentage of soils is 23% and Percentage of clay is 77%.

Determination of Liquid Limit (LL) Using cone penetration method

Liquid limit is the water content at which the soil changes from liquid state to plastic state. In other words, liquid limit is the water content at which the soil passes from zero strength to infinitesimal strength.

Liquid Limit (LL) = 22%

Determination of Plastic Limit (PL)

S.No	Determination No.	1	2	3
1	Container Number	17	22	34
2	Weight of container + wet soil (gm)	20.10	17.02	19.2
3	Weight of container + dry soil (gm)	0.13	0.08	0.03
5	Wt. of container (gm)	20.23	17.10	19.23
6	Wt. of dry soil (gm)	0.68	0.39	0.26
7	Moisture content %	19.1	20.5	11.53

Table 3: Determination of Plastic Limit (PL) Plastic Limit (PL) = 17.04 % Plasticity Index (Pl) = LL - PL = 3.95

Standard Proctor Test (IS: 2720 - Part 7)

Compaction is the process of densification of soil mass by reducing air voids. The purpose of laboratory compaction test is so determine the proper amount of water at which the weight of the soil grains in a unit volume of the compacted is maximum, the amount of water is thus called the Optimum Moisture Content (OMC). In the laboratory different values of moisture contents and the resulting dry densities, obtained after compaction are plotted both to arithmetic scale, the former as abscissa and the latter as ordinate. The points thus obtained are joined together as a curve. The maximum dry density and the corresponding OMC are read from the curve.

CALCULATION

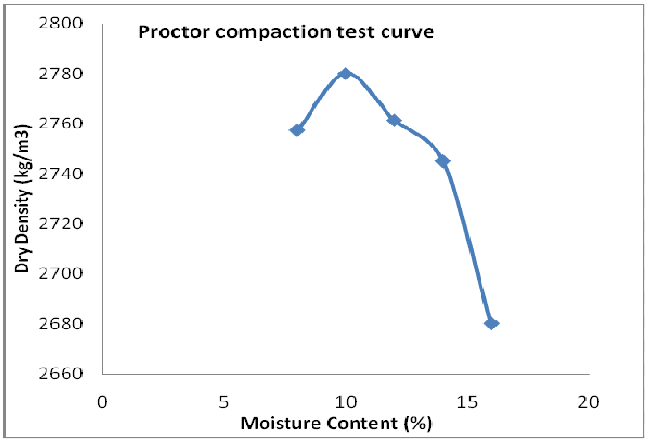
1. Description of Sample = Well Graded Sand
2. Weight of Mould = 4250 gm
3. Volume of Mould = 1000 cc

S.No	Determination No.	1	2	3	4
1	Weight of Mould + Compacted soil (kgs)	2.922	3.00	3.034	3.05
5	Weight of container + wet Soil (gm)	46.34	44.80	50.21	50.99
6	Weight of container + Dry soil (gm)	40.46	39.85	46.41	45.79
10	Water content (%)	5.12	9.08	14.69	18.65
11	Dry Density(gm/cc)	1.704	1.817	1.85	1.786

Table 4: Data Sheet for Proctor Compaction Test.

Results: (As per Graph Below)

1. Optimum moisture content = 10%
2. Maximum dry density = 2780 kg/m^3



Graph 3: Proctor compaction test curve.

The California Bearing Ratio Test (IS: 2720 - Part 16)

Need and Scope

The California bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. California bearing ratio is the ratio of force per unit area required to penetrate in to a soil mass with a circular plunger of 50mm diameter at the rate of 1.25mm / min. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

CALCULATION:

1. Sample = Well Graded Sand.
2. Source of material =Sree Vidyanikethan Engineering college

Results

Only Soil

2.5 mm Penetration CBR = Test load/ Standard load × 100% = (52.5/1370) × 100 = 3.9%

5 mm Penetration CBR = Test load/ Standard load × 100% = (115/2055) × 100 = 5.6%

4. Traffic Design: The recommended method considers design traffic in terms of the cumulative number of standard axles to be carried by the pavements during the design life. Axle load spectrum data are required where cementations bases are used for evaluating the fatigue damage of such bases for heavy traffic.

Calculation of Pavement Thicknesses:

Available Data:

1. Design of CBR of Subgrade Soil: 5 %
2. Design Life of Pavement: 10 years
3. Annual Growth rate: 5 %
4. Distribution of Commercial vehicle for Single Lane: Single Lane
5. Computation of Design traffic for the end of Design life: 0.75

Computation of Design Traffic

The design traffic in terms of the cumulative number of standard axles to be carried during the design life of the road should be computed using the following equation:

$$N = \{365\times[(1+r)^{n}-1]/r\}\times\{A\times D\times F\}$$

N = The cumulative no. of standard axles to be catered for in the design in terms of msa.

A = Initial Traffic in the year of completion of completion of Construction in terms of the number of Commercial Vehicle Per Day (CVPD)

Case-II Soil + 10 % Fly ash+5% iron oxide -Total pavement thickness = 645 mm

Pavement composition interpolated as per MORT&H (IRC37-2012 plate 4)

2.5 mm Penetration CBR = Test load/ Standard load × 100% = (55/1370) × 100 = 4.16%

5 mm Penetration CBR = Test load/ Standard load × 100% = (140/2055) × 100 = 6.8%

CBR Value for subgrade soil = 5.6%

CBR Value for subgrade soil + 10% Fly ash +5% iron oxide =6.8%

CBR Value for subgrade soil + 10% Fly ash+10% iron oxide =12.6%

CBR Value for subgrade soil + 10% Fly ash+15% iron oxide =8.1%

CBR Value for subgrade soil + 10% Fly ash+20% iron oxide =3.8%

Traffic volume count survey:
Commercial Vehicle per day = 800 nos

A = P (1+r)^x
P = No. of commercial vehicles as per last count
x = No. of years between the last count and the year of Completion of construction
D = Lane distribution factor
F = Vehicle damage factor
n = Design Life in Years
r = Annual growth rate of commercial vehicles

Design Calculation of Pavement thickness:
1. Commercial Vehicle at last count "P" =800CV/Day
2. r =7.5%
3. x =1
4. A =840
5. D =1
6. F =3.5
7. N = 23.15 msa (say 24 msa)

Case-I Total thickness of pavement for design CBR 5.6%
For 5% design traffic 24 msa of IRC37, 2012 Total Thickness = 697mm

Pavement composition interpolated as per MORT&H (IRC37-2012 plate 3)

(a) Granular Sub base = 300 mm

(b) Base course = 250 mm

(c) DBM = 107 mm

(d) BC = 40 mm

S.No	Description	Layers	Layers Thickness
1	Soil	Granular Sub base	300
2		Base Coarse	250
		Dense Bituminous Macadam(DBM)	107
3		Bituminous Coarse	81

Case-II Soil + 10 % Fly ash+5% iron oxide - Total pavement thickness = 645mm

S.No	Description	Layers	Layers Thickness
1	Soil	Granular Sub base	260
2		Base Coarse	250
		Dense Bituminous Macadam(DBM)	95
3		Bituminous Coarse	40

Case-III Soil + 10 % Fly ash+10% iron oxide - Total pavement thickness = 575mm

S.No	Description	Layers	Layers Thickness
1	Soil	Granular Sub base	200
2		Base Coarse	250
		Dense Bituminous Macadam(DBM)	85
3		Bituminous Coarse	40

Case-IV Soil + 10 % Fly ash+15% iron oxide - Total pavement thickness = 580mm

S.No	Description	Layers	Layers Thickness
1	Soil	Granular Sub base	200
2		Base Coarse	250
		Dense Bituminous Macadam(DBM)	90
3		Bituminous Coarse	40

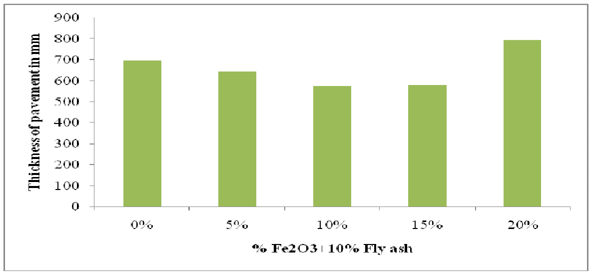
Case-V Soil + 10 % Fly ash+20% iron oxide - Total pavement thickness = 797mm

S.No	Description	Layers	Layers Thickness
1	Soil	Granular Sub base	380
2		Base Coarse	250
		Dense Bituminous Macadam(DBM)	127
3		Bituminous Coarse	40

Pavement Thickness Comparison:

Using iron oxide CBR value of the soil increased by 6.8% and pavement Thickness has decreased by 130mm.

S.No	% Fe2O3+10% Fly ash	Thickness of pavement in mm
1.	0%	697
2.	5%	645
3.	10%	575
4.	15%	580
5.	20%	797



Graph 4: Pavement Thickness Comparison

Conclusions

Life and functioning of flexible pavement depends on sub grade soil. To improve the maintains and functioning of pavement the properties of soil sub grade is improved by adding additives like fly ash and iron oxide. 10% of fly ash is added along with different percentages of iron oxide and is found to be stabilized at 10% fly ash + 10% iron oxide. Using iron oxide CBR value of the soil increased by 6.8% and the thickness of pavement has decreased by 130mm.

Soil stabilization improves the strength of soil. By the increase in soil strength we can decrease the pavement thickness. Reducing pavement thickness the cost of the construction is reduced. All most all sub grades can be improved by the application of stabilizing additives. Most of the advantages obtained for poorer sub grade values of CBR values less than 8%.

Further this research work can be carried out with other additives not only iron oxide and fly ash, commonly used additives are lime, fly ash and cement for the stabilization of sub-grade.

Acknowledgments:

The writers would like to acknowledge the support of the Department of civil engineering at Sree Vidyanikethan Engineering College, Tirupati. I would also like to extend my gratitude to T.P.Gayathri, Vamsi and. Mahesh students of SVEC, for their support and valuable tips throughout the work.

References

i. *R.Vinod Kumar, Pavithra.M(2016) Experimental Study on Design of Flexible Pavement Using CBR Method "International Journal of Engineering Research" Volume No.5, Issue Special 1 pp : 63-68.*

ii. *Er. D Kumar Chowdary and Dr.Y. P Joshi (2014)."A Detailed Study of CBR Method for Flexible Pavement Design" Int. Journal of Engineering Research and Application, Vol. 4:2248-962.*

iii. *"Khanna .S.K & Justo C.E (March 2001)", Highway Engineering, Nem Chand & Bros Publications, Roorkee (U.A), Eighth Edition.*

iv. *IS 2720 Part-5 "Method of test for Soil-Determination of Liquid limit and Plastic limit".*

v. *IS 2720 Part –8 "Method of test for Soil-Determination of Water Content, Dry density relation using a heavy Compaction & light compaction"*

vi. *IS 2720 Part-16 "Method of test for Soil-Laboratory determination of CBR".*

vii. *Partha Chakroborty & Animesh Das "Principles of Transportation Engineering"Ministry of Road Transport and Highways Report of the Specifications for Road and Bridge Work in India.*

viii. *IRC: 37-2012, "Guidelines for the Design of Flexible Pavements" IRC, New Delhi.*

ix. *Highway Material Testing", lab manual by S.K. Khanna and C.E.G. Justo*

x. *ASTM Designation D1883, 2007. "Standard Test Method for CBR (California Bearing Ratio) of Laboratory". Compacted Soils, PP*