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AN EXPERIMENTAL STUDY ON COMBINATION OF GEOSYNTHETIC MATERIAL WITH SAND FOR EVALUATION OF SHEAR STRENGTH PARAMETERS

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ABSTRACT

Soil is a highly complex particulate material, which is highly durable and abundantly available in nature. Due to this, soils are mostly adopted for construction of embankments, as base and sub-base coarse in pavements, filling low lying areas. Primitively, the embankments were constructed with very flat slopes, whereas, with the introduction of concept of retaining, many structures have been developed and designed as per the conditions. The most advance and widely adopted retainment systems is by mechanically stabilized earth (MSE) or reinforced earth, RE, technique, where the soil is reinforced to reduce the forces on the walls and in turn this reinforcement holds the wall and increases stability of the soil. One such reinforcement, termed as geo-synthetic material, is widely adopted, now-a-days, for increasing the stability of RE Walls. In RE walls, the selected geo-synthetic material will be sandwiched between two soil layers to enhance tensile strength of soil and hold the fascia panels in position. In such conditions, interface friction gets generated between geo-synthetics and soil. The interface depends on various parameters, such as type and gradation of soil, type and material of geo-synthetics and drainage conditions. With this in view, the present study is proposed to study the interface friction between various geo-synthetics and different geo-materials including different soils and flyash. Such a study, would give an indication of the values to be adapted for frictional resistance, to the engineer, to practically design/analyze the stability of the retaining wall.

Key words: Geo-Synthetics, Geo-grid, Geo-textile, MSE –wall, Fly-ash, Geo-composite, Direct shear test.

INTRODUCTION

The word soil is derived from the Latin word “solum” (K R Arora,1987) and is used for the upper layer of mantle which can support plants. The term “soil” in soil engineering is defined as an unconsolidated material, composed of solid particles produced by the disintegration of rocks (K R Arora,1987). generally, the soil in nature is found to be in combination of one or more size of particles. Hence, soil is highly complex material both by the particle matrix and also its behavior. In the terms of engineering, the soil has been considered to be a material with good shear strength, compressive strength but weaker tensile strength (K R Arora,1987). Due to its abundance and good strength, soil is considered as the top and easily available and first priority as a good engineering fill material in the major engineering structures like embankments, fills, retaining and mining facilities.

Now way days, retaining walls have been vastly constructed for major purposes such as decreasing width of the embankments, water retainment, mining retainment, stabilizing slopes. With the rapid changes in the retaining wall concepts and also due to introduction of different construction materials, the retaining walls have underwent a phase change in their design, construction and conceptualization. They have been started with typical high width embankments, later by conventional gravity walls, cantilever walls, sheet pile walls and most recent of these is the reinforced earth wall. In a reinforced earth wall, the tensile weaknesses in the soils have been countered by introducing some reinforcement elements such as steel straps, steel rules and timber/steel sheets.It has been observed that for low bending stiffness, the reinforcement may deform locally & become parallel to linear shear zone (Ingold,1983)In the reinforced earth wall technology, the interaction between soil and reinforcement is of utmost importance for the design and performance of reinforced soil structures and this complex interaction depends on the nature and the properties of the reinforcement and soil. The principal requirements of reinforcements are strength and stability (low tendency to creep), durability, ease of handling high coefficient of friction and/or adherence with the soil, low cost and ready availability. With the various problems related to sustainability, durability and performance,(Kamalzare and Moayed,2011) the conventional reinforcements have been now replaced by geosynthetics material (Ingold (1983).

Shear strength

There are various methods for determining the shear strength of the soils vis-à-vis Direct shear test, Triaxial test, Unconfined compressive strength and Vane shear test. The shear strength of the soil is majorly governed by type of soil, compaction parameters, normal stress and rate of strain. The shear strength of the soil is generally expressed with Mohr-Columb equation given ass $S = C + \sigma \tan \emptyset$; and the parameters C&Ø termed as shear parameters are fixed for a given soil. Hence, in broader terms, the shear strength of the soil is only effected by the normal stress.

Retaining Wall

Retaining wall is also known as Mechanically Stabilized earth wall (MSE wall). Generally Retaining walls are relatively rigid walls used for supporting the soil mass laterally so that the soil can be retained at different levels either on two sides or one side. A failure plane, as shown in Fig. 1.1, will get developed in the retained soil due to which an active verge of soil will exert active earth pressure on the wall which causes tensile forces to get develop, as the soil is weak in tension a reinforcement material should be introduced to counteract the forces coming on to the wall as shown in the fig below. retaining wall should be designed properly to meet stability (external and internal) and economic considerations. When the geo-synthetic material is used as reinforcing material, interface friction between soil and geo-synthetic material plays an important role in the design of R.E wall to safe guard the structure against pullout. Therefore, it is important to know the behavior of interface friction between different soils and geo-synthetic materials along with the properties of soils such as unit weight of soil, angle of shearing resistance, cohesion intercept and angle of wall friction

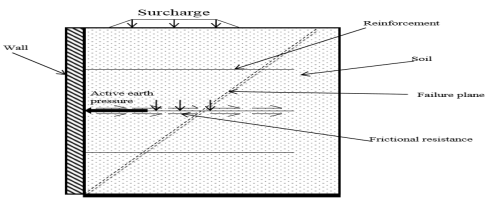


Fig 1.1: Force diagram of Retaining wall

1. OBJECTIVES

1) To study the interface behavior of the soils with flyash and with combination of different geosynthetic material.

2) To study about which combination of geomaterial interface will give the good stability to Retaining wall.

2. METHODOLOGY

The various tests performed for the study as per the standard codes,the tests include, index tests for soil classification, sieve analysis of sand and hydrometer analysis of flyash and results were given in following table no 2&3.the engineering tests to understand the behavior of the soils. These tests were performed on three materials namely Sand (S), Flyash (F) and geosynthetic reinforcement material. The following tests are conducted for the present study and the results were represented in the form of table and plots between the constants according to the standard codes:

a) Sieve Analysis :(IS:2720(Part IV) -1985)
b) Hydrometer Analysis (IS: 2720(Part 4) -1985)
c) Standard proctor test(light compaction)(IS:2720 (Part VII)-1980)
d) Unconfined Compressive Strength(IS:2720 (Part VIII)-1983)
e) Liquid Limit & Plastic Limit (IS: 2720 (Part V)-1985)
f) Specific Gravity (IS:2720(Part III/Sec 1)-1980)
g) Direct Shear Test (IS: 2720(Part 13)-1986)

Materials Used:

a) Reinforcement

Various reinforcements are used to improve the tensile capacity of soils, especially in earth retaining structures, in the construction of reinforced earth walls, reinforced slopes, embankments on soft soils, landfills and other foundation soils. The different reinforcing materials used are: Plant roots, Steel bars (Wire grids), Steel strips, Steel/cast iron Sheets and Geosynthetics.

b) Geo-synthetics

Geo-synthetics were first introduced as reinforcement material for reinforced soil structures (R.E walls) in the 1970's. Geo-synthetics are manufactured from various types of polymers (high density polyethylene, poly propylene, poly vinyl, jute, fibers etc.) to enhance, augment and make cost effective solutions for the geotechnical engineering problems. Geosynthetics are generally the polymeric, artificial fabric products used to solve civil engineering problems.

c) Geo -Textile

Geo-textile is a flexible, textile-like fabric manufactured from continuous poly propylene filaments, UV stabilized to prevent degradation when exposed to sun light. They possess robust and durable, with optimum permeability and soil filtration characteristics. These are used to provide filtration, separation or reinforcement in soil, rocks and waste materials.

d) Geo-Grid

Geo-grids are stiff or flexible polymer coated grid like sheets manufactured from high strength polyester yarns, with large apertures used primarily as reinforcement for unstable soils and waste masses. These are used in the construction of highways, railways, airports and heavy-duty pavements and load transfer platforms, repair of slope sliding.

e) Geo-Composite

These are the hybrid systems of any, or all, of the above geo-synthetic types which can function as specifically designed for use in soil, rock, waste and liquid related problems. These are used for separation, reinforcement, filtration, drainage, and liquid barrier.

f) Fly ash

Flyash is a byproduct of coal, and there are some classes in flyash like class F and class C generated by burning of coal, now a day's coal is majorly using as a good admixture in civil constructions like bricks, concreate mixing. properties of flyash as mentioned in the following sections, table no 1.

Test procedure:

a) Modified Direct Shear Test

In order to cater for the need of the experimentation for the present study, the conventional direct shear test has been slightly modified. With the modification, the shear properties of the soil, sandwiching a geosynthetic (Geo-textile or Geo-grid) has been determined. For this, a portion of oven dried sample has been taken into a tray, mixed with corresponding optimum moisture content (OMC) uniformly. In this method, the lower half was compacted with sample above porous grid plate by fixing the geosynthetic material between the two halves, compact the upper half with sample and place the shear grid plate above it. The loading pad was placed on the top grid plate and the whole assembly was placed in the box of the modified direct shear apparatus as shown in the fig 3.1. The test was conducted by applying horizontal shear load up to failure of the sample. The shear load readings indicated by the proving ring assembly and the corresponding longitudinal displacements were noted at regular intervals. A minimum of three tests were performed on same sample compacted to its corresponding optimum moisture content (OMC) separately and readings were noted accordingly. Cohesion intercept and angle of internal frictional corresponding sample-geosynthetic interface were arrived at.

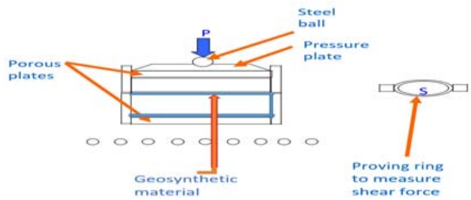


Fig 3.1: Modified direct shear test modelAnd the interface behavior between geomaterial and sandand flyash were studied and for the test purpose large-scale direct shear device (450mm x 450mm x 130 mm) box is considered (Liu et al,2009)and the procedure as per the (IS: 2720(Part XIII)-1986) followed, coming to the proportions of material has been chosen in terms of thickness first the test was conducted for conventional soil and flyash the properties of sand and flyash as mentioned in below table number1, followed by combination of material as shown in figures 4.1 and 4.2, 70% of direct shear test box filled with sand in two layers and remaining 30% of thickness of the shear box is with any one of the geosynthetic material placed in between sand layers and load is applied and then valves are taken from both dial gauges, then the interface behavior was observed between the geosynthetic material and sand and the Shear displacement between the layers is observed and graphs between Shear Stress and Normal Stress are plotted, like the first layer sand and immediately the next layer is any one of the geosynthetic material and again the top layer of the Shear box is sand, similarly the test was repeated for more combinations and the results were given in the table number 4.

3. RESULTS & DISCUSSIONS

The analysis of the results obtained from the various tests performed on the geo-material is included as the part of the study, three geo-material, i.e. sand (S), Flyash (F) and geo-synthetic materials has been considered for example, Non-Woven Geo-textile (GT), Geo-Composite (GC) and Geo-grid (GG) have been used as the reinforcement material

Properties of sand and fly ash

As per the methodologies the test results for different trials and the corresponding graphs have been plotted in this study. The final values of the various tests have been presented in the belowtable no1.

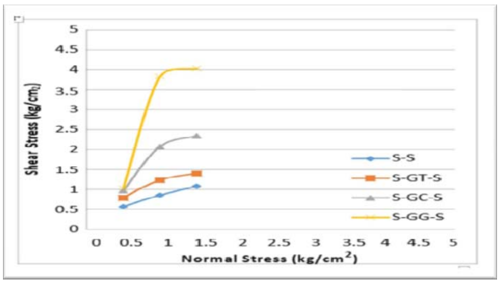
Table 1: Properties of sand and fly ash

	Sand	Fly ash
Classification	SP	Silt Sized particles
specific gravity	2.58	2.31
optimum moisture content(%)	6%	16%
maximum dry density (g/cc)	1.66	1.373
liquid limit(%)	_	_
plastic limit(%)	_	_
angle of internal friction (Ø) in Degree's	51	-
Cohesion (C in kg/cm²)	0.22	-

It can be observed that the geo-materials considered for the study covers a wide range of soil size ranges, including Sand, Silt (Flyash) and. Also, the geo-synthetic products used in the study are the different types of material used for the reinforcement of the backfill material in RE walls. Also, in order to observe the effect of layers of soil, Flyash (widely available fill material) has been considered in the layers. Hence, the effect of the layers of sand and flyash and vice versa has been considered for the analysis. So, four combinations of such layers, sand on top box and flyash in bottom box (SF) and vice versa (FS), has been considered for the study as depicted in Figure4.1&4.2.

Influence of geo-synthetics on the shear strength of sand

With an aim of studying the effect of reinforcement on the shear strength of the soils, the direct shear tests have been performed for the above layers with inclusion of the geo-synthetics at the interface of the two layers. The results of the tests conducted on the sands have been depicted in table no 4, the results show the distinct variance in the inclusion of geo-synthetics. It has been observed that the shear strength of the sand increased with the addition of geo-synthetics, though the variance is not clear in the lower normal stress range, a clear demarcation of the improvement in the stresses can be observed at higher normal stress (Goodhue et al.2001 and Anubhav &Basudhar 2013). It can be also observed that the non-woven geo-textile which has low tensile strength has shown a nominal increase whereas, the geo-composite, with higher tensile strength has increased the shear strength and still higher tensile strength geo-grid has predominately increased the shearing resistance of the sand, though the opening size of geogrid is very high compared to the geo-composite or geo-textile(Goodhue et al.2001; Liu et al.2009; Kamalzare& Moayed 2011; Alfaro et al.1995; Tatlisoz et al.1998 and Ingold 1983). Thus, it can be summarized that the high tensile geo-synthetics also increase the shear resistance.

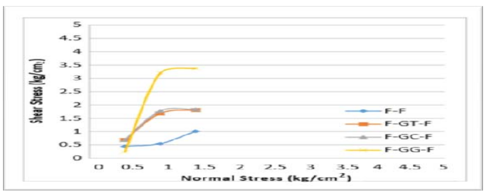


Graph 4.1: Effect of Geosynthetics on the shear strength of sand

Influence of geo-synthetics on the shear strength of flyash

With the flyash, similar results of that of interface with Sand have been observed, other than the improvement of shear strength due to the inclusion of geo-textile and geo-composite. But, it can be clearly observed from graph 4.2, that there is no major increase in the shear resistance due to reinforcement geo-composite or geo-textile. Even then, the geo-grid shows a very clear, distinct and major impact on the shear strength of the flyash.

Fig 4.1: Shearing of the Flyash with geotextile specimen



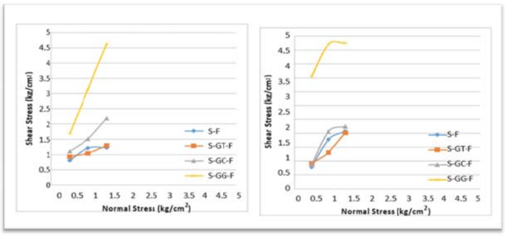
Graph 4.2: Effect of Geosynthetics on the shear strength of flyash

Influence of geo-synthetics on the shear strength of Sand-flyash interface

From the graph 4.3 (a) & (b), it can be observed that the shear strength has no major increase with the addition of geo-synthetic and geo-composite for any combination of the layers i.e. SF or FS. But, the geo-grid has shown a clear increase in the shear strength of the mixture. This is attributed to the interlocking behavior of the layers of sand and flyash between the opening of geo-grid and hence lead to the development of bonding of the geo-grid, which imparts high shearing resistance at the interface.

(a) (b)

Fig 4.2: Shearing at the interface of a) F-GC-S and b) S-GC-F

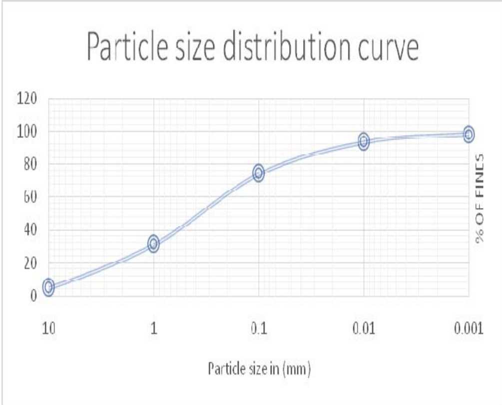


(a) (b)

Graph 4.3:Effect of Geosynthetics on the shear strength of clay &Flyash

Table 02: Sieve Analysis of sand

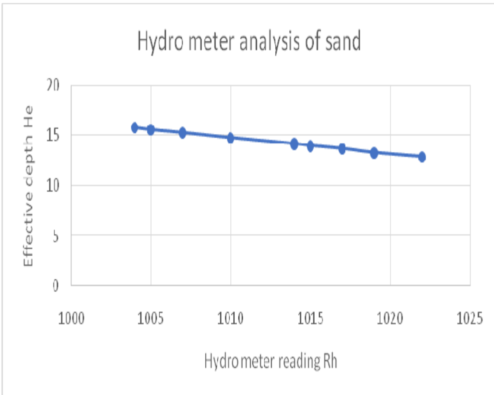
s.no	Sieve size	% of fines
1	4.75mm	98.18
2	2.36	93.62
3	1.18	74.06
4	600μ	31
5	300	4.74
6	180	1.48
7	150	1.38
8	75	1.24
9	Pan	_



Graph 4.4: Particle size distribution curve of sand

Table 3: Hydrometer analysis of sand

S.no	Hydro meter Reading	He (Calibreated Chart Valve)	Particle size D in (mm)	% of fines
1	1022	12.9	0.069	74.06
2	1019	13.3	0.049	63.48
3	1017	13.7	0.035	56.43
4	1015	14	0.025	49.37
5	1014	14.2	0.017	45.85
6	1010	14.8	0.0095	31.74
7	1007	15.3	0.0068	21.16
8	1005	15.6	0.0056	14.11
9	1004	15.8	0.0014	10.58



Graph4.5: Hydro meter curve of sand

Table 4: Direct Shear Results of Interface Friction

Direct Shear Results of Interface Friction					
Material	Normal Stress (kg/cm²)			C(kg/cm²)	Ø (°)
	0.5	1	1.5		
	Shear Stress (kg/cm²)				
Sand	0.57	0.85	2.16	0	57.8
Flyash	0.44	0.54	1.01	0.09	29.7
SF	0.8	1.21	1.22	0.66	22.8
FS	0.78	1.77	2.07	0.25	52.2
S-GT-S	0.79	1.23	1.4	0.53	31.4
F-GT-F	0.68	1.68	1.81	0.09	48.5
S-GT-F	0.93	1.04	1.29	0.73	19.8
F-GT-S	0.91	1.31	2.02	0.3	48
S-GC-S	0.97	2.07	2.35	0.42	54.1
F-GC-F	0.68	1.77	1.84	0.27	49.2
S-GC-F	2.3	1.51	3.19	1.44	41.7
F-GC-S	0.86	2.06	2.25	0.33	54.3
S-GG-S	1.03	4.03	3.84	0.16	70.4
F-GG-F	0.23	3.2	3.37	0	72.3
S-GG-F	0.56	1.16	4.63	0	76.2
F-GG-S	4.05	5.2	5.25	3.63	50.2

4. CONCULSIONS

From the above study, the following conclusions can be made:

1) From the studies conducted on different material and a combination of the layers, it has been observed that the sand-geogrid-flyash and flyash-geogrid-sand layers have yielded higher shear strengths. Hence, it can be deduced that the inclusion of flyash as layers not only enhances the interface shear strength but also reduces the lateral pressures substantially.
2) It has been observed that the inclusion of geosynthetics, i.e. geotextile, geocomposite and geogrid in the order of increase of tensile strength, have been detrimental in improving the shear resistance, with an anomaly for sand flyash mixtures. Also, it can be concluded that the shear strength at the interface increases with the tensile strength on the geosynthetic material.
3) In the combinations of the different material layers and geosynthetic interface, it has been observed that the shear strength of the sand-geosynthetic-flyash has increased shear strength than the sand-geotextile-sand.
4) In the study, it has been observed that the sand-flyash interface, which has yielded higher shear strength without any geosynthetic has shown an negative impact, i.e. decrease in the shear strength at the interface with the addition of geosynthetic, irrespective of the type or the tensile strength of the material.

From the total study, it can be concluded that an R E wall, with a combination of sand-Flyash layers reinforced with geo-grid has the maximum stability than any other combinations.

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