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Laboratory and Field Performance of stabilized soft subgrade

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***Abstract**: Usually the service life of pavement on weaker clayey subgrade is affected due to their high plasticity and compressibility behaviour. These soils possess low strength, CBR value and have high affinity to moisture. Hence seasonal changes affect properties of these soils adversely. Stabilization techniques using waste materials are listed in literature for improving properties of these types of soft subgrades. This paper discusses the performance of stabilized soft clayey soil for suitability as subgrade using two types of admixtures Robo sand and fly ash. Dynamic cone penetration test and CBR tests are carried out in lab and field on composite soil with varying admixture content and the results are presented. It is observed that there is a considerable improvement with admixture in both index & engineering properties. A reduction in plasticity and improvement in soaked CBR with admixture is observed. Results indicated a relatively high performance of robo sand admixture over fly ash.*

***Keywords:** Clayey soil, CBR, stabilization, fly ash, robo sand.*

I. INTRODUCTION

1.0 General

Transportation engineers often face problems in pavement due to soft subgrades. These soft subgrades have low density and high affinity towards moisture. Due to this the life of pavement will be affected. In general soft subgrades are identified by their insitu density and CBR value. One of the remedy as suggested previously is improving engineering properties using various techniques. Among all techniques stabilization technique is best suited for soft soils. Various researchers carried out studies using admixtures namely lime, cement and flyash etc. Laboratory experiments confirmed that strength and stability of clayey soils can be improved by adding various admixtures like lime, cement, flyash, kiln dust etc., the lime clayey soil mixture exhibits higher strength compare to clayey soil fly ash mixture [1]. The influence of fly ash on organic and inorganic clayey soils is different; strength improvement with varying percentage of fly ash for inorganic soils is high compared to organic soils [2]. Influence of waste sand on engineering properties on clayey soils varies with varying percentages and CBR value increased by 20% with the addition of 20% of waste sand [3]. The influence of sand on cohesive soil is significant and with addition of 15% of fine sand strength of soil is doubled [5]. The field performance of stabilized expansive soil with fly ash and density is maximum at 25% fly ash and workable in field [6]. Few complex situations with soft subgrade can be solved by providing stiffer aggregate layer over soft subgrade and the problem of mixing of subgrade with aggregate can be avoided with separator geotextile [7]. The lab performance may be different to that of field due to heterogeneous conditions. Inorder to understand the actual behaviour of subgrade, field tests are recommended. The field performance of marine clayey soil treated with lime, GBFS and geotextile - clay foundation soil bed has exhibited the justified load carrying capacity in wet season [4]. In few cases owing due to the difficulty in field set up the field CBR performance can be predicted indirectly from DCPT (Dynamic cone penetration test) data conducted in field and later can be correlated using equations [8].

1.1 Scope and objective of present study

The scope of present study is to suggest suitable stabilizing materials and evaluate the quantum of improvement.The main objective of the present study is to perform i) laboratory studies on stabilized soil, ii) field CBR test on the stabilized soft subgrade bed, iii) DCPT in field on stabilized bed, iv) comparison of results. The admixtures utilized for study are waste industrial materials. The details of tests and results obtained are presented in the subsequent sections.

II. EXPERIMENTAL STUDY

2.1 Materials used

During the experimental study tests are conducted using the following three types of materials. The material includes i) local soil predominantly clayey in nature,ii) Artificial sand (robo sand) a product obtained from stone crushers, iii) flyash a product obtained from Thermal power plant NTPC. The robo sand is a well graded soil containing predominantly sand size particles. The fly ash is class C type containing predominantly silt sized particles with no plasticity. Mechanical stabilization is followed by mixing proportions of robo sand and fly ash to soil. The details of proportions adopted are described in the subsequent headings.

2.2 Preparation of soil admixture mix, details of tests and parameters studied

The soil admixture mix is prepared by mixing the soil with admixture of desirable proportion by weight of soil. For a given admixture content, admixture is mixed with soil and required weight of soil mix is taken from the mixture prepared. For all the mix proportions dry weight of soil is taken as basis. Using the prepared mix, laboratory and field tests are conducted. Laboratory tests include index properties, gradation, proctor compactionTests and CBR. Field tests include, field CBR and dynamic cone penetration test. The tests were carried out in accordance of Indian Standard code of practice. The following parameters are determined in experimental study on stabilized soil;

- Atterberg limits
- Grain size distribution
- Optimum moisture content and maximum dry density
- CBR(soaked) in lab and field
- Dynamic cone penetration index.

CBR test is conducted on sample after soaking for 96 hours. The sample is prepared in mould maintaining density and moisture content as obtained during compaction test. The moisture content and density after soaking is noted for preparation of sample in field later. The additives are varied from 0 to 50% by weight of soil. Since the testing program involves different admixtures in varying proportions, for indicating purpose, symbols are adopted for admixtures and for different combination of admixture and soil. Table-1 describes the ranges of admixture and nomenclature adopted for describing various samples with admixture.

2.3 Subgrade preparation for field CBR test

Field CBR is conducted on few prepared subgrade samples with additives. The tests are conducted on subgrade prepared by filling with admixture soils in pits. Initially pits of size 0.5m x 0.5m x 0.5m are excavated. The pits are filled and compacted with prepared soil-additive mixture. For uniformity density and moisture content of lab CBR (soaked) test samples is maintained for filling. Field density tests are carried out for ensuring required conditions. For application of load, reaction loading method is adopted. Observations are recorded for load and corresponding deformation of plunger. The field CBR is calculated from the load-penetration data.The tests are conducted on different stabilized subgrade fills in different test pits. The layout of test pits, schematic diagram of testing and field test set up are shown in fig I, II and III.

2.4 Dynamic Cone Penetrometer Test

DCPT test is carried on the same subgrade prepared for Field CBR test (section 2.3 above). The test is conducted by driving a cone of 60^0 apex angle and 20mm diameter by dropping weight of 8kg from a height of 640mm. The penetration with blows is recorded. A graph is drawn between penetration and blows. The slope of graph is indicated as DCPI (mm/ blow). The test trails are conducted at few locations over the prepared subgrade and average of DCPI is reported. Test set up for DCPT and testing is shown in the fig IV.

III. PRESENTATION OF LABORATORY RESULTS AND DISCUSSIONS

3.0 Tests are carried out on soil with varying admixtures namely, index and engineering properties. The results of lab tests are presented from section 3.1 to 3.4 in tables II to IV and from fig. V to VIII.

3.1 Presentation of Index properties of parent soil

The index properties of samples are presented in table-II. It is impiled from the CBR value that the soil is very soft and needs improvement. From the index properties the soil is grouped as CI. The results on admixture robo sand indicate the soil is well graded sand and the fly ash is non-plastic.

3.2 Variation of index properties of stabilized soil

The variation of index properties with admixture is presented in table-III. It is noted that with the addition of admixtures the plasticity index has decreased. This is an indication of improvement in soil properties. The result trend indicates effect of fly ash is more than that of robo sand. The net decrease in PI is due to reduction of liquid limit in the case of Robo sand whereas the same due to increase of plastic limit in the case of flies ash. This explains that the soil is becoming stiffer due to admixtures. The consistency indices showed a decrease of liquid limit and Plasticity index from 48.32 to 41.45, 23.3 to 18.59 and 48.32 to 37.6, 23.3 to 6.49 respectively using robo sand and fly ash. With the increase in robo sand affinity to water decreased due to which liquid limit is decreased. The same trend is observed with fly ash also. However as expected the amount of decrease is more with fly ash than robo sand. The reduction is negligible from 40 to 50% for both the admixtures.

3.3Presentation of results of compaction test

The compaction characteristics of soil with admixture soil are presented as detailed below. The compaction curve for various samples is presented in fig. V. The effect of robo sand and fly ash in on maximum dry density (MDD) and optimum moisture content (OMC) is plotted in the figure VI.

From Fig V it is observed that the density affected due to decrease of robosand content. As expected low density of fly ash than robo sand has affected the density of mixture. The reason of decrease in density can be substantiated with the trend shown for OMC i.e, increase with fly ash. The addition of fly ash adds more fines resulting increase in OMC. The density trend showed a peak of 18.31 kN/ cu.m for the sample SRSFS41 containing 40% sand and 10% fly ash. The performance of stabilized mixture is due to the reduction of void ratio with increasing robo sand for SRFS41. This is evident from table IV.

3.4 Presentation of laboratory CBR results for stabilized soil

The laboratory results of CBR test (soaked) are presented and fig. VII. The variation of CBR is similar to that of density. From table VI it is observed that peak CBR is obtained for SRSFS41 followed by SRS4. SRSFS41 which contains 40% sand and 10% flyash and SRS4, which, contains 40% sand alone. The improvement in CBR with robo sand and fly ash is presented in Fig. VIII. It is evident that the influence of sand is higher than fly ash at high contents. The trend in CBR increase shows that the variation is gradual for robo sand. However with fly ash the variation is gradual till 40% but sudden increase from 40% to 50%. It may be due to filling of voids in coarser robo sand and cementations properties in fly ash.

IV. PRESENTATION OF IN-SITU RESULTS AND DISCUSSIONS

4.0 In situ tests namely field CBR and Dynamic cone penetration tests are conducted on stabilized subgrade fill. The tests are conducted on selected fills for comparison. Field CBR are conducted on four types of samples S, SRS4, SFS3 and SRFS41 The results of field tests are presented in section 4.1 to 4.2 and in fig. IX & X and tables V , VI & VII.

4.1 Presentation of field moisture and density

As discussed in 2.3 above, the field testing is carriedout maintaining moisture and density corresponding to four days soaking. The field density tests are conducted after filling and are presented in table V. The data shows that the diference in moisture content is less than 2%. The same difference is obtained for density also. This shows that the fill prepared is identical to lab and can be compared for performance. Field CBR test results and lab CBR results are presented in table VI.

It is observed that field CBR is higher than lab for all samples. The heterogeneous surrounding soil has influence on the result. From Table-VI it is seen that for SRS4 strength in laboratory was improved by 1.9 times and for SFS3 increment was 1.36 times. This is due to when robo sand is added the voids in coarser particles of robo sand were occupied by clayey particles and maximum dry density increased contributing to higher strength. When fly ash is added to clayey soil, water reacts with pozzolans SiO_2, Al_2O_3 present in fly ash and attains cementaceous properties contributing to strength. When robo sand and fly ash are added in combination the maximum CBR is obtained for SRSFS41 combination and the increment is 2.34 times the natural soil CBR.

3.2 Dynamic Cone Penetrometer Test Results

DCP tests were conducted on the same subgrade indicated with S, SRS4, SFS3 and SRFS41. The DCPT graphs were shown in fig. IX, it is observed that the trend is almost same for all the subgrade types. The obtained DCP index is reported in table VII Higher DCPI indicates poor subgrade and vice versa. The DCPI results obtained are consistent with maximum density and CBR.

4.2.1 Variation of DCPI with Field CBR

The variation of the DCPI with field CBR is presented in fig. X, DCPI decreased with increasing CBR values for different compacted subgrade samples. CBR and DCPI both represent the penetration resistance. Higher CBR values represents the higher resistance to penetration and the higher value of DCPI characterizes the poor sub grade and vice versa. From the fig. X it can be seen that DCPI results are consistent with soaked CBR. With CBR increase from 2.06% to 4.54% the DCPI is found to be decreasing from 25.02 to 18.55 mm/blow respectively.

The variation of DCPI is related to CBR as
log (DCPI) = -2.5945log(CBR)+log(30.144) … (1)
Simplifying
Log (CBR) = 0.5701-0.385log (DCPI) ……..… (2)

V. CONCLUSIONS

The following conclusions are drawn based on the field studies carried out comparing with the laboratory Investigations:

i. The addition of the admixtures shall contribute in reducing plasticity and improve gradation.
ii. In general both the admixtures have influence on compaction characteristics. However the influence of Robo sand is more that of fly ash. The max density is obtained at 40%RS+10%FS.
iii. From the results on few of the field CBR tests conducted on natural soil and treated soil, it is concluded that, in-situ conditions have influence when compared with intact specimens. The field results obtained is higher than that of lab. However the stress-strain response is similar in both the type of tests.
iv. From Laboratory and field CBR results it can be concluded that S+40%RS+10%FS can be considered as optimum mix.
v. DCPI test results are in consistance with field CBR. The DCPI can be used to determine approximate CBR and based on the few tests a relation can be drawn as Log (CBR) = 0.5701- 0.385log (DCPI).

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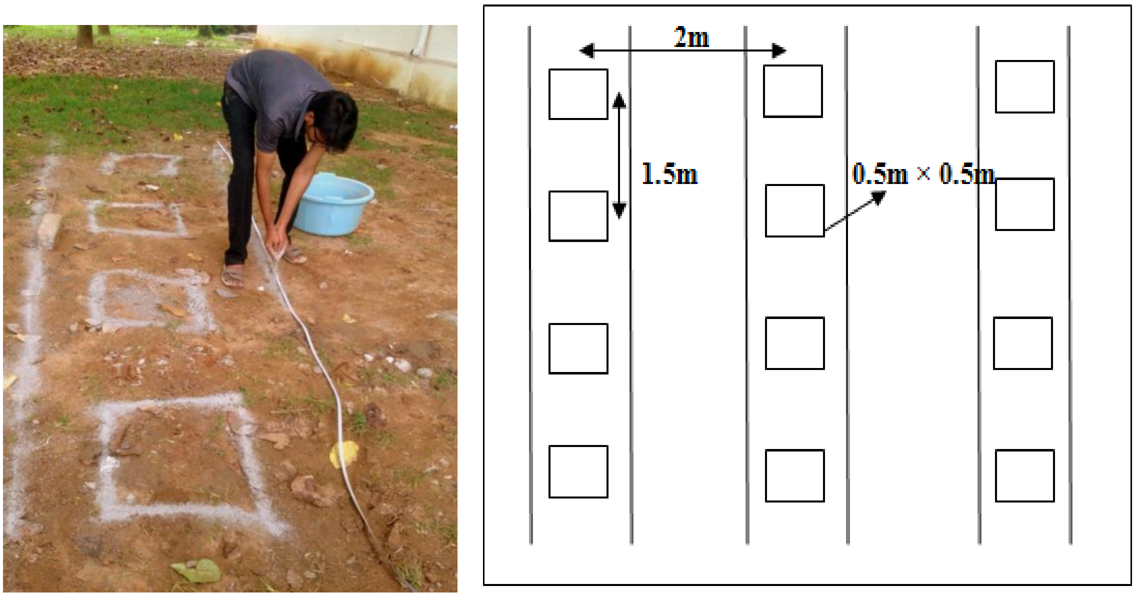
BIOGRAPHIES

Satish Sajja, presently pursuing M.Tech in Transportation engineering in Department of Civil Engineering, GMR Institute of Technology, Rajam, AP, India. He had one year academic experience and two and half years of industry experience.

Mr. V.K. Chakravarthi is currently associated as Senoir Associate Professor in Department of Civil Engineering at GMR Institute of Technology, Rajam, A.P, India. He has a total 19 years of experience in Industrial projects and academics.



(a) (b)

Figure I a) Marking of Test pits b) Layout of Testing area

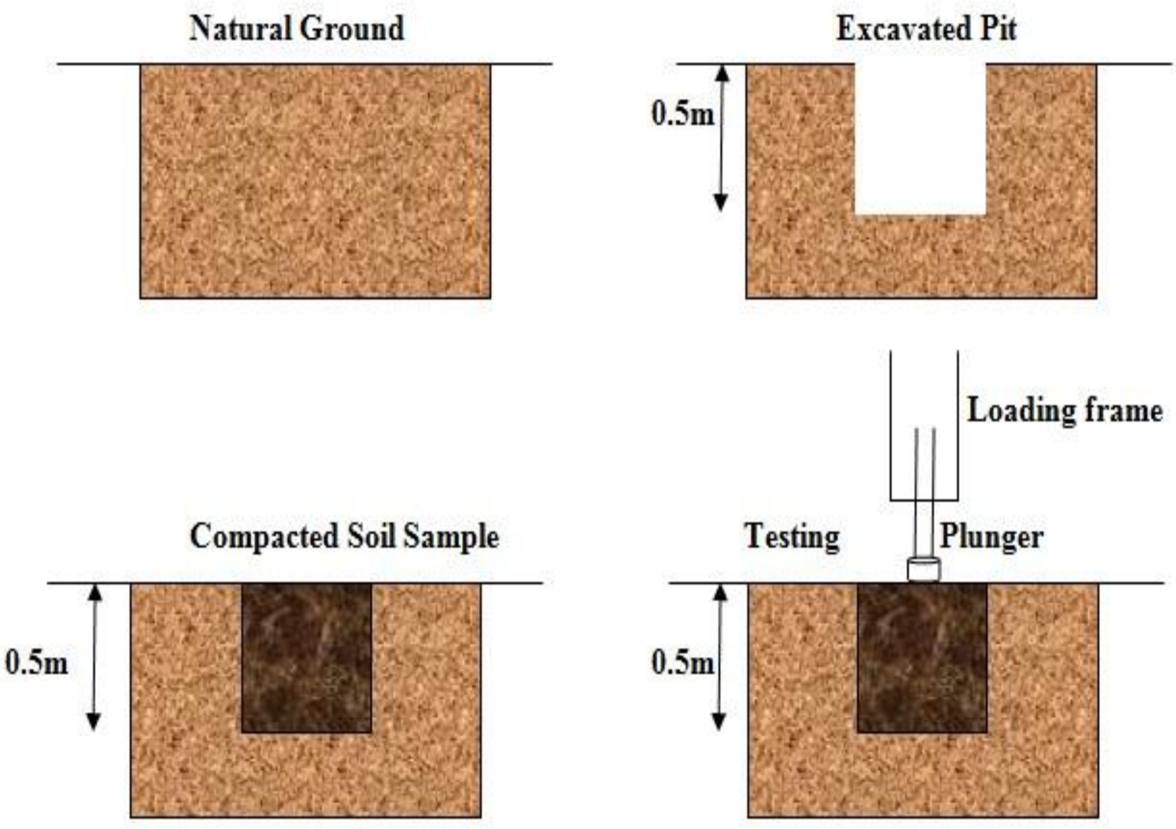
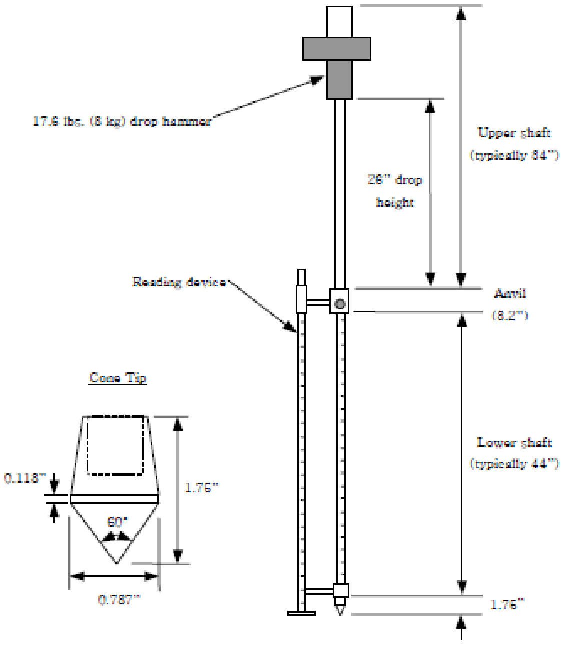


Figure II Schematic line diagram of Field CBR test

Figure III **Author's performing** Field CBR Test



(a)

(b)

Figure IV a) DCPT test arrangement b) **Author** performing DCPT

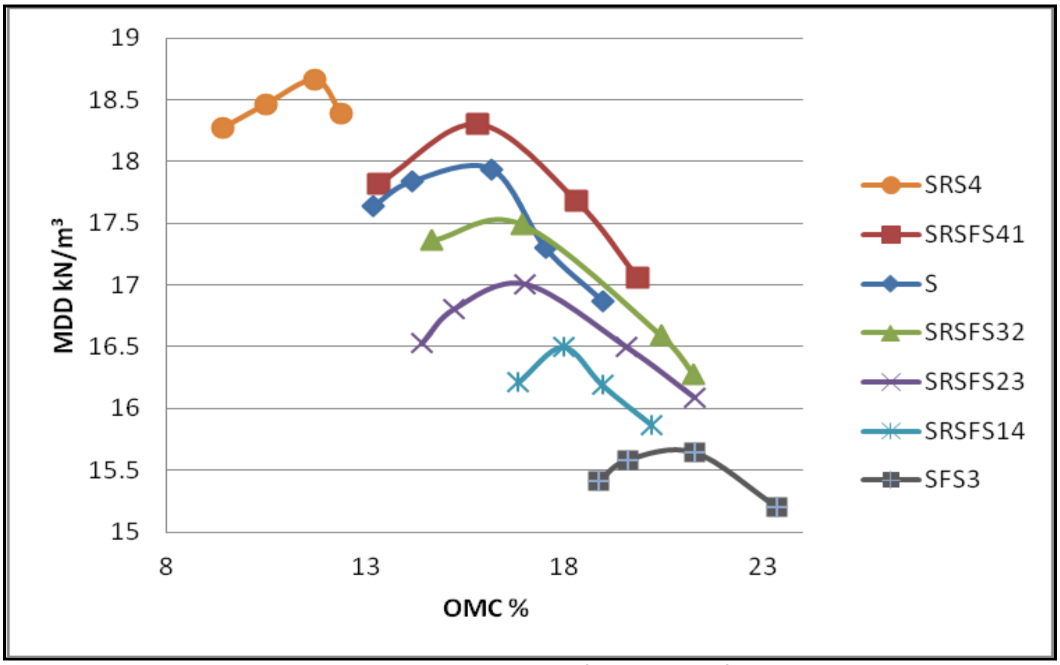


Figure V Compaction characteristics of soil –sand- fly ash mixtures

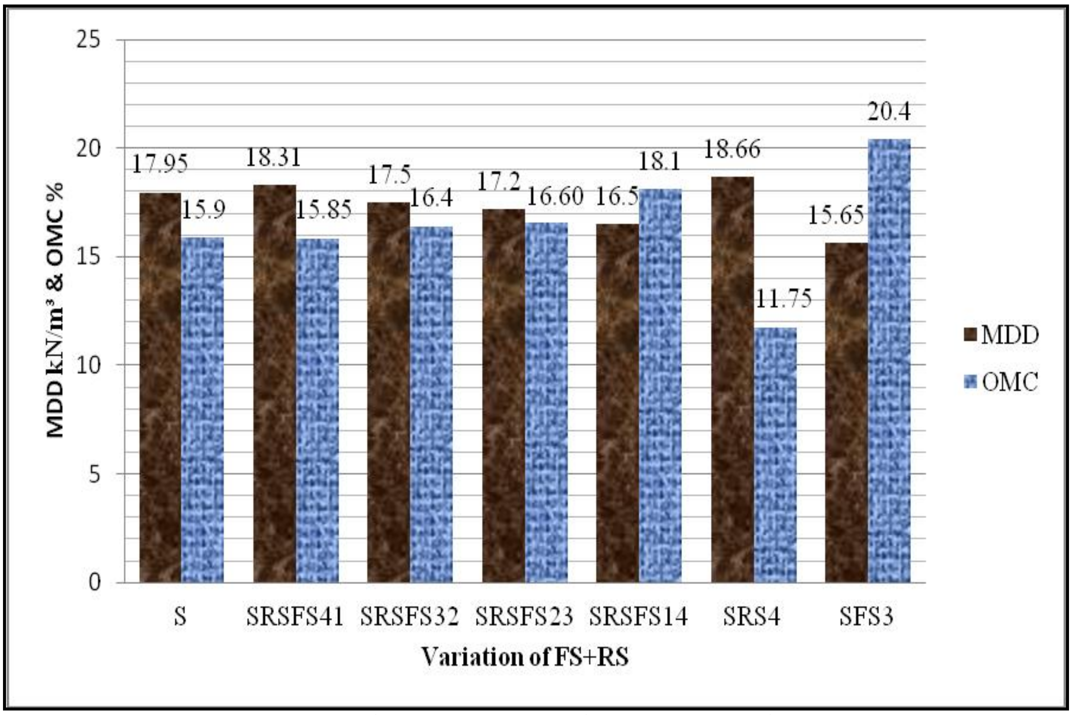


Figure VI Variation of MDD and OMC of soil-robo sand -fly ash mixtures

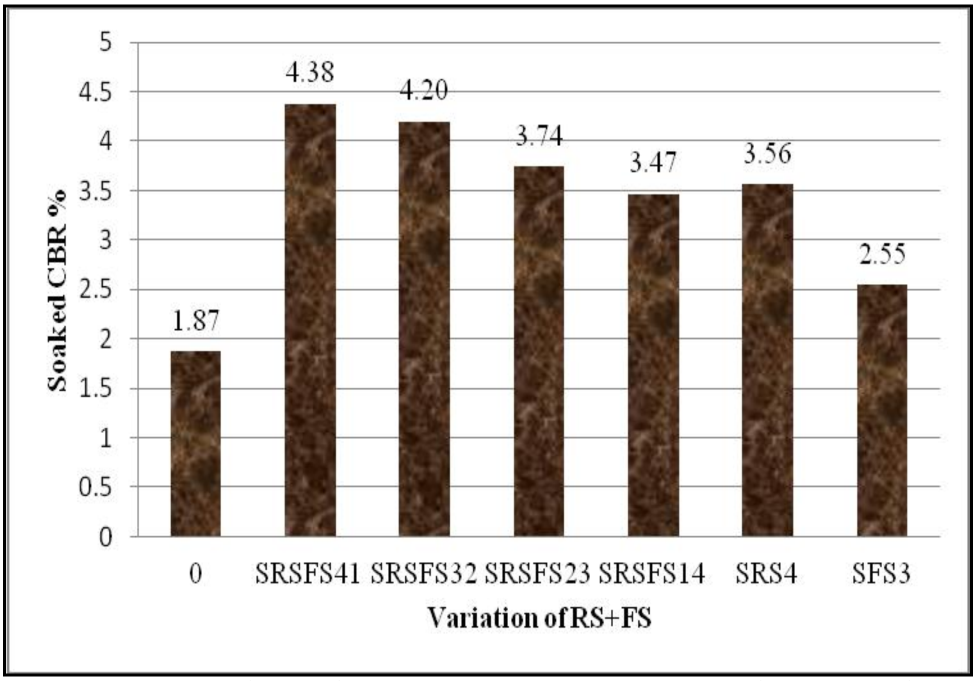


Figure VII Variation of CBR of soil mixed with varying percentages of robo sand &fly ash

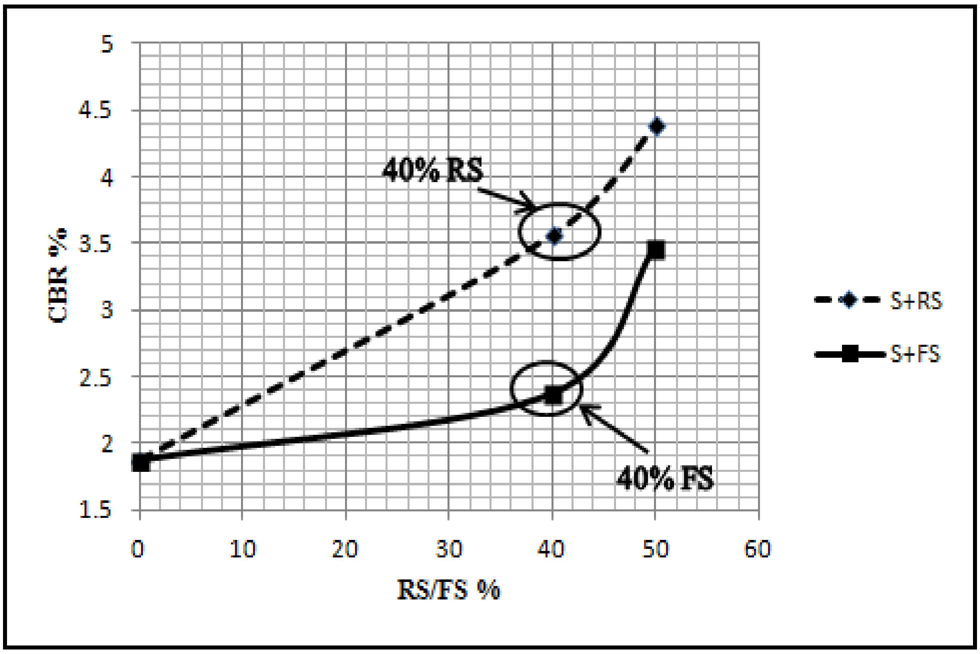


Figure VIII Comparison of CBR of soil mixed with varying percentages of robo sand & fly ash

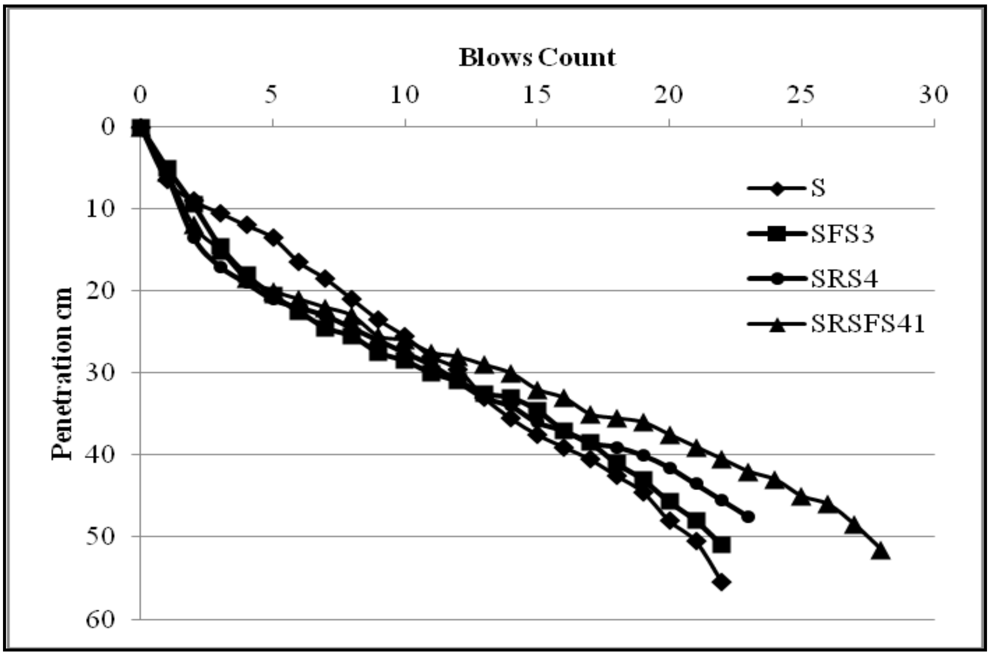


Fig IX Graph of DCP Test on various subgrades

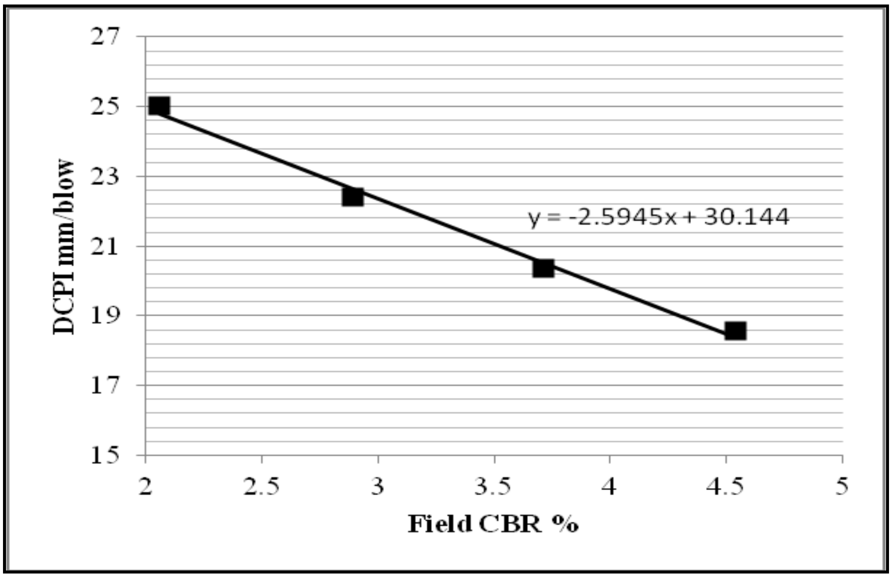


Figure X Varation of DCPI with CBR

Table I Ranges of admixtures and nomenclature adopted

Proportions of sample, admixture	Symbol
Soil	S
Robo Sand	RS
Fly ash	FS
Soil+40%Robo Sand+10%Fly ash	SRSFS41
Soil+30%Robo Sand+20%Fly ash	SRSFS32
Soil+20%Robo Sand+30%Fly ash	SRSFS23
Soil+10%Robo Sand+40%Fly ash	SRSFS14
Soil+40%Robo Sand	SRS4
Soil+30%Fly ash	SFS3

Table II Geotechnical properties of materials used

Property / Soil type	S	RS	FS
Specific Gravity	2.64	2.66	2.04
Liquid Limit, %	48.32	-	-
Plastic Limit, %	25.02	-	-
Plasticity Index, %	23.3	-	-
Fines(%)	65.24	0.00	71.94
Uniformity Coefficient, C_u	-	6.00	-
Coefficient of Curvature, C_c	-	1.127	-
USCS Classification	CI	SW	NP silt
MDD, kN/m^3	17.95	16.09	10.4
OMC, %	15.9	7.8	22.1
CBR (Soaked) (%)	1.87	-	-

Table III Consistency limits with varying percentages of robo sand and fly ash

RS %	LL %	PL %	PI %
0	48.32	25.02	23.3
10	46.00	24.54	21.46
20	44.30	24.05	20.25
30	43.40	23.71	19.69
40	42.10	23.07	19.03
50	41.45	22.86	18.59

FS%	LL%	PL %	PI %
0	48.32	25.02	23.3
10	46.20	26.71	19.49
20	44.40	28.28	16.12
30	40.60	30.11	10.49
40	39.00	31.18	7.82
50	37.60	31.11	6.49

Table IV Void Ratio for different soil- robosand -fly ash mixtures.

Soil	Density kN/m³	void ratio
S	17.95	0.4708
SRSFS41	18.31	0.4134
SRSFS32	17.5	0.4434
SRSFS23	17.2	0.4326
SRSFS14	16.5	0.4558

Table V Presentation of Laboratory, Field Bulk Density and moisture content

Soil	Lab CBR bulk Density kN/m^3	Field CBR Bulk Density kN/m^3	Moisture content after 4days soaking in Lab %	Moisture content in field %
S	20.66	20.69	21.54	21.16
SRS4	20.77	20.83	17.93	17.29
SFS3	18.84	18.55	20.46	19.17
SRSFS41	21.05	20.91	18.67	17.73

Table VI Presentation Laboratory and Field CBR results

Test Pit No.	Soil	Lab CBR(%)	Field CBR (%)
1	S	1.87	2.06
2	SRS4	3.56	3.71
3	SFS3	2.55	2.89
4	SRSFS41	4.38	4.54

Table VII Presentation of DCPI vs. Field CBR

Soil type	DCPI (mm / blow)	Field CBR (%)
S	25.02	2.06
SRS4	20.37	3.71
SFS3	22.39	2.89
SRSFS41	18.55	4.54