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SHEAR STRENGTH BEHAVIOUR OF MODIFIED MARGINAL SOIL WITH JUTE GEOTEXTILE REINFORCED FLY ASH MIX

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Abstract-The performance of reinforced earth structures mainly depends on its soil–reinforcement interaction in terms of shear and frictional strength behaviour and drainage properties. In the present scenario, due to non-availability of conventional backfills like sand, it is forced to use locally available soils having high fine content (> 15%) known as marginal soil as backfills which have undesirable engineering properties like high plasticity, pore water pressure development and low strength characteristics. Due to industrialization, with the increased usage of coal and production of coal ash in power generation the dumping of flyash has also became a major environmental as well as economical issue. So bulk utilization of flyash in geotechnical applications can minimise the disposal and land acquisition problems. Hence, the present work aims to replace the soil with flyash up to its optimum quantity. Further investigation was carried out to study the shear strength characteristic of cement modified soil-flyash mix with jute geotextile reinforcement by conducting large triaxial test under drained conditions and its performance was compared with that of original soil. The study reveals that geotextile reinforced cement modified marginal soil-flyash mix(60%+40%) has shown significant improvement in shear strength parameters and found to be suitable as backfill material for retaining earth structures. The ill-effects of excess fines and plasticity in marginal soil is taken care by the addition of cement while the geotextile serves the function of internal drainage and tensile reinforcement.

Keywords- Backfill, Soil, Fly ash, Shear Strength, Jute Geotextile, Large Triaxial Test

I. Introduction

Reinforced earth technology has attained wide acceptance throughout the world for development of structural designing base. The reinforced soil structures consists of three components namely backfill, reinforcement and facing components. This technique has been utilised to develop many civil engineering constructions like Retaining dividers, Earth dams, Spill ways, Bridges, Embankments, slope streets and so on. The performance of these structures depends upon the development of promising interfacial frictional resistance amongst soil and reinforcement (Bathrust 1990, Yoo et al.2004). To develop these frictional stresses, standard backfill material containing under 15% fines is recommended (FHWA-NHI-0043, 2001).In any case, at a few project sites, the prescribed backfill soil is not available and henceforth, there has been a need to utilize locally available soil regardless of considerable deviation of the properties from standard soil criteria(Won and Kim, 2007). The utilization of such poor soil, referred as marginal soil lead to a few issues like poor drainage and excess plastic fines including failure of structures (Mitchell and Zornberg, 1995; V.R Murthy 2009, Geol, 2006). To conquer the defects of poor drainage and excess plastic fines, a few endeavours were made to encourage internal drainage and soil stabilisation by reasonable means.

In India, thermal power plants are producing flyash as a by-product in huge quantity (180MT/year) which occupies normous valuable land (nearly 65000 acers) for disposal. The disposal of this ash poses severe threat to environment causing many health problems. So, here it has become mandatory to thick different ways and means to utilize coal ash in large scale for geotechnical projects. So that, it will reduce not only land acquisition, disposal problem but also saves the cost of raw materials in the constructions.

Jute Geotextiles with its distinguishing features like high moisture absorption capacity, flexibility and drainage properties etc., find its application in erosion control, separation, filtration and drainage in civil engineering works. It is having the advantages such as abundant availability, superior drapability, greater moisture retention capacity, lower costs compared to synthetic geotextiles with ease of installation and bio-degradable properties.

For backfill purpose in soil walls and retaining walls cohesion less soils like sand is required. Now a days its availability is scarce and expensive. A lot of research work is being done to find out alternatives for sand as backfill material (Xiaobin Chen 2013, A.K Bera 2014).

II. Objectives of the present study

In the present investigation, an attempt has been made to modify the locally available marginal soil by using cement and mixed with flyash in various combination and to study for its suitability in reinforced earth constructions. Based on that the following objectives were kept in view while carrying out the experimental work.

- To modification the locally available marginal soil using cement

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- To incorporate the flyash in soil up to its maximum quantity
- To study the effect of reinforced modified soil and flyash mix in terms of its shear strength parameters
- To optimise the percentage of soil, cement and flyash for backfilling purpose

III. Materials and Methodology

The following materials are used in the present work to carry out large triaxial tests.

The soil used in the study is collected from an unused land near Kazipet Railway Station, Warangal, Telangana. The properties of soil are presented in Table 1

Cement:

Ordinary Portland cement of 43 grade is used for the present study.

Geotextile:

Woven jute geotextile commonly used for making gunny bags having tensile strength of 18 kN/m is used as reinforcement in test samples.

Fly ash:

The fly ash used in the present study is brought from NTPC Ramagundam power plant in Telangana. The flyash is classified as Class F with CaO percentage of 3.14 (which is less than 10%) by conducting EDAX test in NFTDC Hyderabad. Further, it was having the following chemical composition SiO_2 (61.5%), Al_2O_3 (10.27%), Fe_2O_3 (3.12%), CaO (3.14%), TiO_2 (0.99%), MgO (0.42%). Maximum dry density and optimum moisture content of the flyash was obtained from mini-proctor compaction test as 1.29g/cc and 18% respectively. The flyash was observed to be non-plastic from consistency tests.

Soil–Cement:

In order to avoid the problems caused by the presence of excess fines, marginal soil id mixed with small percentage of cement. The marginal soil–cement mixes with different cement contents are tested for their Atterberg limits. While mixing with 2.5% cement only, the soil has become non-plastic, but to account for the possible non-uniform mixing, 3% cement is used for further experiments and the values of Atterberg Limit Tests are given in Table2.

Test Procedure:

To know the shear behaviour of soil, a series of large triaxial tests were conducted on 100mm diameter and 200mm height cylindrical samples of marginal soil with and without cement addition. The tests were further progressed by mixing the cement modified marginal soil with varying percentage of flyash (10%, 20%, 30%, 40% and 50%). These tests were also done with varying the number of geotextile layers (1 and 3 layers) within the sample. The Large triaxial test are conducted since it could depict the failure mechanisms clearly even with the use of composite sample having four different materials.

Sl. No.	Property	Soil	Flyash
1.	Specific Gravity	2.59	2.03
2.	Gravel (%)	3	0
3.	Sand (%)	54	23
4.	Fines (%)	43	77
5.	Liquid limit (%)	37	NP
6.	Plastic limit (%)	15	NP
7.	Plasticity Index (%)	22	-
8.	IS Classification	SC	-
9.	Optimum moisture content (%)	12	18
10.	Maximum dry density (g/cm^3)	1.78	1.29

Table 1: Properties of Soil and flyash

Table 2: Atterberg Limits of Marginal Soil-Cement Mixes

Property	Cement Content			
	0%	2%	2.5%	3%
Liquid Limit	37	34	NP	NP
Plastic Limit	15	16		

Sample Preparation

A split cylindrical mould is used in preparing the samples of 100mm diameter and 200mm height by providing static compaction. For the preparation of plain marginal soil samples, the required dry weight of the oven dried soil as obtained from MDD value is taken and mixed with the water needed as per the OMC value. After mixing the soil thoroughly, the wet mix is divided into five equal parts by weight and each part is filled in the cylindrical mould layer by layer. Each layer was given the number of blows as specified by modified proctor compaction test manual. The sample was extracted from mould and kept in a polyethene bag to prevent from the moisture loss.

In case of cement modified samples, the required oven dry weight of soil is taken and the intended cement content is added in weight and then mixed with the optimum moisture content of virgin soil. This soil–cement mix is compacted in the same manner as for virgin soil samples by static compaction. The cement modified marginal soil and flyash mix samples are also made as same as the virgin soil by dry mixing the flyash with cement mixed marginal soil. The percentage of cement is taken based on the weight of marginal soil only. After dry mixing thoroughly, water is added based on the OMC value of the mix and mixed properly. The remaining steps as same as in case of the virgin soil. In case of the reinforced samples, geotextile is placed in the middle of the proposed layer while filling the soil inside mould.

Large Triaxial Tests

Large triaxial tests are carried out on samples made of plain marginal soil, cement modified soil, flyash and soil mix with and without reinforcement using large triaxial cell under drained conditions in order to understand the influence of cement modification and reinforcement effect on the shear strength parameters of soil. The test sample was placed on the pedestal with filter papers and porous stone on both sides. The sample is then enclosed by a thin rubber membrane with the help of membrane stretcher. The membrane around the sample was sealed using 'O' rings at the top and bottom to the loading pad of triaxial cell. The cell is placed on the pedestal of compression testing machine and the cell is filled with water.

The samples are tested at different confining pressures of 100kPa, 150kPa and 200kPa with the deviator load applied at a constant strain rate of 0.12 mm/min for drained tests until failure or up to 20% strain. The axial deformation of the samples are recorded using a dial gauge of 0.01mm capacity and the axial load is recorded from a 5 ton capacity proving ring. The test samples are shown in Fig1

Fig 1: Arrangement of soil specimen in large triaxial cell

IV. Results and Discussions

In this section, the results of large triaxial tests are presented. The peak deviator stress and stress-strain behaviour for soil in different combinations are presented.The shear strength parameters in terms of angle of internal friction (φ') and cohesion (c') have been evaluated.The stress- strain behaviour virgin soil was presented in Fig 1

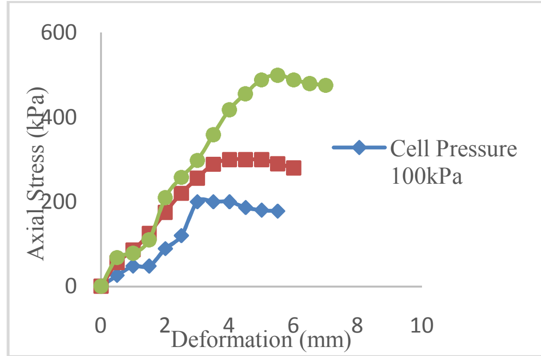

Fig 1: Stress-Strain curve of marginal soil

The above Fig gives a clear idea of the variation of deviator stress with increase in confining stress. It can be observed that with increase in axial strain the deviator stress is increased gradually up to its peak and there after decreased with increase in strain. The peak stress is also increased with increase in confining pressure. Mohr circle are drawn for marginal soil to find out the shear strength parameters of the soil. It is observed that the soil was having cohesion of 33.1 kPa and angle of friction of 23^{o}. This value of cohesion is due to the presence of fines. In case of cement modified soils, the similar stress strain pattern is observed at the same changes of confining pressure but the peak deviator stress obtained here is higher compared to that of virgin soil. The reason for the increment could be supported by non-plastic nature and increased stiffness of soil upon cement modification. The shear strength parameters of cement modified soil are obtained as c'= 38.6 kPa, φ'= 32.3^{0}.

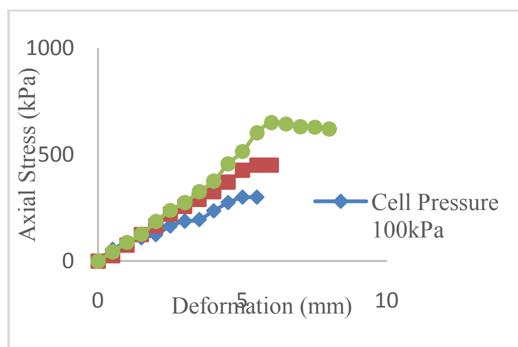

Fig 2: Stress-Strain curve of cement modified marginal soil

Since the test is aimed to find out the optimum composition of the mix such that maximum amount could be utilized for the backfill purpose. Therefore trial tests (Strength studies are not shown here) are made with different combinations of modified soil and flyash and found that 60% soil+ 40% flyash as optimum composition. Further increase of flyash (>40%) in mix the strength is observed to be decreased because of its decreased cohesive nature between particles.The stress-strain pattern of 60%modified soil with 40% flyash is shown in Fig 3. From this it has been observed that the shear strength parameters are influenced by the flyash content. The value of the cohesionc'= 45.5 kPa and φ'=37.1^0 for flyash content 40%whereas for flyash content 45 %. C'=32.9 kPa and φ'=36.5^0 respectively.

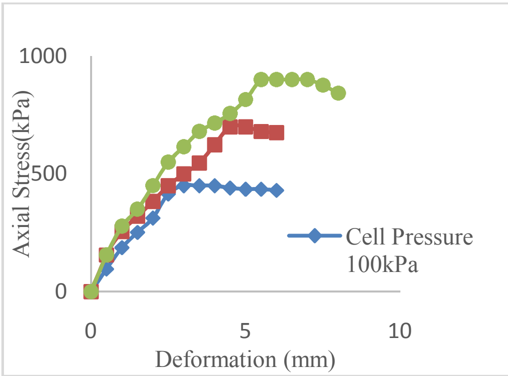

Fig 3: Stress-Strain curve of modified soil (60%) +Flyash (40%)

In order to study the effect of reinforcement on shear strength parameters of the proposed soil-flyash mix (60%+40%) triaxial tests are conducted on jute geotextile reinforcement with one and three layers. Fig 4 and 5 shows the stress strain behaviour of reinforced modified soil-flyash mix.With the addition of one layer of geotextile, no considerable shear strength development has taken place and which indicates that little interaction of soil- geotextile reinforcement. In this case, the cohesion and angle of internal friction were observed to be C'=48kPa and φ'=38.6^{0}respectively. When the reinforcement layers increases from single to triple, the shear strength further increased from 48kPa to 62.4kPa and angle of internal friction increases from 38.6^0 to 42.8^0.The increase of strength might have occurred due to semi rigid nature of cement modified marginal soils. From the test samples the geotextile layers are observed to be subjected to sliding without any sign of rupture under drainage condition.On the whole, the experimental results clearly indicating a pattern of increase in strength with increase in number of reinforcing layers and increase inconfining pressure.

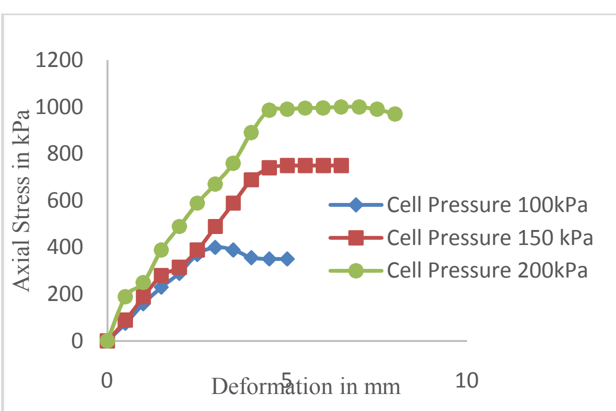

Fig 4: Stress-Strain curve of modified soil (60%) +Flyash (40%)+ 1Layer reinforcement

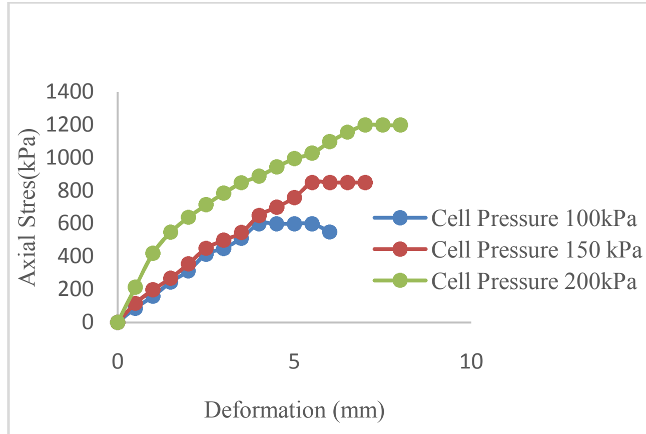

Fig 5: Stress-Strain curve of 3 layers reinforced cement modified marginal soil (60%) flyash (40%) mix

Table: 2 Shear Strength Parameters of Cement Modifiedmarginal soils with different reinforcement under different configurations

Configuration	C'(kPa)	φ'(degrees)
Marginal soil	33.1	23
M.S+3%cement	39	32
60% Modified M.S+ 40% Flyash	45.5	37.1
60% Modified M.S+ 45% Flyash	32.9	36.5
60% Modified M.S+ 40% Flyash+1 G.T layers	48	38.6
60% Modified M.S+ 40% Flyash+3 G.T layer	62.4	42.8

V. Conclusion

The following conclusions are drawn based on the large triaxial compression test results on different combinations of soil with flyash and reinforcement.

- Cement modification of locally available marginal soil could make it suitable for backfill in reinforced soil structures by overcoming the ill-effects of excess fines and their plasticity.
- The use of flyash up to 40% with modified soil giving improved shear strength properties.With further increase offlyash thestrength of sample is observed to be decreased (not shown in this paper).

- With the increase in the percentage of flyash up to 40%, there is an increase in cohesion intercept from 33.1kPa to 45.5kPa while the angle of internal friction increases from 23^0 to 37.1^0
- Provision of jute geotextile reinforcement is observed to facilitate quick drainage in specimens during testing, indicating the potential use of geotextiles as reinforcement while being used in marginal soils and flyash mix.
- The failure of reinforced soil specimen is shifted from bulging type to partial bulging and shearing after cement modification of marginal soil.
- The reinforced specimens have shown ductile behaviour at and beyond peak stress indicating the gradual failure as against the unreinforced soil specimens.
- The optimum combination is found out to be 60% modified marginal soil with 40% flyashforthree layers of jute geotextile.
- From this study it is revealed that the marginal soils could be made use in reinforced soil construction by cement modification with optimum flyash by provision of internal drainage in terms of geotextile reinforcement.

VI. References

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