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Shear Behavior of Sand Reinforced with Plastic Strips

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Abstract: *This research study presents the experimental work carried out to study the effect of plastic strips on shear behavior of sand. Here, in this study sand has been used as base material and plastic strips as reinforcement material. Small direct shear box applied as indicator test on sand in reinforced and plain/unreinforced conditions. Grain size distribution tests and modified proctor tests were conducted on sand specimens in plain condition. In first attempt direct shear tests were conducted under different normal stress conditions on representative specimens of sand in plain/unreinforced conditions and various parameters of direct shear tests were considered. In second attempt sand specimens were reinforced with random inclusions of plastic strips of different sizes and concentration of 0.1% and 0.2% of the weight of dry soil specimen. Direct shear tests were repeated under different normal stress conditions as followed in case of unreinforced conditions, and various parameters of direct shear tests were considered as followed in case of plain/unreinforced sand specimens. Results of reinforced and unreinforced conditions specimens were matched. It was observed that reinforced sand specimens yields better results than unreinforced sand specimens. An improvement in angle of internal friction of sand was found as 16.67% with plastic strips dimensions of 6x15mm and at concentration of 0.2% of weight of sand specimen, so graphs of compression/dilation, shear stress and Mohr-Coulomb envelops of the corresponding plastic strips dimension and concentration have been presented in this paper.*

Keywords: *Sand, plastic strips, direct shear test, reinforced & unreinforced specimens, friction angle.*

I. INTRODUCTION

Soil reinforcement technique is very important for all type soil, especially for weak type soil, where chances of failure is comparatively more. In ancient time materials having low tensile strength like gross roots, sisal, bamboo etc were used as reinforcement materials, however after 1960s other materials like steel strips, waste rubber tyres, reclaimed plastic waste, carpet waste, fibers etc have been utilized for soil reinforcement purposes. Geosynthetics has been used very prominently in soil reinforcement; however, they are expensive as they utilize a major part of project cost. Use of steel strips is also very prominent as it enhance engineering properties of soil very significantly, but its corrosive nature need to be considered in designing process of the soil reinforcement project while using steel as reinforcement material. In soil reinforcement, the term soil includes sand, silt, clay and gravel, and reinforcement means natural or synthetic materials capable to withstand the tensile stresses. These reinforcement materials may be added to soil in different shapes such as fibers, bars, sheets, strips, grids & so on. Reinforcement have been caused an improvement in shear resistance, shear strength, stiffness, axial strain and resistance to deformation etc. Plastic waste when used as reinforcement materials in stabilized soil, it caused a reduction in brittleness of the stabilized soil. In current era the use of soil reinforcement technique, especially in geotechnical engineering application is very common, like in road construction the stabilization of subgrade materials, in slope stability analysis such as slope embankment, earth retaining structures etc. In geotechnical engineering application, geosynthetics have a wide range of application as a reinforcement material, however some new reinforcing materials have also been investigated to extend the soil reinforcement concept to some readily available, cheap and accessible materials which are usually destined to landfill. (Gray & Ohashi, 1983; Gray & Al-Refeai, 1986; Maher & Gray, 1990; Benson & Khire, 1994; Consoli et al, 2002; Consoli et al, 2007).

In most of developing countries like Pakistan solid waste is generated in very huge amount. Here in Pakistan, almost 20 million tons of solid waste is generated per year, which increases 2.4 percent annually, where the amount of plastic waste is about 9.0 percent of the total municipal solid waste generation. Due to unavailability of proper waste collection system, waste are usually found in spread out condition along roadside, in residential areas, recreational and commercial areas etc. However, in developed countries, the solid waste been generated has collected through proper waste collection system and finally disposed of into sanitary landfills, incinerators, or other recycling stations where it may recycled for other purposes.

II. RESEARCH MATERIALS

In this research study sand has been used as base material and plastic strips as reinforcement inclusions.

A. SAND SOIL

The base material been used here was composed of local sand soil. The desired soil sample was collected from quarry site situated near Karachi, Pakistan. This source was selected as the sand used in construction activities here is mostly collected from this source. It is abundantly available, clean and easily accessible.

B. PLASTIC MATERIALS

Plastic strips of various sizes were prepared from shopping bags. The shopping bags were collected from commercial market. These plastic strips were introduced to sand at various percentages of the weight of soil specimen.

III. RESEARCH METHODOLOGY

A. Small Direct Shear Testing

Small size direct shear machine was used in this study as shown in figure (1). This machine is composed of various parts such as shear box assembly – which consists of horizontally split-table shear box. Sand specimen is placed inside this assembly. One dial gauge is attached to this shear box through load beam to measure the vertical movement of soil specimen during testing. Second dial gauge is connected next to the shear box assembly, which measure the horizontal movement of the soil specimen. Next to this a proving ring is attached, which put shear force on soil specimen. Third dial gauge is placed inside the proving ring which measure the shear force applied on soil. The desired vertical loads are applied on soil through hanger attached to the loading frame. This machine also consists of a touch screen, from where different testing options can be selected.
This study presents the effects of plastic waste on shear behavior of sand. Soil sample was collected from main source and test specimens were prepared in laboratory. For determining their basic properties, some basic laboratory tests such as grain size analysis, compaction test, specific gravity and Atterberg limits were performed. In first stage direct shear tests were applied to sand in plain conditions, and in second stage, plastic strips of various sizes were introduced into sand at various percentages and direct shear tests were repeated for comparison and interpretation.

"Figure 01. Direct Shear Machine".

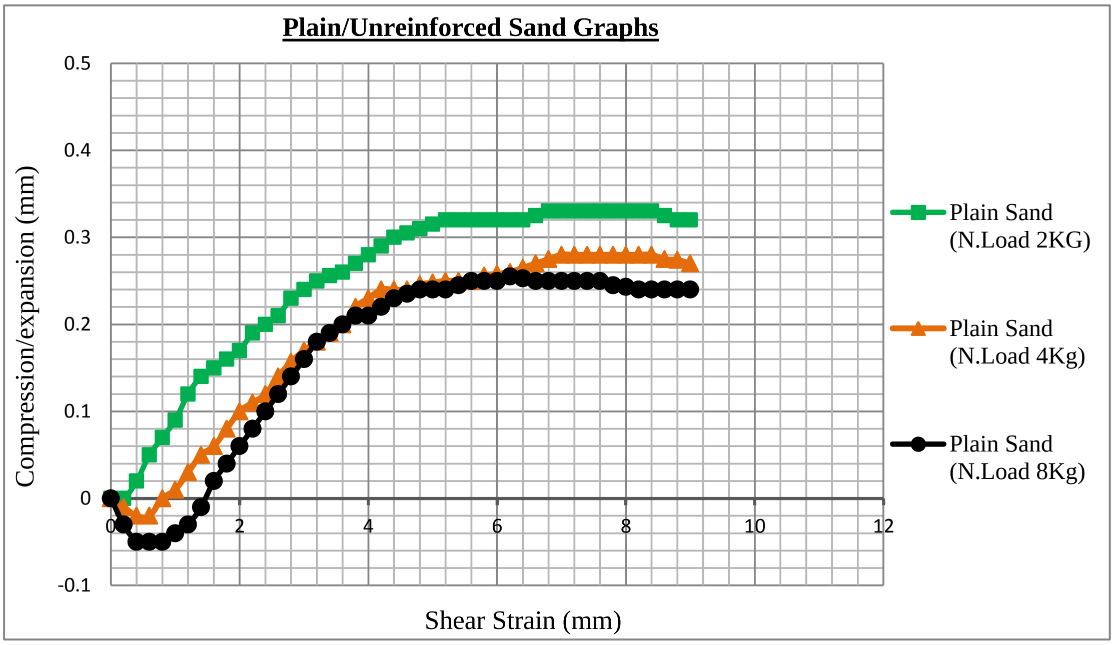
IV. TESTS RESULTS AND ANALYSIS

As stated before that in this study sand soil was used as base material and plastic strips were used as reinforcement elements. Direct shear tests were carried out on sand specimens according to ASTM D-3080. In first stage sand was tested in plain conditions and in second stage it was tested in reinforced conditions. To investigate the plastic strips effects on shear behavior of soil, following relations have been considered.

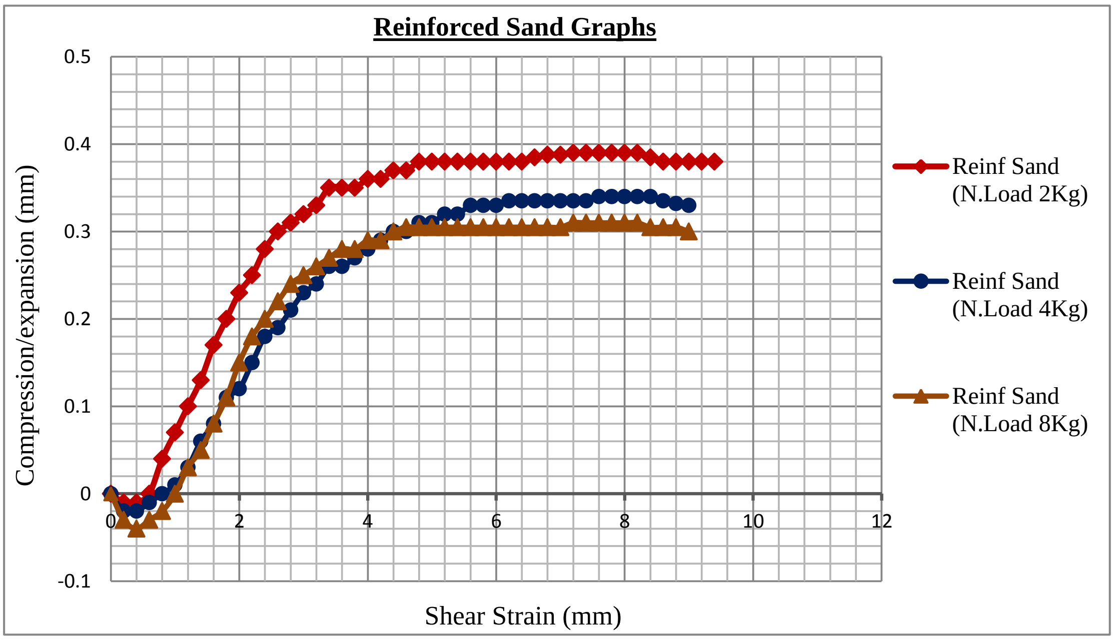
- Compression/expansion vs shear strain relation
- Shear stress vs shear strain relation
- Mohr-Coulomb Envelops

A. Compression/expansion relation of soil

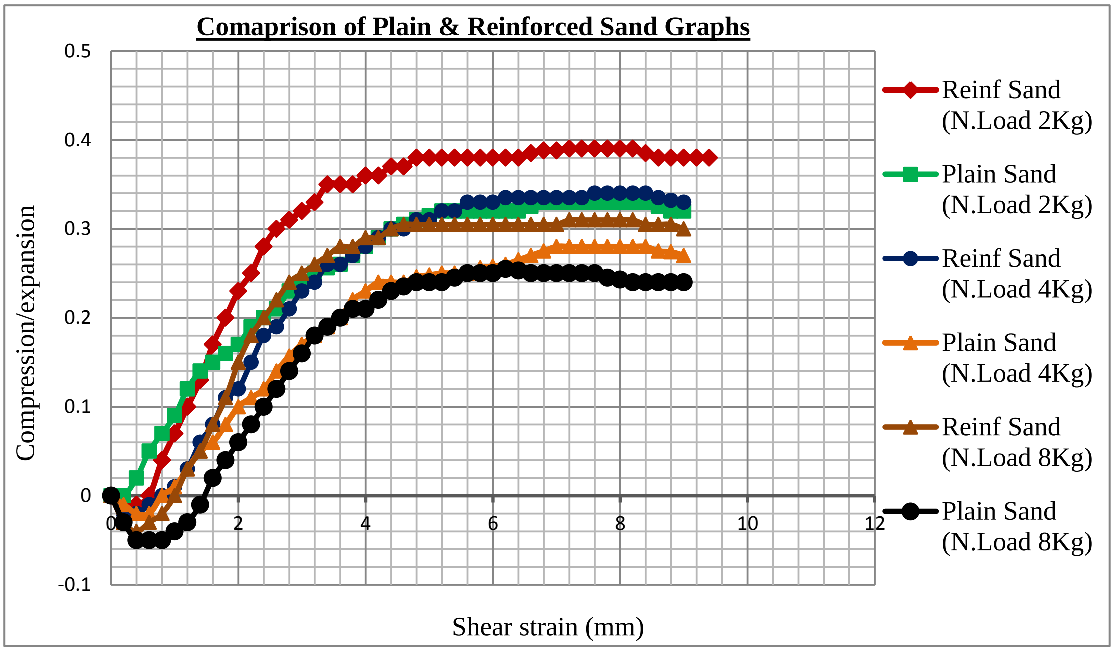
Three sand specimen in plain conditions were subjected to direct shear testing under various normal loading conditions. First specimen was tested with normal load of 2kg applied at the ratio of 1:10 through normal loading frame and hanger arrangement, which resulted normal stress of 60 kpa, second specimen was tested with normal load of 4kg applied at the ratio of 1:10, which resulted normal stress of 115 kpa, and in the same way third specimen was tested with normal load of 8kg, which produced normal stress of 224 kpa. In test results it was observed that initially each specimen executed compression and then it started expansion and kept it continue up to failure as shown in figure 02. Similarly, three sand specimen in reinforced conditions were tested in direct shearing machine under different normal loading conditions as followed in plain conditions. First specimen was tested with normal load of 2kg, second specimen was tested with normal load of 4kg and third specimen was tested with normal load of 8kg. Here in reinforced conditions too, initially each specimen executed compression and then start expansion and kept it up to failure. However, the amount of expansion in reinforced conditions specimen were more than plain condition specimens as shown in figure 03. To observe the difference, graphs of plain and reinforced specimens have been compared in figure 04.



“Figure 02. Compression/expansion graphs of plain sand”.



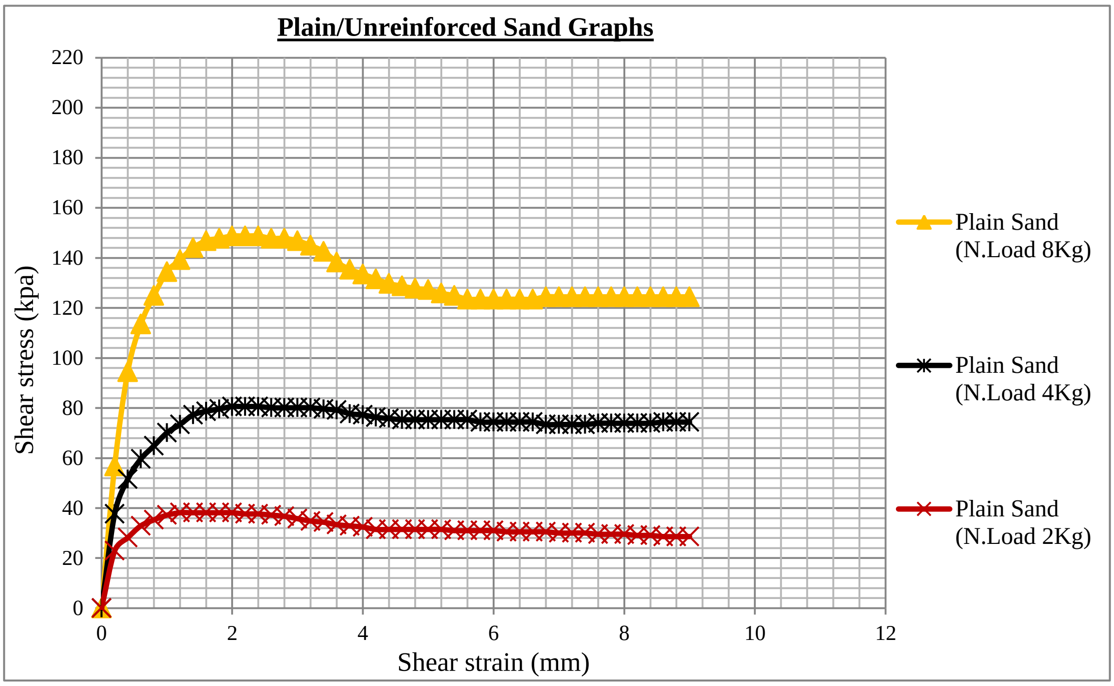
“Figure 03. Compression/expansion graphs of reinforced sand”.



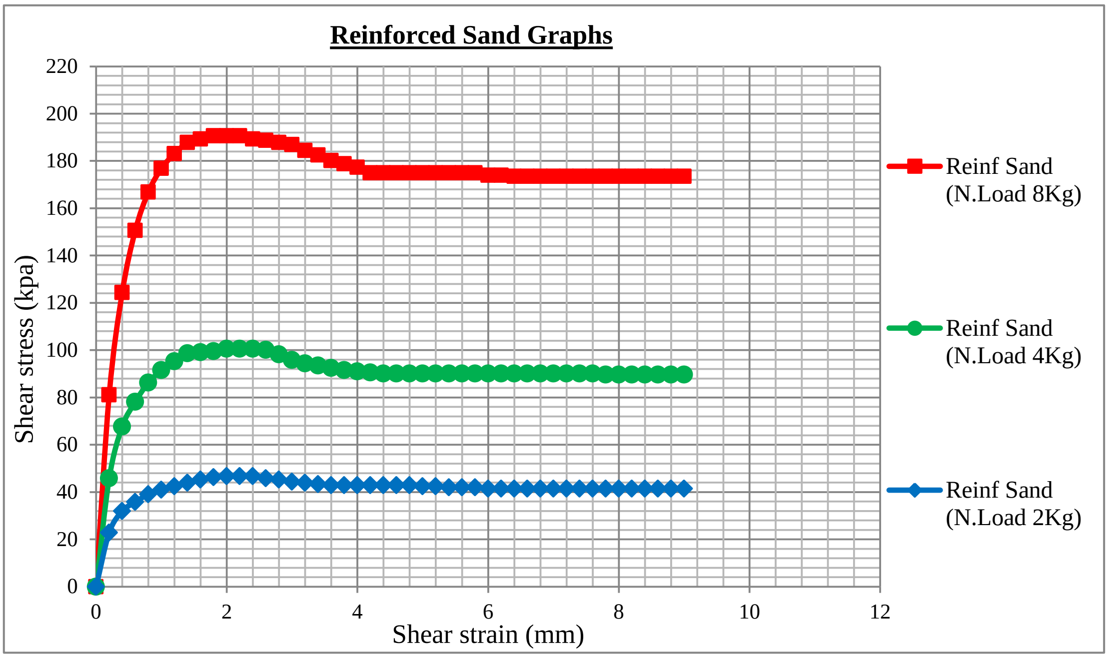
"Figure 04. Comparison of compression/expansion graphs of plain & reinforced sand".

B. Shear stress vs shear strain relation of soil

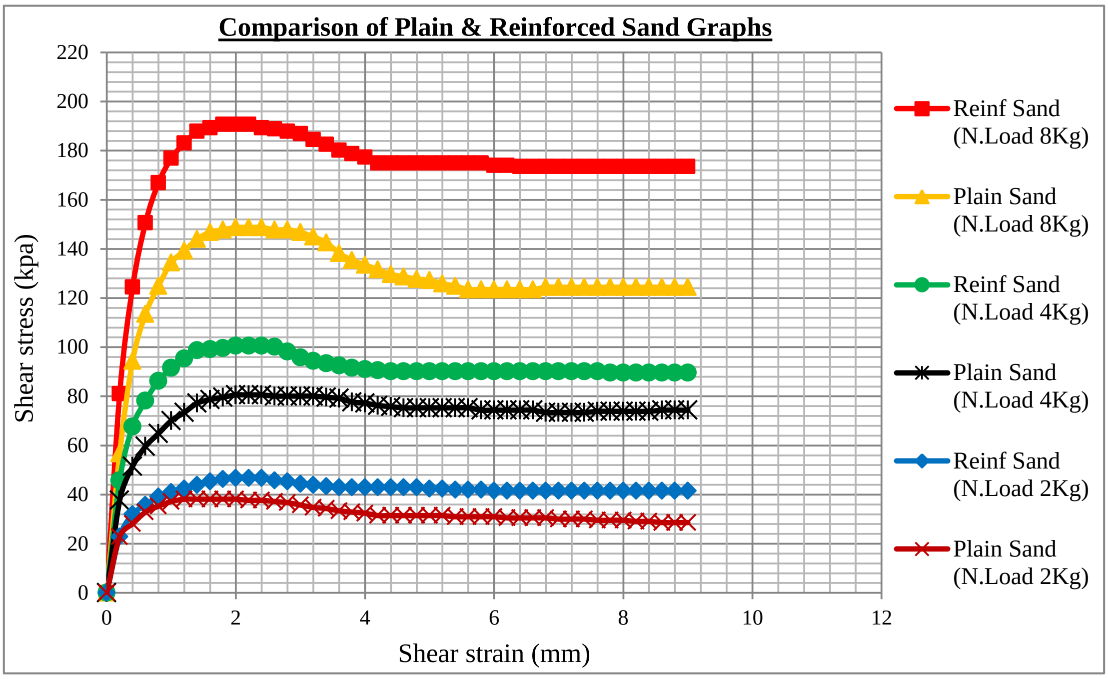
As stated in previous section that three similar sand specimens in plain conditions were tested in direct shear machine under three different normal loads such as 2 kg, 4 kg and 8 kg respectively. In tests results, the shear stress relation of all the three specimen in plain conditions were observed as shown in figure 05. Similarly, three similar sand specimen in reinforced conditions were tested in direct shear machine, and their shear stress relations were noticed as shown in figure 06. An enhancement in shear stress values were found due to plastic strips inclusions. To observe the effect of plastic strips on shear stress relation of sand, shear stress graphs of plain and reinforced conditions have been compared in figure 07.



"Figure 05. Shear stress vs shear strain graphs of plain sand".



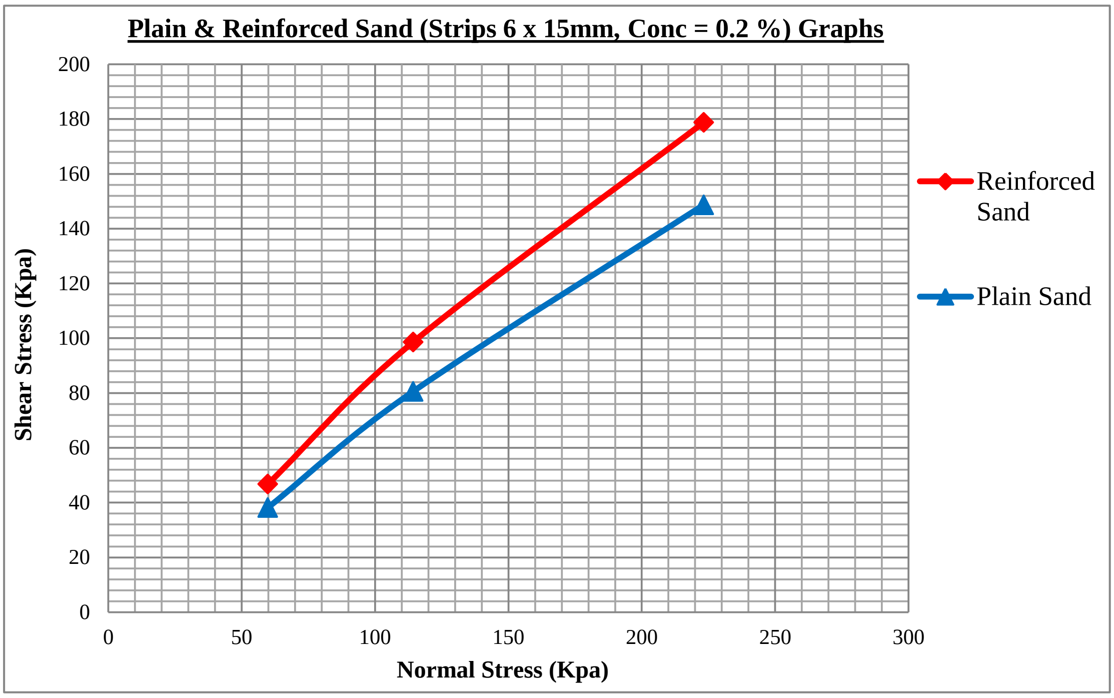
"Figure 06. Shear stress vs shear strain graphs of reinforced sand".



"Figure 07. Comparison of shear stress vs shear strain graphs of plain & reinforced sand".

C. Mohr-Coulomb Envelops of sand

Peak shear stress values of three sand specimens in plain conditions were recorded in direct shear tests and their relationship with corresponding normal stress values were presented in graphical form. Similarly, for three reinforced sand specimens peak shear stress values were recorded and their relationship with corresponding normal stress values were presented on graph paper. To investigate the effect of plastic strips on friction angles of sand, Mohr-coulomb envelops of plain and reinforced sand have been presented in figure 08.



"Figure 08. Mohr-Coulomb envelops of plain and reinforced sand".

Plain/Unreinforced Sand (Φ) = **33.34^{0}** Reinforced Sand (Φ) = **38.90^{0}**

Increase (Φ) = **16.67 %**

V. CONCLUSIONS

A number of direct shear tests were conducted on sand in plain and reinforced conditions, and various tests results like compression/expansions, shear stress and friction angles of plain and reinforced states were determined. The following conclusions are presented here:

- An increase in friction angle of sand specimens was witnessed as 16.67 % with plastic strips of 6mm width and 15mm length and at application of 0.2 % of the weight of specimen.
- An enhancement in shear stress performance of sand specimen was witnessed with plastic strip inclusions.
- Similarly, an enhancement in compression/expansion performance of sand specimen was witnessed with plastic strip inclusions.

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