International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 10, Issue 8 (August 2014), PP.08-17

Influence of fines (%) and geo-grid reinforcement on engineering properties of subgrade -A lab Study

Unnam Rajesh[1], V K Chakravarthi[2]
[1]*Post Graduate Student, Department of Civil Engineering, GMR Institute of Technology, Rajam, AP, India.*
[2]*Sr. Associate Professor, Department of Civil Engineering, GMR Institute of Technology, Rajam, AP, India.*

Abstract: - Subgrade soil and its properties are very important in the design of road pavement structure. The subgrade function is to give adequate support to the pavement from beneath. The strength of week subgrade need to be enhanced from longevity perspective Reinforcing weaker soils using geo-synthetics like geo-grids to improve its strength is popular in many civil engineering projects namely, highway pavements, air field construction etc. Recently geogrid has gained increasing acceptance in road construction. The geogrid improves the ability to obtain compaction in overlying aggregates, while reducing the amount of material required be removing and replacing. In the present study engineering performance for soil subgrades reinforced with different types of geogrids varying in aperture sizes. Laboratory tests are conducted on the reinforced subgrades. The lab tests include index & engineering properties.Soaked and unsoaked CBR tests are carried out on unreinforced and reinforced samples. The results obtained have shown possible usage of geogrid in improving soaked CBR performance which or otherwise is very low.

Keywords: - subgrade, geo-grid, Reinforcement, CBR

I. INTRODUCTION

A. Problems Associated with soft soils:

In most cases the pavements shows rutting, potholes, cracks, and settlements at various locations especially in rainy seasons. The performance and service-life of the pavement mostly depend on the stiffness and strength of the subgrade soil. While selecting the materials for the sub-base and base course of the pavement road engineer must assist the subgrade characteristics. Hence, the evaluation of subgrade strength assumes great importance in pavement design.

B. Utilization of geogrid: case studies

Geosynthetics are man-made plastic products shaped in many forms (i.e. grids, textiles, nets and cells) that possess and may contribute significant tensile strength to the bottom portion of a highway pavement section. Geosynthetics are having many Civil Engineering applications like (i.e. separation of the soil layers, reinforcement for the subgrade soil, for drainage works, reinforced steep slopes etc).Geosynthetics are important for Highway constructions. The strength of the subgrade soil will be increased by reinforced with Geosynthetics. The thickness of the pavement will be reduced due to Geosynthetics reinforced soft subgrades.

Geosyntheics (Geogrids) with high tensile strength used in combination with soil of high compressive strength have been found to be effective in the design of many civil engineering applications. In the recent years, enormous amount of laboratory studies have been carried out to understand the effectiveness of Geosynthetics when used in combination with soil especially for the applications in paved and unpaved roads **(Choudary & Gill (2011), Latha & Asha (2010), Ziaie et al. (2011)**. Several design methods for paved and unpaved roads based on CBR value are available in literature. The improvement in CBR value of soil by using geogrids has been studied by many researchers **(Sujatha & Balaji (2012)**, **Monther Abdelhadi et al. (2013), Pradeep singh & Gill (2012), Sarika et al. (2011)**. A few researchers have carried out laboratory studies on improvement on reinforced CBR **(Amin et al. (2011), Nagrale et al. (2010) & Naeini (2009). Senthil kumar et al. (2012)** has suggested a laboratory method for the design of geotextile reinforced unpaved roads by conducting modified CBR tests. The reinforcement is used at the interface of the soil and aggregate layers. A few researchers have carried out laboratory studies on waste material mix composite systems like soil-fly ash-geogrid, soil-lime-Geogrid, and soil-pond ash-geogrid **(Ambika et al. (2013), Garendra et al. (2012)**. 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 **(Chakravarthi et al. (2013))**.

C. Scope and objective of present study:

The objective of present study is to suggest usage of geo-grids as reinforcement for improvement of weak subgrades & quantification vis-à-vis type of geo-grid and testing conditions. The scope of work includes testing of different soils for their engineering properties using three types of grids under different test conditions. The soils are chosen based on their plasticity and geo-grids are based on their tensile capacity & aperture size. Studies are carried out with and without geo-grid on soil samples and engineering properties namely, compaction characteristics. Unconfined compressive strength and CBR value are determined. The details of test procedure, preparation of specimens and results obtained are presented in the subsequent headings.

II. EXPERIMENTAL STUDY

Experimental studies are carried out for determination of index and engineering properties of soil subgrades. The engineering properties are determined on subgrade samples in lab. Details of materials used, procedure of preparation & testing of geogrid reinforced specimen in lab are described in the headings A to D. The test are carried out as per IS 2720 (part 4, 5, 7, 10 and 16).

A. Material used:

Two types of locally available soil samples predominantly clay of varying in fines (%) content & Plasticity characteristics and three types of Geo-grids (STRATA make) varying in aperture size, allowable tensile capacity are used in the present study. The geo-grids are manufactured by STRATA GEO SYSTEMS (INDIA) Pvt. Ltd, MUMBAI. The soil properties and details of geogrid are presented subsequent sections.

Table I: Details of Geogrids (source; STRATA)

Geo-grid	Nomenclature	Tensile strength (kN/ m) MD and CD	Creep limit Strength (kN/m)
SG 40X40	SG1	40	27.4
SG 30X30	SG2	30	20.5
SG 15X15	SG3	15	10.2

B. Details of tests and parameters studied:

Laboratory tests are conducted to determine index properties, gradation, proctor compaction Tests and CBR. The tests are carried out as per IS 2720 (part 4, 5, 7, 10 and 16).

The following parameters are determined in experimental study

- Atterberg limits (liquid and plastic limit)
- Fines (%) content
- Optimum moisture content (OMC), and maximum dry density(MDD)
- Unconfined compressive strength, q_u
- CBR(unsoaked & soaked) for unreinforced & reinforced samples

C. Preparation of sample and conduct of Unconfined compressive strength test:

The test is conducted on samples maintaining moisture content, density obtained at optimum conditions and soaking conditions (soaked CBR). The samples are prepared maintaining density and moisture content as obtained from compaction test using constant volume moulds. Cylindrical samples prepared of size 38mm dia and 76mm height are tested in loading frame. The load and deformation data is recorded. A Graph is plotted against vertical stress and axial strain. The Unconfined compressive strength of the soil is reported from the graph. The test is conducted for samples of soil-1 and soil-2.

D. Preparation of sample and conduct of CBR test:

CBR tests are conducted on unreinforced and reinforced soil samples in the lab. Initially soil is compacted in mould maintaining optimum conditions of density & moisture content. CBR test is performed in loading frame. The mould with soil is later soaked for 4 days in water and the tests is repeated. The process is adopted for soil-1 and soil-2. A Single layer of geogrid is placed at mid height of soil in mould while compacting in CBR mould and the test is conducted. The mould with geogrid placed soil is kept for soaking and test is repeated. The same procedure is followed with different geo- grids for soil-1 and soi-2 respectively. Using typical cross section of specimen with geogrid reinforcement and test setup for CBR in lab is shown in fig. I &

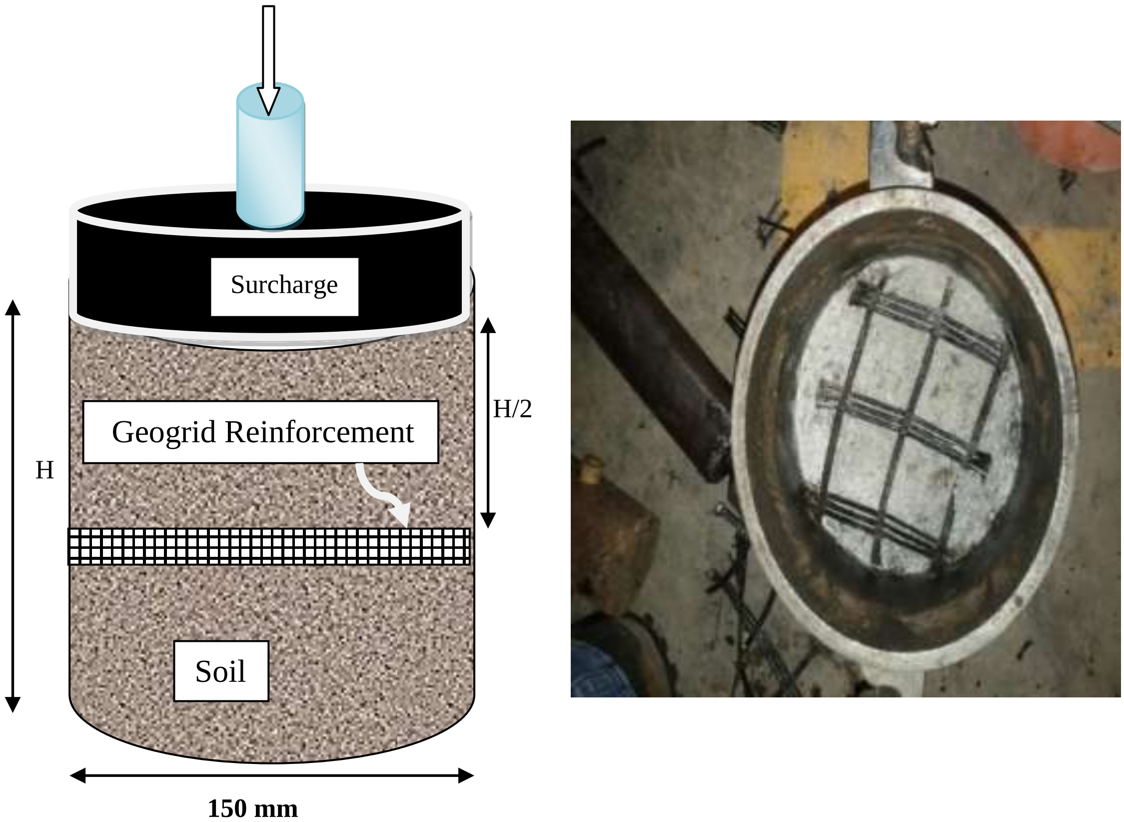
fig. II respectively. For all the samples, moisture content and density is measured after soaking and recorded for comparison. The nomenclature adopted for denoting CBR values are tabulated in table-II and that of moisture content in table-III.

Table II: Details of CBR notations adopted for various testing conditions

Soil type / Testing condition	Soil-1		Soil-2	
	Unsoaked	**Soaked**	**Unsoaked**	**Soaked**
Unreinforced soil	C_{s1}	C_{ss1}	C_{s2}	C_{ss2}
Soil+ Geogrid-1 (SG-1)	C^{1}_{s1}	C^{1}_{ss1}	C^{1}_{s2}	C^{1}_{ss2}
Soil+ Geogrid-2 (SG-2)	C^{2}_{s1}	C^{2}_{ss1}	C^{2}_{s2}	C^{2}_{ss2}
Soil+ Geogrid-3 (SG-3)	C^{3}_{s1}	C^{3}_{ss1}	C^{3}_{s2}	C^{3}_{ss2}

Table III: Notation for moisture content of samples after soaking

Testing condition	Notation
Unreinforced soil	ω_{ss}
Soil+ Geogrid-1 (SG-1)	ω^{1}_{ss}
Soil+ Geogrid-2 (SG-2)	ω^{2}_{ss}
Soil+ Geogrid-3 (SG-3)	ω^{3}_{ss}



(a) **(b)**

Fig I: a) Cross-section of sample with geo-grid for conducting Lab CBR test
b) Placing and position of the geo-grid in CBR mould during preparation

(a) **(b)**

Fig II: (a)Preparation of sample by author for conducting CBR test (b)Author is performing CBR test

III. PRESENTATION OF TEST RESULTS

In the experimental study tests are carried out on geogrid reinforced soil with varying geogrid and soil type. Results of tests obtained are presented and discussed in the subsections A, B, C and D as detailed below.

A. Presentation of Properties of soils:

Two types of soil samples are tested in the lab and index & engineering properties are determined. The index and engineering properties are presented in table-IV. The index properties indicate the soils are low in compressibility and having fines (%) 63.73 and 58.78 respectively. Compaction test graphs are presented in fig. III & IV. The compaction tests showed the OMC is less for soil-2 due to low fines content. However the density is almost same for both the soils.

Table IV: Details of index and engineering properties of Soils

Properties	Soil-1	Soil-2
Specific Gravity	2.65	2.7
Liquid limit (%)	45.50	36.9
Plastic limit (%)	22.15	18.14
Plasticity index (%)	23.35	18.76
Fines (%)	63.73	58.68
IS Classification	CI	CI
OMC (%), ω	15.61	13.21
Maximum dry density γ_d (kN/ m^3)	17.9	17.36
UCS, q_u{unsoaked} (kPa)	89.21	113.24
UCS, q_u {soaked} (kPa)	50.76	71.78
CBR (%) {unsoaked}	3.37	4.83
CBR (%) {soaked}	1.82	1.91

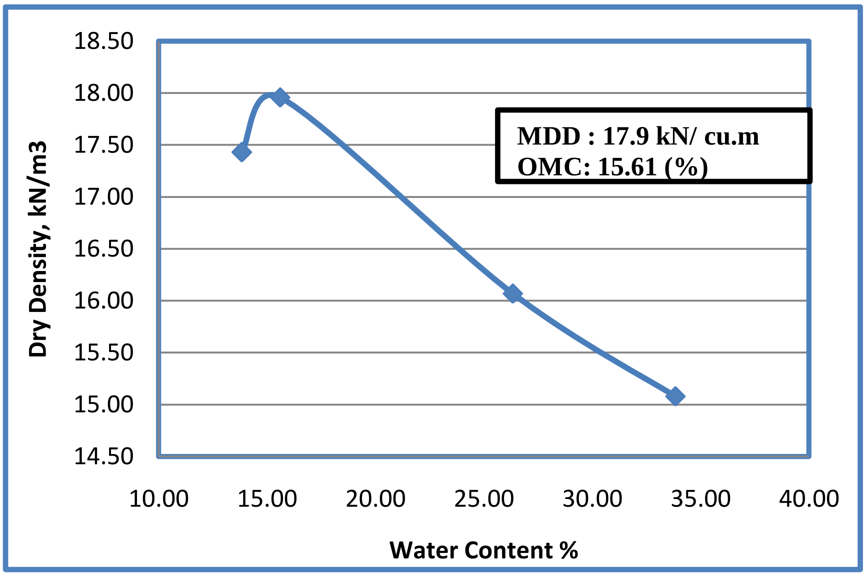


Fig 1II: OMC & MDD Graph for Soil-1

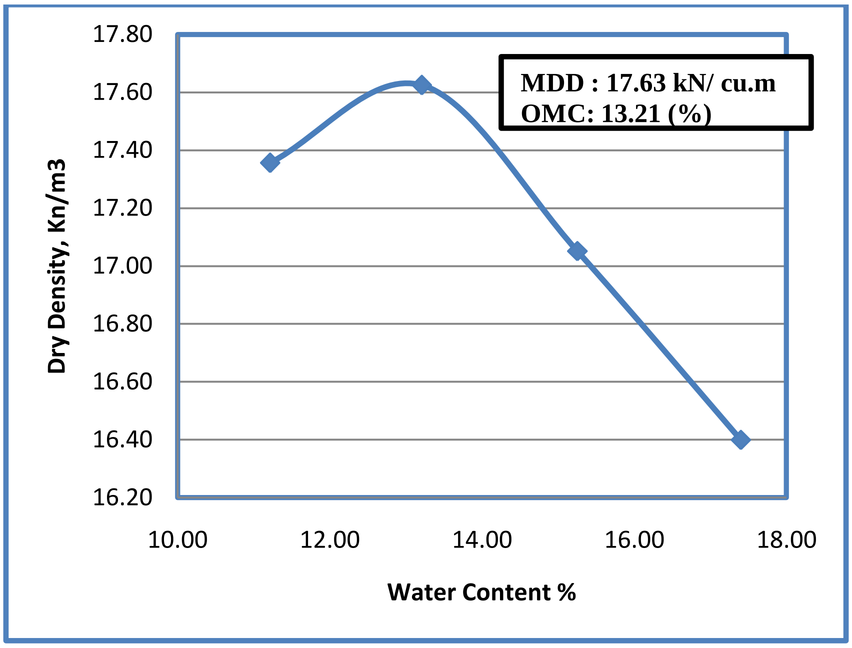


Fig IV: OMC & MDD Graph for Soil-2

B. Presentation UCS test results on soils:

UCS test is conducted on cylindrical samples of size 38mm dia x 76 mm height in UCS testing machine. As discussed in section II the test is conducted on samples with different conditions of moisture content. For test two trials are conducted on each sample and the average is reported. The stress-strain curve for the soil samples is presented in fig. V to VIII. The results are presented in table-IV. UCS is found to vary from 89 to 51 kPa and 113 to 72 kPa for soil-1 and soil-2 unsoaked and soaked samples respectively.

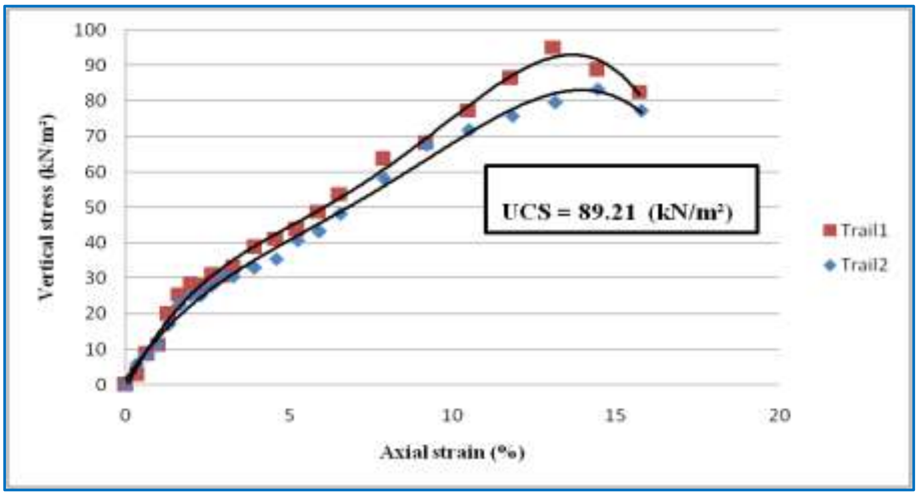


Fig V: UCS (unsoaked) graph for Soil-1

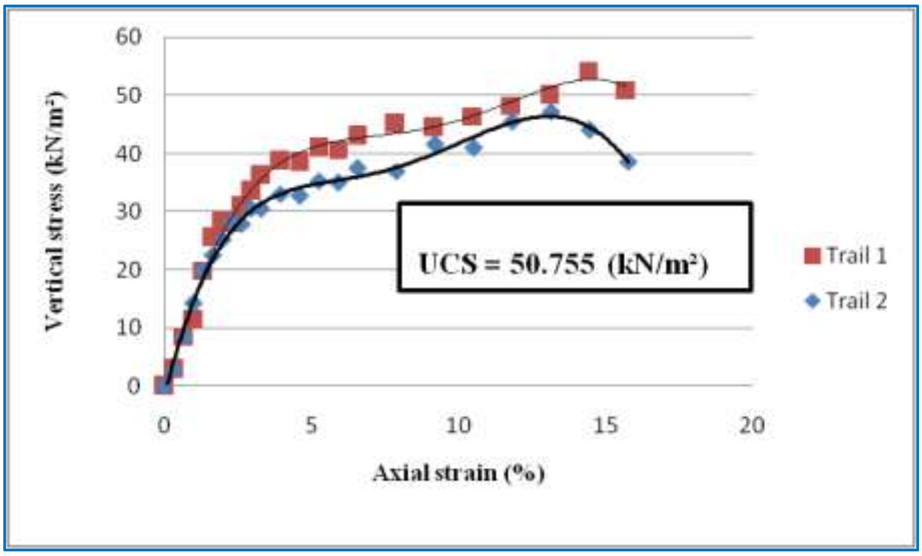


Fig VI: UCS (soaked) graph for Soil-1

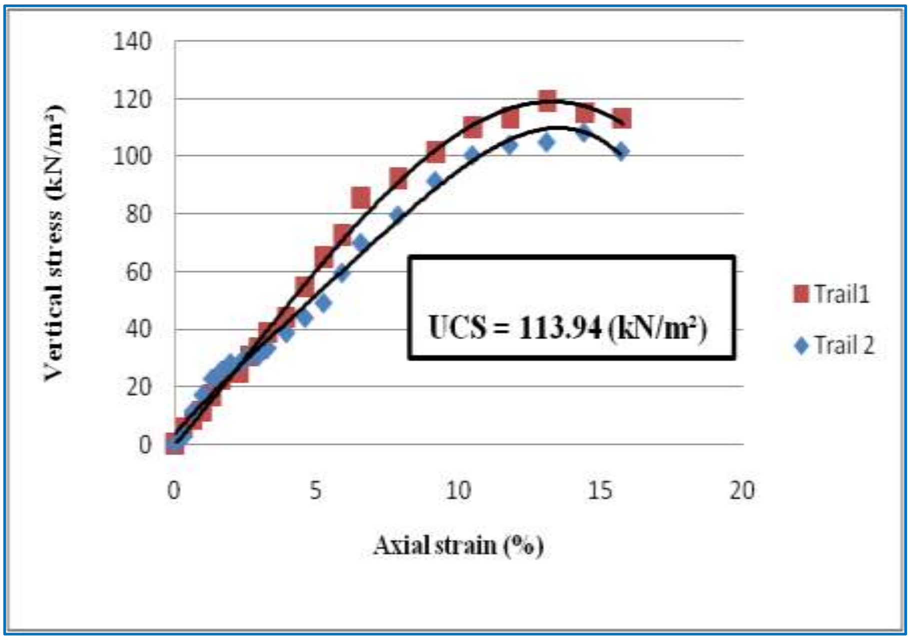


Fig VII: UCS (unsoaked) graph for Soil-2

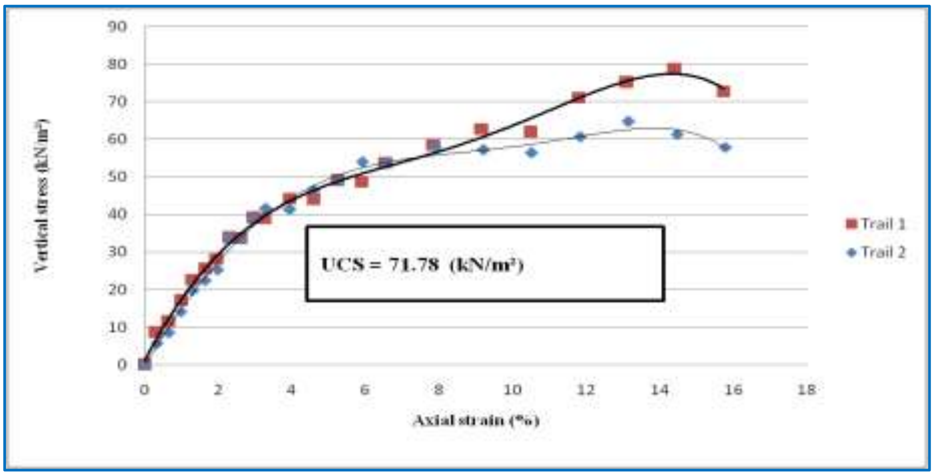


Fig VIII: UCS (soaked) graph for Soil-2

C. Presentation of CBR results of soil subgrades:

Results of CBR tests are presented in table-V and in graphs fig. IX to XII. From the test results, as expected the soaked CBR is less than unsoaked CBR. The CBR value is found to decrease from 3.37 .to 1.82 upon soaking for soil-1. The response of soil-2 is similar. For soil-2 CBR value decreased from 4.83 to 1.91 after soaking.

From the table it is also observed that the trend is same using reinforcement. CBR is found to decrease from 6.11 to 3.92, 5.38 to 3.46, and 4.75 to 3.29 for soil-1 and 8.76 to 5.01, 8.30 to 4.28, and 7.67 to 4.01 for soil-2 respectively after soaking.

The effect of soaking is evident from table- VI. It can be seen that both types of soils exhibited moisture absorption. The absorption is more in s-1 than s-2. The moisture content is increased from 15.61 to 21.14, 20.68, 20.51 and 20.64 for soil-1 and from 13.21 to 18.75, 18.36, 18.96 and 18.64 for soil-2 respectively. This illustrates the reduction in CBR after soaking.

Table V: Presentation of CBR results

Parameter	Soil-1	Soil-2
C_s	3.37	4.83
C^1_s	6.11	8.76
C^2_s	5.38	8.30
C^3_s	4.75	7.67
C_{ss}	1.82	1.91
C^1_{ss}	3.92	5.01
C^2_{ss}	3.46	4.28
C^3_{ss}	3.29	4.01

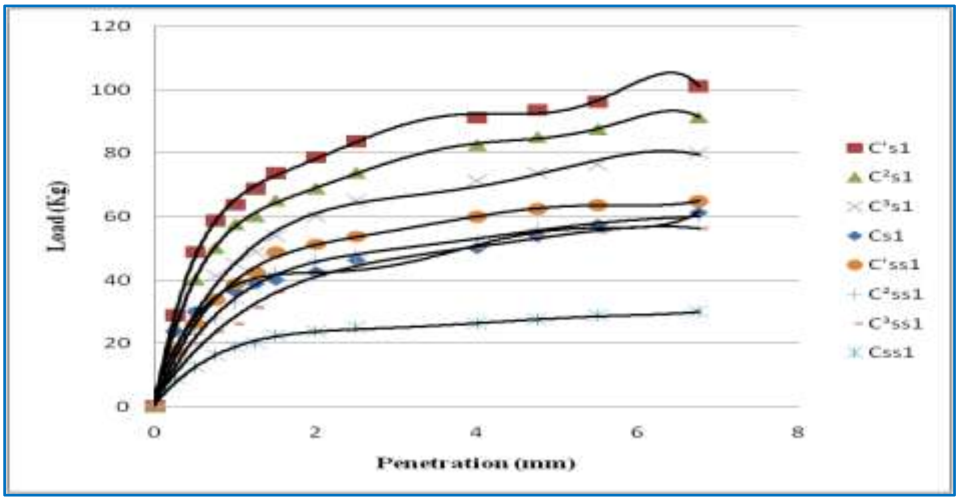


Fig IX: CBR Graph for soil-1 (unsoaked & soaked condition)

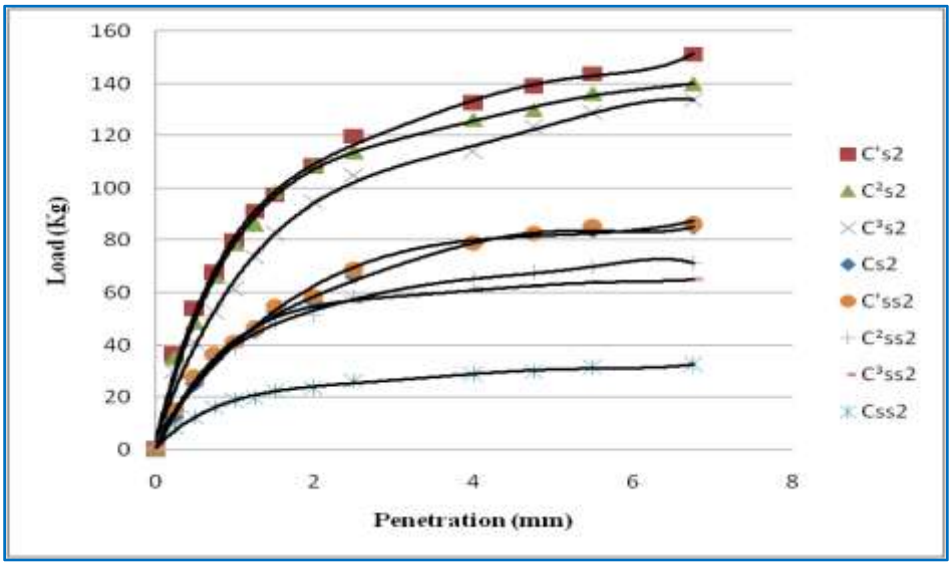


Fig X: CBR Graph for soil-2 (unsoaked & soaked condition)

Table VI: Presentation of moisture content of soil before and after soaking

Parameters	Soil-1	Soil-2
ω	15.61	13.21
ω_{ss}	21.14	18.75
ω^{1}_{ss}	20.68	18.36
ω^{2}_{ss}	20.15	18.96
ω^{3}_{ss}	20.64	18.64

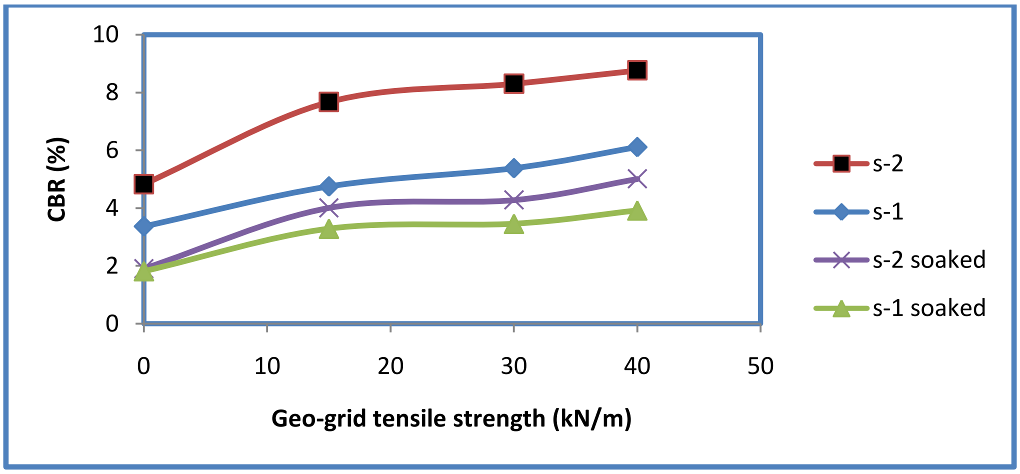


Fig XI: Variations of CBR (%) value for Geo-grid tensile strength

D. Presentation of CBR Performance ratio effect of reinforcement:

The engineering performance of both types of soils and improvement using three types of geogrids is studied through the following factors determined as shown in table VII.

Table VII: Details of Performance factors

Soil type / Performance ratio	Soil-1	Soil-2
R_{Fi}	C_{s1}^{i}/ C_{s1}	C_{s2}^{i}/ C_{s2}
R_{fsi}	C_{s1}^{i}/ C_{ss1}	C_{s2}^{i}/ C_{ss2}
R_{fssi}	C_{ss1}^{i}/ C_{ss1}	C_{ss2}^{i}/ C_{ss2}

Where i=0 represents unreinforced sample and i=1, 2 and 3 represents reinforced sample with various grids.

The performance ratios as detailed in table VII are computed and presented in table VIII. It is observed that the CBR of soil samples is greatly affected due to soaking and improved due to reinforcement. The performance ratio with reinforcement is improved from 1.85 to 3.35, 2.95, and 2.6 for soil-1 and 2.5 to 4.58, 4.34 and 4.01 for soil-2 respectively tested in unsoaked condition.

It is noted that an improved performance in soaked CBR for both soils compared with unsoaked results. While the improvement is 1.4 to 1.8 in unsoaked specimens, the corresponding improvement is 1.79 to 2.15 in the case of soaked specimens.

The presence of fines (%) has a significant role in the improvement. The geogrid contributed in improving soaked CBR performance from 1 to 2.15, 1.9 and 1.79 for soil-1 and 1.8 and 1 to 2.62, 2.24 and 2.09 respectively for soil-2. When compared the results of soil-2 with soil-1 the performance in soil-2 is more that of soil-1. The presence of more fines (%) content and high absorption of moisture in soaking in soil-1 has affected the improvement to that of soil-2.

Table VIII: Presentation of performance ratio

Parameter	Soil1	Soil2
R_{F0}	1	1
R_{F1}	1.81	1.81
R_{F2}	1.59	1.72
R_{F3}	1.40	1.59
R_{fs0}	1.85	2.52
R_{fs1}	3.35	4.58
R_{fs2}	2.95	4.34
R_{fs3}	2.60	4.01
R_{fss0}	1	1
R_{fss1}	2.15	2.62
R_{fss2}	1.90	2.24
R_{fss3}	1.79	2.09

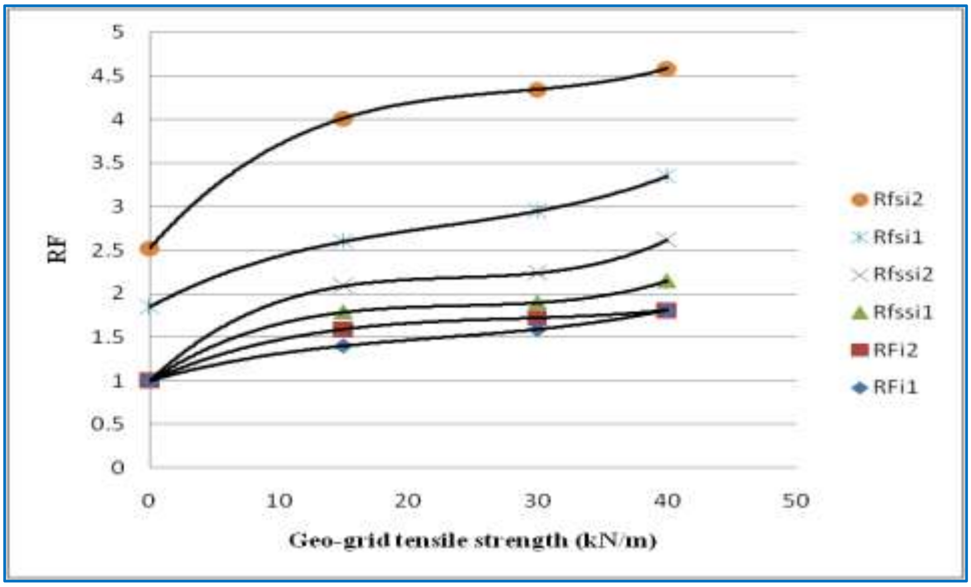


Fig XII: Variation of Performance Ratio with Geo-grid

IV. CONCLUSIONS

[1]. The soil plasticity and percent fines influences index properties, compaction characteristics and CBR.

[2]. It is concluded that the moisture absorbing by soil depends on the amount of fines. From the response of geogrid-soil interaction it is concluded that geo-grid reinforcement is more effective in soil-2 than soil-1 due to the lower amount of fines (%)

[3]. Unconfined compressive strength affected by amount of fines (%) content and moisture

absorption. A decrease in UCS due to moisture.

[4]. The performance of soils in soaking condition can be improved using geo-grid. A maximum improvement up to 2.3 times and minimum of 1.7 is possible with geo-grid for the soaked performance.

[5]. The results of improvement are functions of soil plasticity, moisture absorption and interaction of grid with soil.

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BIOGRAPHIES

Rajesh Unnam is presently pursuing M.Tech in Transportation Engineering in Department of Civil Engineering, GMR Institute of Technology, Rajam, AP, India. Prior to joining he had 6 months of Industry experience.

V.K. Chakravarthi, is currently associated as Senior 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