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INTERFACES BEHAVIOUR BETWEEN CONCRETE AND BFRP WRAPPED CONCRETE WITH SC SOIL

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ABSTRACT

Most of the civil engineering structures involve some type of structural element with direct contact with ground soil. The study of the interaction between structural element (foundation) and supporting soil media is of fundamental importance to both geotechnical and structural engineers. Results of such study can be used in the analysis of stresses and deformations within the supporting soil medium. In recent years, Fibre Reinforced Polymers (FRPs) have been introduced in the field of geo-technical engineering to solve such problems as earthen retention, unstable slopes and strengthening of foundation structures. Hence it is important to study the interfacial behavior between these materials with soil. To provide some insight into the interface behavior, direct shear tests were conducted between concrete and Basalt Fiber Reinforced Polymer (BFRP) wrapped concrete with SC soil. The parameters varied in this investigation were surface roughness (which include smooth to rough), and normal stress (0.05 N/mm^2 to 0.20 N/mm^2). Experimental results show that surface roughness of concrete specimens was significantly changes the interface friction angle. Shear strength at the interface increases with increase in normal stress and surface roughness.

Key words: Direct shear test, SC soil, internal friction angle, interface friction angle, BFRP.

INTRODUCTION

The shearing behavior of a soil-structure interface governs the response of many geotechnical systems, ranging from laboratory and in-situ tests to piled foundations and tunnel jacking. Conventional structural design methods neglect the soil-structure interaction effects. Neglecting soil-structure interaction is reasonable for light structures in relatively stiff soil such as low rise buildings and simple rigid retaining walls. The effect of soil-structure interaction, however, becomes prominent for heavy structures resting on relatively soft soils for example nuclear power plants, high-rise buildings and elevated-highways on soft soil. Hence the foundation designer must consider the behavior of both structure and soil and their interaction with each other. Many of the foundation structures have been found to deteriorate with time. It is essential to retrofit the deteriorated foundation structures for the better performance under external loads. In response to growing needs for strengthening and rehabilitation of structures, many researchers have considered application of Fiber-Reinforced Polymer (laminated) sheets/strips as an effective strengthening and rehabilitation method. To provide some insight into the interface behavior between concrete and Basalt Fiber Reinforced Polymer (BFRP) wrapped concrete with SC soil, an experimental study was performed to evaluate the importance of various factors. Uesugi and Kishida (1986) performed an experimental study of frictional resistance at yield between dry sand and mild steel. The results show that the shearing resistance at the interface depends on the normal stress; surface roughness and sand type. Tsubakihara et al. (1993) conducted laboratory tests on friction between cohesive soils and mild steel; experimental results indicate that the friction is dependent on the roughness of steel. Frost and Han (1999) conducted experiments to investigate the behavior of sand-FRP interfaces and concluded that interface shear behavior between FRP composites and granular materials depended on the relative roughness (surface roughness/particle mean size), the normal stress level, the initial density of the soil mass, and the angularity of the particles. Frost and Lee (2001) investigated the geomembrane surface roughness on geomembrane-geotextile interface strength. The results show that surface roughness has a first-order effect on the strength of geomembrane-geotextile interfaces. Fleming et al. (2006) investigated the shear strength of geomembrane-soil interface under unsaturated conditions. The results show that a plowing failure mechanism resulted in the mobilization of significantly higher shear strength at the geomembrane–soil interface. Gireesha and Muthukkumaran (2011) studied the interface friction angle of different structural materials (concrete, steel and wood) against well and poorly graded sands with varying relative density. The experimental results show that both internal and interface friction angle decrease with increasing relative density of both well and poorly graded sand.

SOIL CHARACTERISTICS

Engineering properties of the soil is listed in Table.1. The soil was classified as clayey sand (SC) according to IS: 1498 – 1970.

Table 1. Engineering properties of the soil used in the study

% Passing			Atterberg Limit			Dry unit weight (kN/m^3)			Type of soil (IS 1498)
4.75mm	425µ	75µ	LL (%)	PL (%)	Ip	γ_d(max)	γ_d(min)	γ_d(test)	
99	64	49	47	26	21	15.25	13.12	14.34	SC

TESTING APPARATUS

The direct shear tests for this entire study were carried out in a conventional direct shear box apparatus. The apparatus consists of a two piece shear box of 60 mm x 60 mm in cross-section rests over sliding rollers supported by a loading frame and which can be pushed forward at a constant rate by geared jack, driven by an electric motor. The gearbox with its motor is used with the step less speed control box. The speed control of the shear box is calibrated in mm/min. Test speed could be controlled by choosing the appropriate gear wheel from the gear box. The lower half of the shear box is rigidly held in position in a container and the upper half of the box butts against a proving ring. The normal stress to the specimen is by a vertical load hanger which rests on the yoke above the soil specimen, and hangs vertically downwards permitting selected weights to be held on its loading pan. The shear force was measured by means of a proving ring. The horizontal displacement of the soil specimen was measured with the help of a dial gauge.

TESTING METHODOLOGY

For the interface frictional test, four concrete specimens of size 6cm x 6cm x 1.4 cm were prepared. The concrete specimens were prepared by first mixing the sand and cement, adding water and mixing gradually, subsequently filling the prepared boxes with concrete. Three different surface of concrete (smooth, medium and rough) were suitably obtained by travelling. Next day, the specimens were remoulded and immersed in water for curing. After sufficient curing, specimens were taken out and one specimen was wrapped with BFRP mat. Direct shear test was conducted between these specimens with SC soil. Four different concrete specimens are shown in figure 1.The specimens were placed in the lower half of the direct shear box and the upper half of the shear box was filled with SC soil at predetermined density. The modified direct shear test setup is shown in figure 2. When a shearing force is applied to the lower box through the geared jack, the movement of the lower part of the box is transmitted through the specimen to the upper part of the box and hence on the proving ring. The deformation in proving ring indicates the shear force. The horizontal displacement during the shearing process is measured by mounting a dial gauge at the top of the box. Samples were sheared at 1.25 mm/min. For each tests four normal stress 0.05 N/mm^2, 0.10 N/mm^2, 0.15 N/mm^2 and 0.20 N/mm^2 were used.

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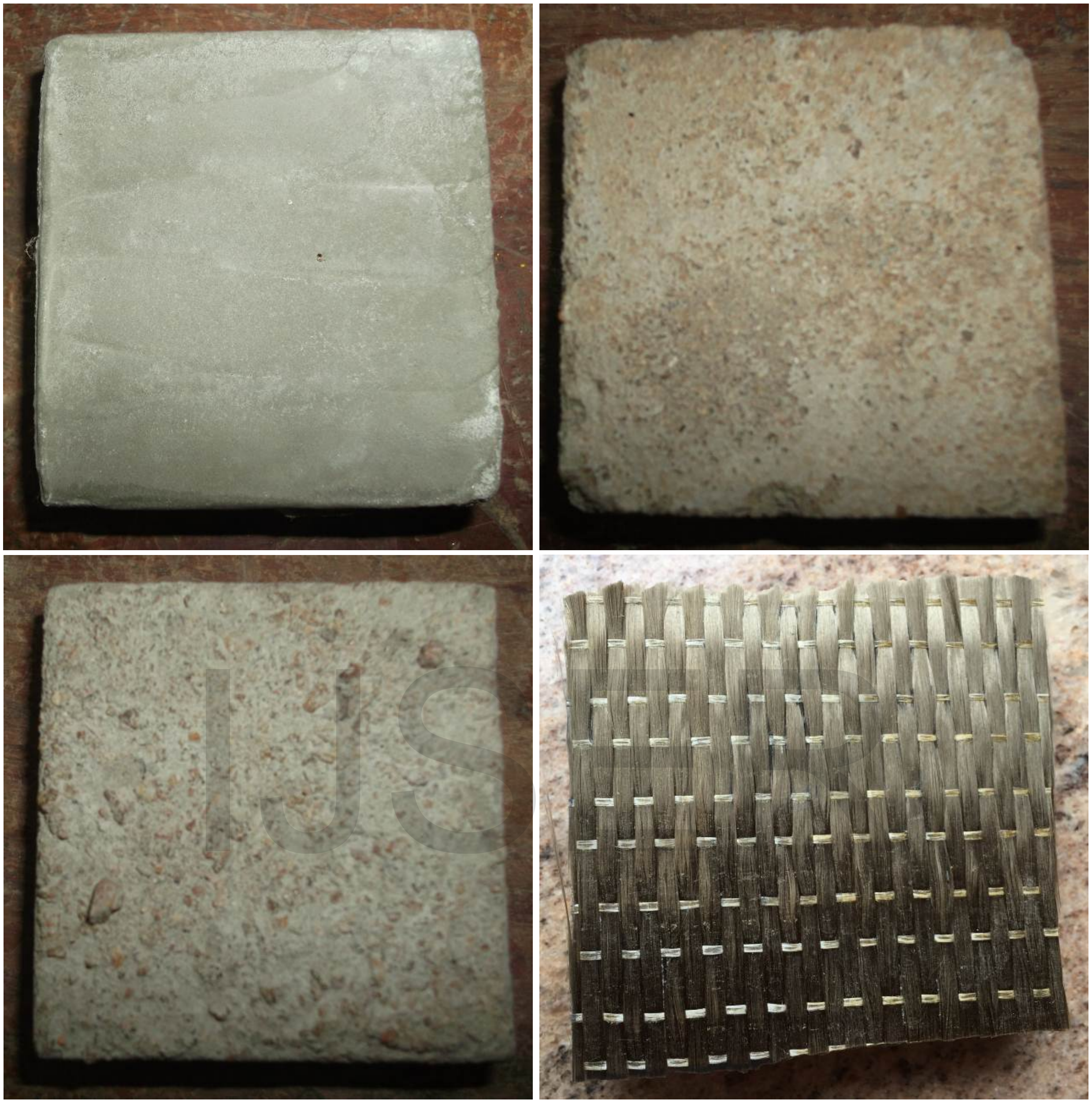

Fig. 1. Concrete specimens used in this study

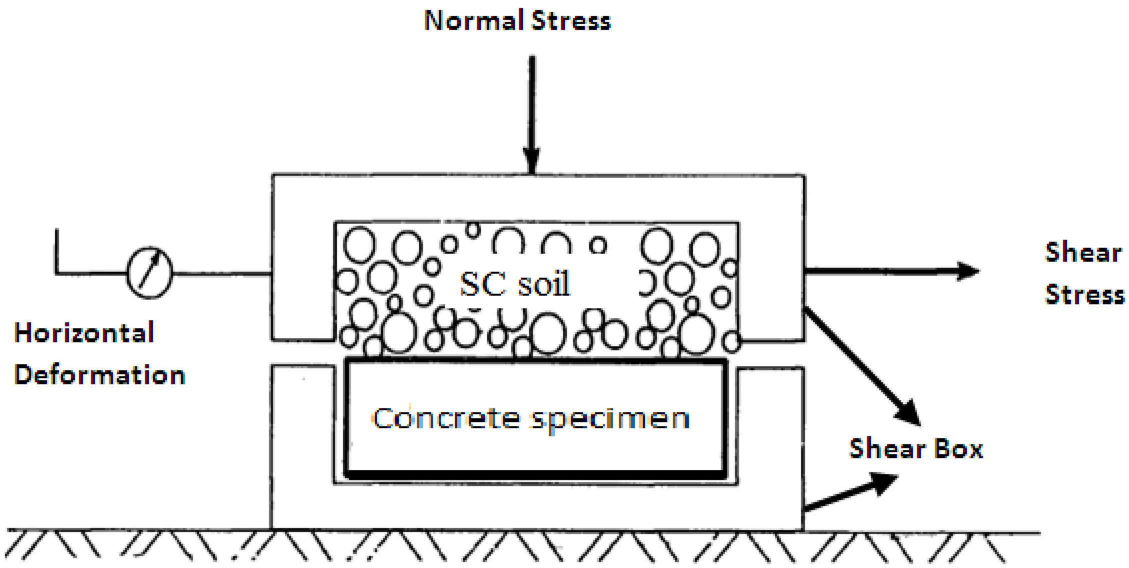

Figure 2: Test set up for interface friction measurement

TEST RESULTS AND DISCUSSIONS

Effect of surface roughness on interface friction

Surface roughness of the material is one of the important factors that influence the shear strength parameters. Generally, Absolute roughness (R_a) is considered for calculating interface friction between two different materials. It is a measure of the surface roughness of a material. This roughness is generally expressed in units of length as the absolute roughness of the material. Surface roughness of concrete specimens used in the study is given in the table 2. The results obtained for the SC soil under different normal stresses were analysed to obtain the required shear strength parameters. The obtained shear strength parameters are presented in table 3. Interface friction angle against surface roughness of concrete specimens with SC soil is shown in figure 3. It indicates that interface friction angle increases with the increment of the surface roughness of the concrete specimens used in this study. The highest peak shear strength is achieved when the surface is rough.

Table 2. Surface roughness

Concrete specimens	Surface roughness, R_a (µm)
Smooth surface concrete	0.62
Medium surface concrete	0.88
Rough surface concrete	1.82
BFRP wrapped concrete	0.72

Table 3: shear strength parameters

Type of interaction	Angle of internal/interface friction
SC soil – SC soil	32.12°
SC soil – Smooth surface concrete	27.78°
SC soil – Medium surface concrete	30.84°
SC soil – Rough surface concrete	38.42°
SC soil – BFRP wrapped concrete	28.61°

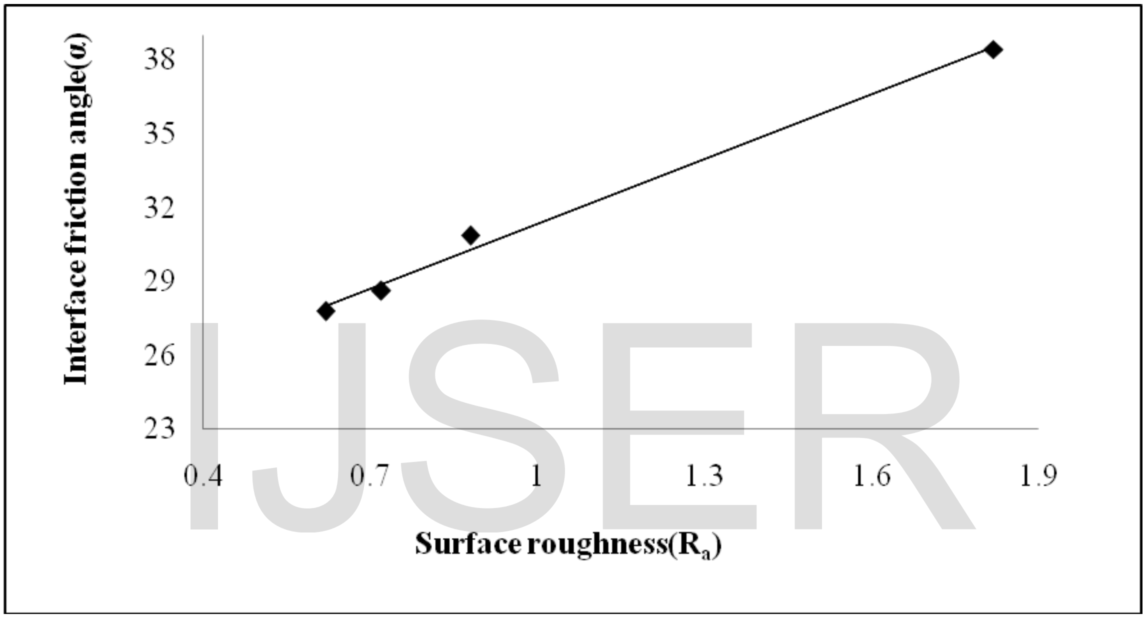

Fig. 3. Interface friction angle against surface roughness of concrete specimens with SC soil

CONCLUSION

Direct shear tests were conducted to investigate the interface friction angle between SC soil with concrete specimens. The tests were performed under four values of normal stress 0.05 N/mm^2, 0.10 N/mm^2, 0.15 N/mm^2 and 0.20 N/mm^2. Examining the data obtained from direct shear test, it could be seen that, the shear strength at the interface increases with increase in surface roughness of concrete specimens. The shear strength increases with increasing normal stress.

- Angle of interface friction between smooth surface concrete specimen with SC soil was 9.92 % lower than medium surface concrete specimen.
- Angle of interface friction between rough surface concrete specimen with SC soil was 24.58 % higher than medium surface concrete specimen
- Angle of interface friction between BFRP wrapped concrete specimen with SC soil was 7.23 % lower than medium surface concrete specimen

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