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Behavior of Geosynthetic-encased Granular Column in Silty Sand Soil by Direct Shear Test

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ABSTRACT: This paper investigates the reaction of geo-synthetic encased granular columns (EGCs) in loose silty sands under lateral loading. 48 large scale direct shear tests are performed on granular columns to study the effect of Area Replacement Ratio (Arr), encasement, normal stress, group action and granular column grading. The results showed that in the case of ordinary granular columns (GCs) the residual and peak strength increased up to 80% for 10 kPa normal stresses and up to 35% for 30 kPa normal stresses, respectively. Also the residual strength increased by increasing area replacement ratio. In the case of geo-synthetic encased granular columns (EGCs) the residual strength increased from 15% to 40% compared with GCs. In the case of a group of encased granular columns at 60 kPa normal stress, the residual strength increased from 23% to 40% compared with a group of not-encased granular columns. But In the case of the single encased granular column at 60kPa normal stress, the residual strength increased from 15% to 25% compared with single not-encased granular columns. By increasing the size of grains of EGCs at 60 kPa, the normalized residual strength increased up to 36% compared with not-encased granular column. The results of tests showed that the effect of granular columns in lateral resistance decreased by increasing fine content.

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1- Introduction

Stone columns or granular pile is a very common method to improve soft clay and loose silt and silty sand with high fine content [1]. The ground improved by granular columns behaves as a composite with higher strength and stiffness compared to virgin soils [2]. Granular and stone columns are used to improve the bearing capacity of foundation soils, accelerating the rate of consolidation of soft clay, and reduce the liquefaction potential of liquefiable soils [3-6]. The use of geo-synthetic as an encasement in the case of very soft soils reinforced by stone columns, can be effectively overcome the insufficient lateral confinement of surrounding soil [7-9]. The behavior of stone columns under vertical loads is very well understood [10], but there aren't many investigations about lateral bearing capacity. Encased stone columns fail in bending instead of shear [11]. Lateral bearing capacity of granular columns increasing by using geo-textile encasement, but after the rupture, the strength is reduced to the levels of ordinary columns [10].

This paper investigates the reaction of geo-textile encased granular columns (EGCs) in loose silty sands under lateral loading. The effect of fine content of bed soil, normal stress, column encasement, group action of granular columns, area replacement ratio, and grain size granular column aggregates on the lateral resistance of the composite are investigated.

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2- Methodology

Sand with different silt content from 0% to 30% was used to prepare the bed soil. Poorly graded gravel with two types of granular aggregates D_1 (D_{50}=7 mm) and D_2 (D_{50}=10.20 mm) were used to form granular columns. Non-woven geo-textile was used for encasement. The ultimate tensile strength of geo-textile was 39 kN/m and the thickness was 3.3 mm. A single granular column of either 55 mm (GC1) or 110 mm (GC2) diameter was used to study the effect of the single granular column. Four 55 mm diameter columns were also installed in a square arrangement to study the group effects. The test was conducted at different normal stresses from 10 kPa to 120 kPa. Two types of granular aggregates were used for forming the granular columns. All tests were performed in saturated conditions.

Open-ended UPVC tubes with inner diameter corresponding the diameter of the granular column was used inside the shear box. For each test, a pre-weighted amount of dry soil was poured into the shear box around the UPVC tubes and densified in five layers of equal thickness to achieve a relative density of 30%. The required amount of granular aggregate was placed inside the UPVC tubes in five equal layers and compacted by applying 50 blows to each layer. After pouring and compacting the aggregate to the full height of the shear box, the UPVC tubes were gradually withdrawn from bed soil by pulling them up vertically. Then samples were saturated.

3- Results and Discussion

3- 1- Effect of ordinary granular column (GC) and geo-synthetic encased granular column (EGC)

The shear stresses are found to increase due to reinforcing the bed soil with ordinary granular columns. The maximum shear stress has increased from 25% to 85% at 10 kPa normal stress and from 5% to 35% at 30 kPa normal stress. The maximum shear stress decreased by increasing the fine content of bed soil. In all cases, the peak and residual shear stress have increased by increasing in area replacement ratio.

The failure mechanism has changed, due to use of geo-textile encasement. In the case of ordinary granular column, the column was completely sheared, but in the case of encased granular column, the encasement did not undergo any rupture. In the case of geo-textile encased granular column, the residual stress has increased. As shown in Figure 1, the normalized residual shear stress of geotextile encased granular column ($\Delta\tau_{EGC} / \tau_{GC} = (\tau_{EGC} - \tau_{GC}) / \tau_{GC}$) reduces by increasing fine content of bed soil.

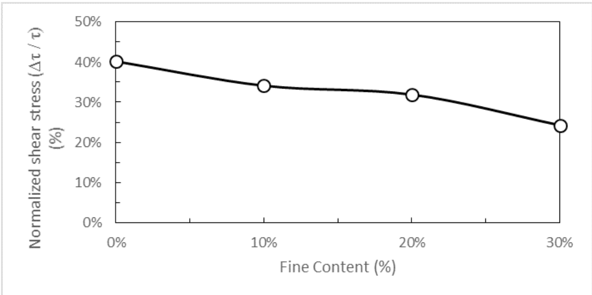

Figure 1. $\Delta\tau_{EGC}/\tau_{GC}$ vs. FC (%) at 30 kPa normal stress

3- 2- Effect of normal stress, group action of columns and increase in grain size of column aggregates

Figure 2 shows the normalized residual shear stress of geo-textile encased granular columns at two different normal stress. As shown in the figure, normalized residual shear stress reduces by increasing normal stress.

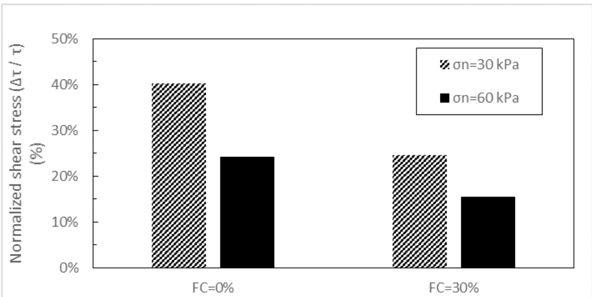

Figure 2. Normalized shear resistance at two normal stress

Four granular columns in a square plan arrangement were used to study the effect of group action of GCs. A group of GC1 has the similar Arr to the single GC2. Figure 3 shows the diagram of shear stress versus horizontal displacement for single EGC2 and group of EGC1 at 60 kPa normal stress. As shown in the figure, the residual shear stress has increased due to group action.

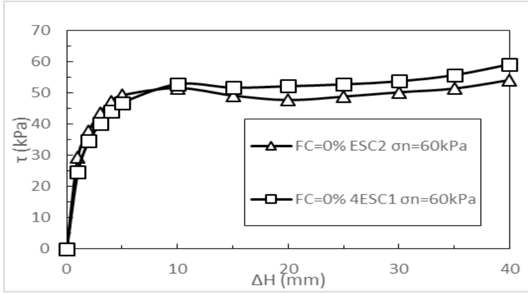

Figure 3. Shear stress vs. displacement of EGCs (FC=0%)

Figure 4 shows the normalized residual shear stress of geo-textile encased granular column in two different grain size. As shown in this figure, the normalized residual shear stress in the case of D_2 is more than the case of D_1. Also the normalized residual shear stress in the case of bed soil with 30% fine content, is less than the case of bed soil without fine content.

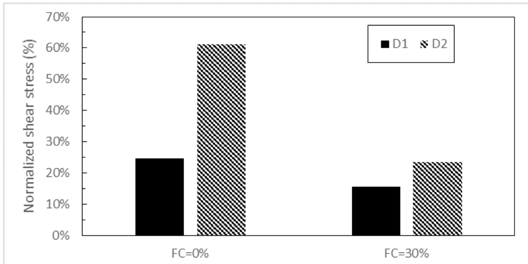

Figure 4. $\Delta\tau_{EGC}/\tau_{GC}$ for two grain size of aggregate columns

4- Conclusions

Based on the results of this paper the following conclusions are made:

1. The effect of granular column reduces by increase in normal stress.
2. In the case of the geotextile encased granular column, the residual stress has increased compared to ordinary granular column.
3. In all tests, the strength and stiffness of the combined soil-granular column system have reduced due to increase the fine content.
4. The results showed that the shear resistance of a group of granular columns is more than the shear resistance of a single granular column with same area replacement ratio.
5. The shear resistance has increased by increasing the grain size of granular column aggregates.

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