SKIN FRICTION BETWEEN UNDISTURBED OVER CONSOLIDATED SILTY CLAY SOILS AND CONCRETE

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ABSTRACT

Up to date, in many foundation design problems (especially for piles foundation), the shear strength (skin friction) between soil and construction materials of the foundation was usually estimated or correlated without any direct methods for measurement.

The modern trend is to establish skin friction coefficients through laboratory experiments in which the factors influencing the results may be controlled quantitatively.

In this study strain controlled Direct Shear Tests were performed using shear to simulate the shear behavior area between concrete (foundation materials) and undisturbed over consolidated silty clay, to determine the shear strength of soil – foundation interface, considering the following variables : (1) Concrete, smooth surface condition, (2) Undisturbed over consolidated silty clay, (3) Variation of the normal load between the friction surface. The tests conveniently revealed both shear strength parameters as for soil test (cohesion and angle of internal friction), and interface angle of friction was in the range of 14° to 17°, while the adhesion was in the range of 13 to 16 kPa.

The ultimate shear strength was mobilized through 4 to 7 mm displacement in the direction of shear slip; this was a great advantage of Direct Shear Test performance.

KEYWORDS

undisturbed, over-consolidated, silty clay soils, soil-concrete interaction, skin friction, direct shear test.

الخلاصه

غالباً ما تستخرج معاملات مقاومة القص بين التربه ومواد الأنشاء(احتكاك التماس) في الأسس مختبرياً بدون طرق مباشِره للحساب.

يميل التوحه الحديث لأستخراج معامل التماس من تجارب مختبريه التي يمكن خلالها السيطره على الظروف والمعاملات المؤثره عليها.

في هذا البحث أجريت مجموعه من تجارب القص المباشر مسيطر الأنفعال في صندوق القص لمحاكاة تصرف القص بين الخرسانه (مواد الأساس)وتربه طينيه غرينبه مسبقه الأنضمام غير مشوشه لحساب مقاومه القص بينهما.أجريت التجارب أخذين بنظر الأعتبار المتغيرات والظروف (1)خرسانه ناعمه السطح (2) تربه طينيه غرينيه مسبقه الأنظمام غير مشوشه (3) تغيّر الحمل العمودي عل سطح التماس.عكست الأختبارات بشكل أعتيادي معاملات القص كما في تجارب التربه الطبيعيه (التلاصق وزاوية الأحتكاك الداخلي),و كانت زاوية احتكاك التماس ضمن الحدود بين 14° - 17 ° بينما ألتصاق بحدود 13 – 16 كيلوباسكال .

تأهبة مقاومة القص العظمى للتماس من 4- 7 ملم أزاحه بأتجاه شقّة القص . هذهِ هى فائدة كبيره من استخدام اختبار مقاومه القص المباشر .

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INTRODUCTION

In the field of geotechnical engineering, it's well known that the designs of piles foundation depend upon end bearing and /or skin friction between the piles and soil. There are various ways to determine the pile capacity and most of them rely on full scale field tests using full size piles, but such tests are expensive and the results may apply only to the site where the test was performed. The value of skin friction factor to use in determining the load capacity of piles is a subject of much debate and testing (Budhu, M. 2000).

The soil parameters needed for static analysis of single and group piles capacity consist of the angle of internal friction φ and the cohesion c. The strength parameters have been determined from laboratory triaxial tests on undisturbed samples with experience used to extrapolate this data to obtain the design parameters. Also , they used in situ parameters of cone penetration test or pressure meter test and probably most pile design still relies heavily on standard penetration test N values in sand and field tests for shear strength in cohesive soil deposits (Bowles, J.E. 1988).

Many geotechnical problems involve estimation of stresses transferred along the interface between soils and solid surfaces. While considerable work have been done on the interfacial friction between cohesion-less soils (sands) and solid surfaces. The interfacial shear resistance between fine grained soils and solid surfaces depends on whether its mobilization takes place in the drained or in the undrained condition. Also most of these studies are on normally consolidated soils, the influence of over- consolidated soils has received little attention (Acar et. al 1982, Ampera, B. and Aydogmus, T. 2005)

The objective of this study is to use the Direct Shear Test Box to study interface friction and adhesive between undisturbed over consolidated clay soil and foundation material.

TEST PROGRAM

The test program consists of 12 Direct Shear Test on specimens of cohesive silty clay soil and concrete slice (foundation materials). The soil is placed in the bottom part of the Direct Shear Test Box and the concrete slice placed above it (in the top part of the box) as shown in **Fig.1**. Test series (S1 – S5) were performed on five undisturbed cohesive silty clay soils, a total of twelve Direct Shear Tests were carried out.

These 12 tests were conducted in such away that in the first six tests the rate of strain was higher than the second group, in addition to, the natural properties difference of the tested soils. **Table 2** shows the details information of the test series performed.

Its worth to mention, that all the soil series properties and characteristics physically and chemically, also the field work were carried out in accordance with (ASTM standards D 3080). **Table 1** presents the properties of tested soil.

SAMPLE PREPARATION

To prepare the test sample, for the direct shear test, the soil part of the specimen was undisturbed cohesive silty clay soil extracted directly from Shelby tube (Five undisturbed samples obtained from various locations in Babil governorate, 110 km south of Baghdad, were used in this work. It was extracted from different depths. The boring equipment used in carrying out the field work was rotary drills rigs, with the use of thin wall tube samplers Shelby tube for taking undisturbed samples .The disturbed samples were obtained, to determine the classification of soils, the samples that secured by the Standard Split Spoon Sampler were also used as disturbed samples, the water table was found at the time of boring be 3-4 m deep) using hollow box cutter sampler (6 × 6× 2 cm) specified for Direct Shear Test. The other part was a slice of concrete cube which was cast using job mix (1:1.5:3) and cured for 28 days. Then the soil pushed to the bottom half of the Direct Shear Box before tighten the two halves of box. Later the concrete slice (foundation material) was put in the upper half of the Shear Box, as shown in **Fig. 1**. Finally the test was conducted in the usual manner (Das, B. M. 2002, and Lambe, T. W., 2000).

Slices of concrete cubes made to fit the Shear Box device dimension by making projection of 6 mm in the direction of applied shear and less than 1 mm in the opposite direction. The detailed characteristics of these soil samples are presented in **Table 1**. Note that the soils are denoted by series symbols (S1 – S5).

DIRECT SHEAR TEST

A conventional strain controlled Direct Shear Box machine with specimen dimensions of (6×6×2 cm) was used. Series of shear strength test on 12 samples were conducted in such away that the soil is placed in the bottom part of the Direct Shear Box and the concrete (foundation material) is placed above it, i.e. in the top part of the box. The test were carried out at two constant rate of strain 1.2 mm/min and 0.3 mm/min.

The tests were carried out in soaked condition using normal pressure ranging from 26.2 kPa to 349 kPa, as illustrated in **Table 2**.

Typical results of sample number five are shown in **Fig. 2**.

RESULTS AND DISCUSSION

Fig. 2, shows the results of Direct Shear Test between a cohesive soil and concrete (foundation material) in soaked condition at a stain rate of 1.2 mm/min. The ultimate shear strength was mobilized at about 10 % strain of sample dimension.

Fig. 3 and **Fig. 4**, illustrates the results between shear stress and normal stress for the first six specimens, the results show a friction angle and adhesion between the tested soil and concrete. The adhesion achieved from the cohesion properties of soil and angle of friction (interface friction) obtained from rough surface of concrete (foundation material).

Comparison of results of **Fig. 3** and **Fig. 4** with the results shown in **Fig. 5 and Fig. 6** indicates that testes at lower rate of strain i. e 0.3 mm/min had increased the adhesion and decreased the angle of internal friction slightly. This is due to the low applied strain that permits the soil to consolidate and to increase the contact area with the concrete face. The shear strength along the surface of contact of the soil and the foundation can be given as in eq. (1):-

$$\tau_f = c_a' + \sigma' \tan \delta' \qquad (1)$$

Where τ_f = Shear strength between the two different material.

c_a' = Adhesive.

σ' = Effective normal stress.

δ' = Effective angle of friction between the soil and the foundation material.

The shear strength parameters between a soil and a foundation material can be conveniently determined by a Direct Shear Test. The Direct Shear Test is simple to perform, but it has some inherent shortcoming .The reliability of the results may be questioned because the soil is not allowed to fail along the weakest plane but is forced to fail along the plane of split of the shear. This shortcoming is related to the original test for soil only to determine their strength parameters.

Despite of this shortcoming, this is a great advantage of the Direct Shear Test; where the shear strength between the soil and the foundation material can be obtain during ordinary site investigation for pile foundation construction.

CONCLUSIONS

This paper has presented the results of an experimental work on five different soil samples used as underneath soil for construction site. From the results of this work, the following conclusions can be warranted:

1. Interface friction angle of undisturbed cohesive soil- concrete (foundation material) can be determined using Direct Shear Test. This is a great advantage of the test.
2. The shear strength between undisturbed cohesive soils – concrete (foundation material) is mobilized at a 10 % strain of sample towards the shear direction that is about 4 – 7 mm horizontal displacement or slip.
3. The shear strength between undisturbed cohesive soils – concrete (foundation material) consisted of adhesion and interface angle of friction.
4. Normal pressure is the most effective parameter on the shear between the soil and concrete.
5. It's preferable to use this test with other tests to estimate the pile load capacity or the length of pile proposed.
6. It's recommended to do this work again, but with either foundation material and other undisturbed soils type or remolded disturbed soils.

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Table 1 – Properties of Tested Soils

Soil Series	Depth (m.)	Sample No.	Consistency Limits		Natural Water Content (%)	Dry Density (kN/m^3)	Specific Gravity G_s	Consolidation Test				Sieve Analysis % Passing No. 200	Soil Type	Strength	SPT	Chemical Tests	
			Liquid Limit LL (%)	Plasticity Index PI (%)				Natural Void Ratio e_o	P'_c	Comp. Index c_c	Rebound Index c_r					Organic Matter (%)	Soluble Salts (%)
S1	2.0-3.0	1, 2	40	18	17.2	15.7	2.69	0.739	120	0.18	0.031	97.4	CL	Med. To Stiff	14	8	1
S2	2.5-3.0	3, 4	55	28	24.6	15.2	2.71	0.835	90	0.19	0.034	98.3	CH	Med. To Stiff	18	20	1
S3	3.0-4.0	5, 6	48	25	27.2	13.9	2.69	0.851	85	0.16	0.031	96.3	CL	Med. To Stiff	16	11	1
S4	2.0-3.0	7, 8, 9	44	21	21.5	15.4	2.68	0.824	95	0.14	0.026	85.5	CL	Med. To Stiff	12	6	0.5
S5	5.5-6.5	10, 11, 12	43	23	25.9	14.4	2.68	0.788	125	0.17	0.031	97.0	CL	Med. To Stiff	23	×	×

× Not tested

Table 2 – Details of Test Series Performed

Soil Series	Sample No.	Normal Stress (kPa)			Rate of Strain (mm/min)	After Test		Interface Strength	
		1	2	3		Water Content (%)	Dry Density (kN/m^3)	Adhesion C (kPa)	Angle of interface friction Φ (°)
S1	1	41.9	71.0	129.3	1.20	26.3	15.4	36.13	14.86
	2	41.9	71.0	129.3	1.20	28.1	14.9	13.2	17.43
S2	3	41.9	71.0	129.3	1.20	25.20	15.0	16.35	10.5
	4	45	76.4	139	1.20	23.0	15.6	5.15	17.9
S3	5	45	76.4	139	1.20	29.0	14.3	4.0	18.53
	6	45	76.4	139	1.20	24.0	14.9	5.2	17.6
S4	7	45	76.4	139	0.30	24.2	15.6	12.93	16.4
	8	114	192.4	349	0.30	×	×	39.85	13.4
	9	114	192.4	349	0.30	×	×	21.49	15.10
S5	10	114	192.4	349	0.30	26.7	16.0	24.13	15.4
	11	114	192.4	349	0.30	×	×	45.8	8.3
	12	26.2	40.8	70	0.30	×	×	3.1	13.6

×Not tested

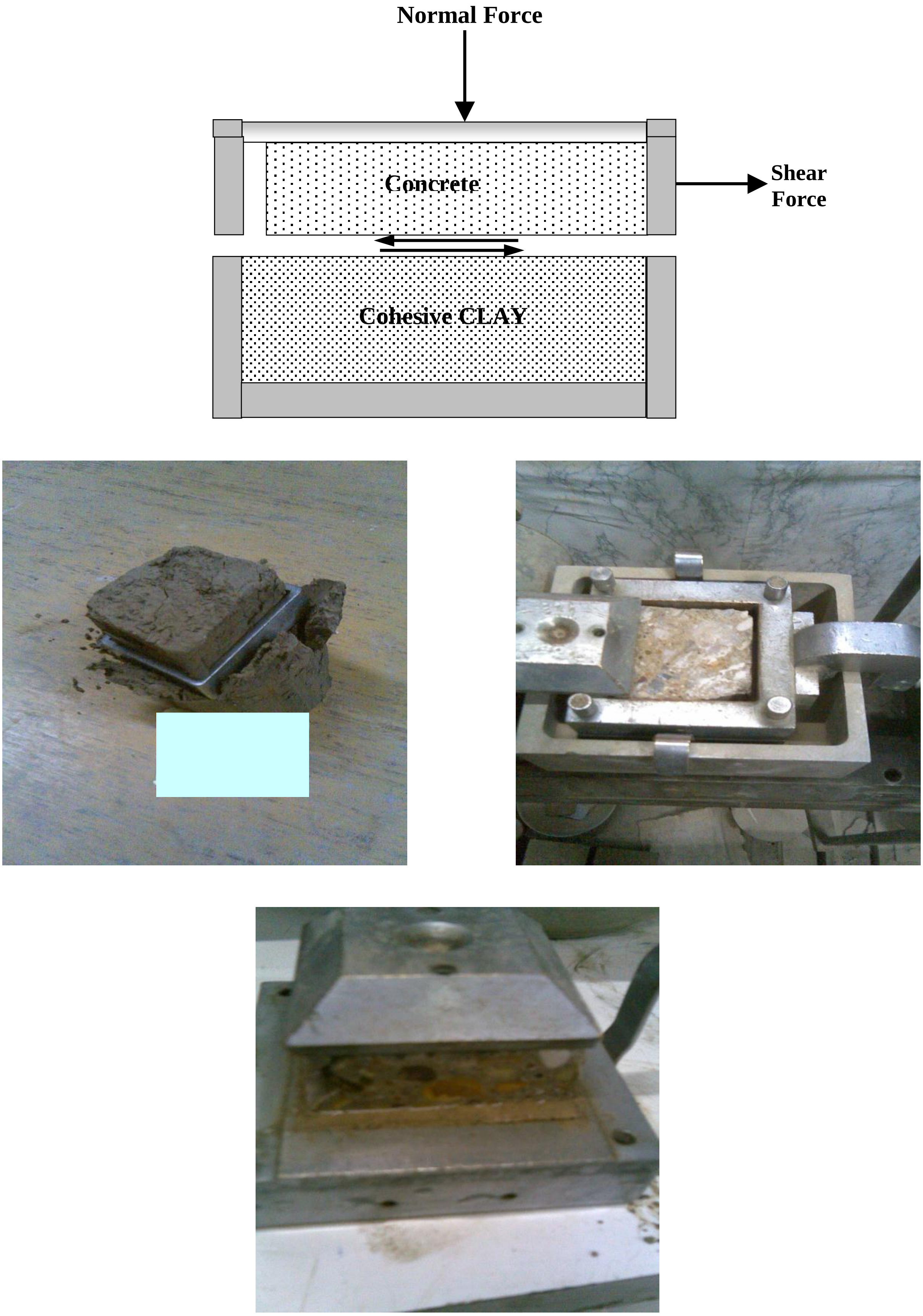

Fig. 1 Direct Shear Test to Determine Adhesion and Interface Friction Angle of Cohesive Clay – Concrete

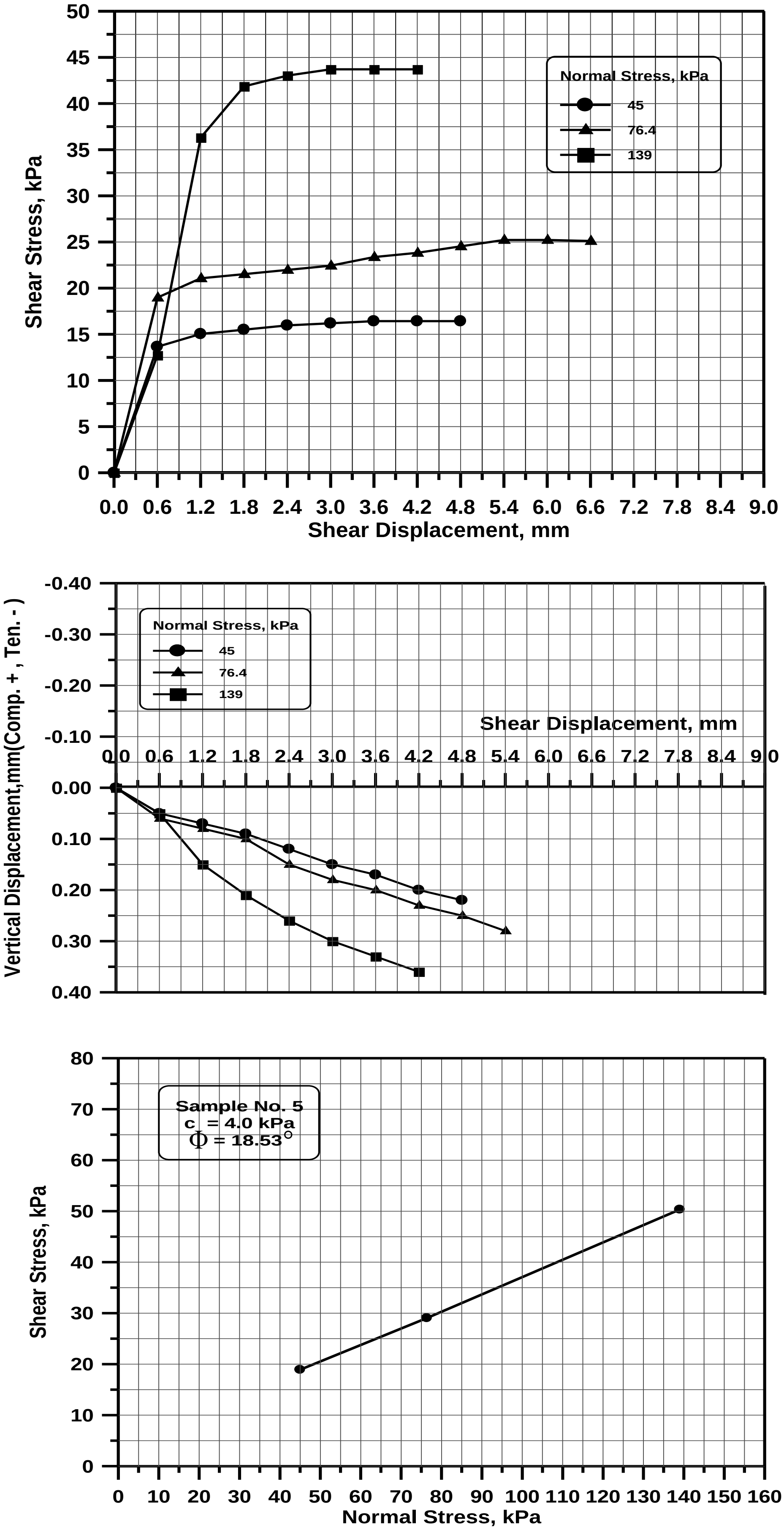

Fig. 2 Results of Direct Shear Test for Sample Number 5

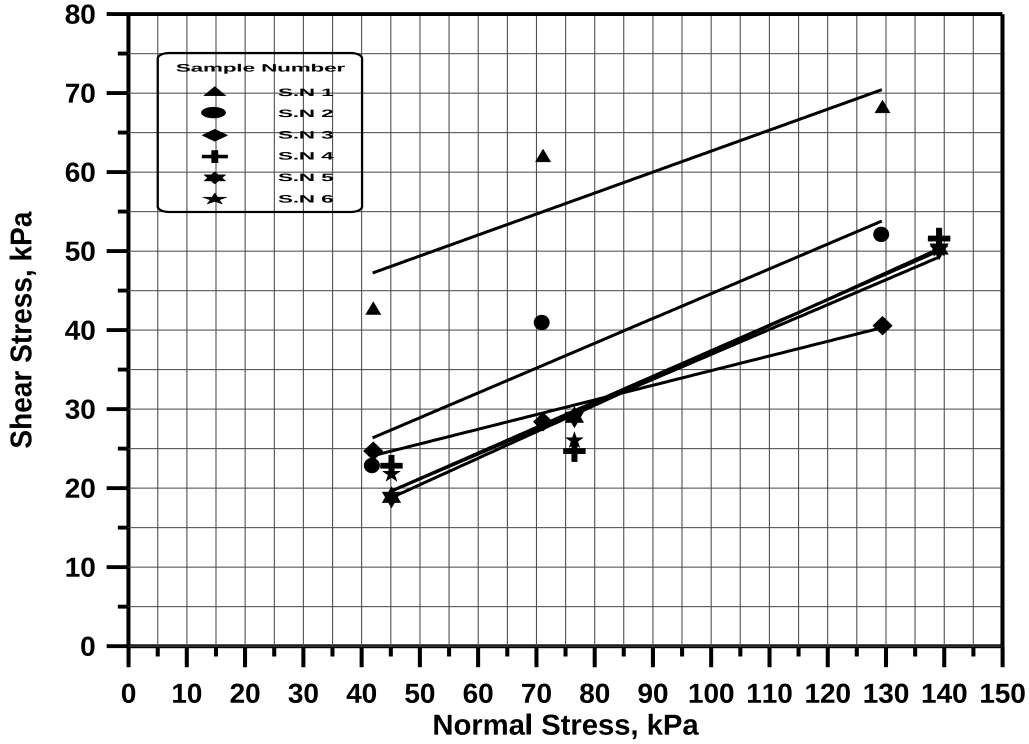

Fig. 3 Results of Direct Shear Test of over Consolidated Clay Soil-Precast Concrete in undrained Condition

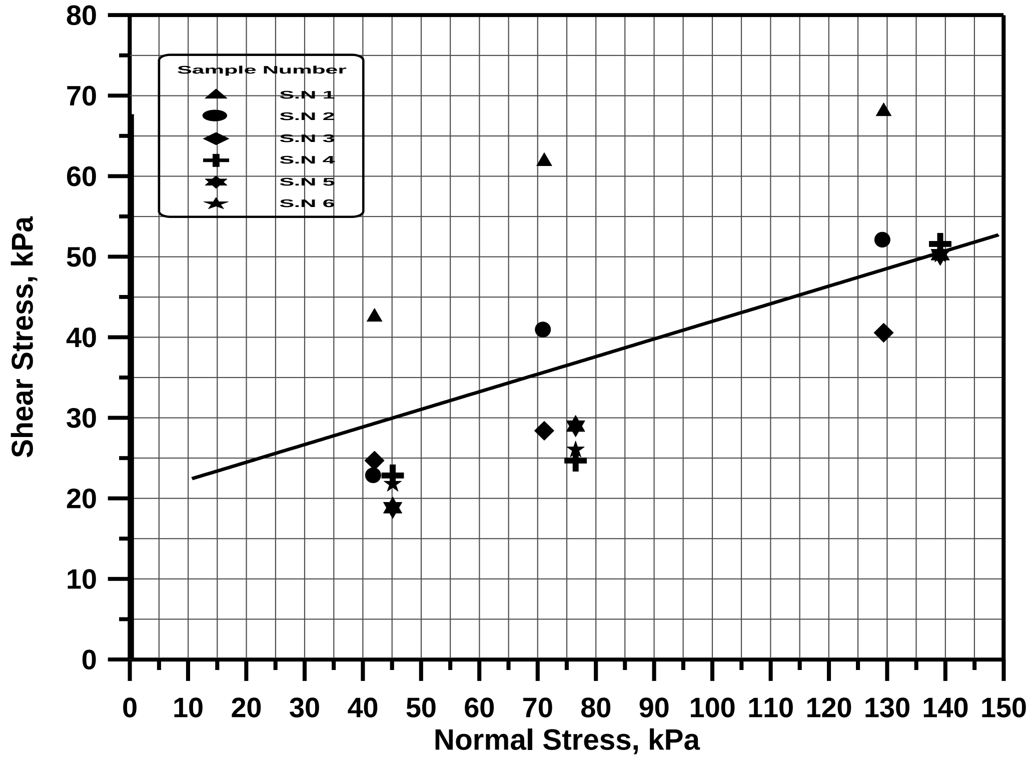

Fig. 4 Determination of Skin Friction of over Consolidated Clay – Precast Concrete in undrained Condition

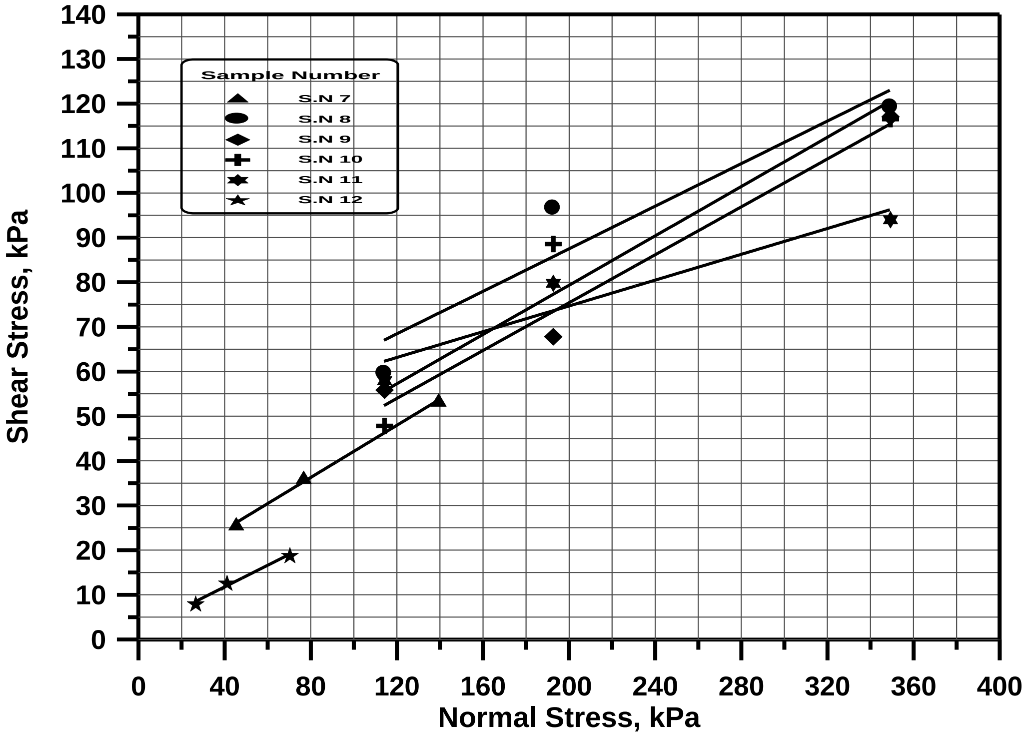

Fig. 5 Results of Direct Shear Test of over Consolidated Clay Soil-Precast Concrete in undrained Condition

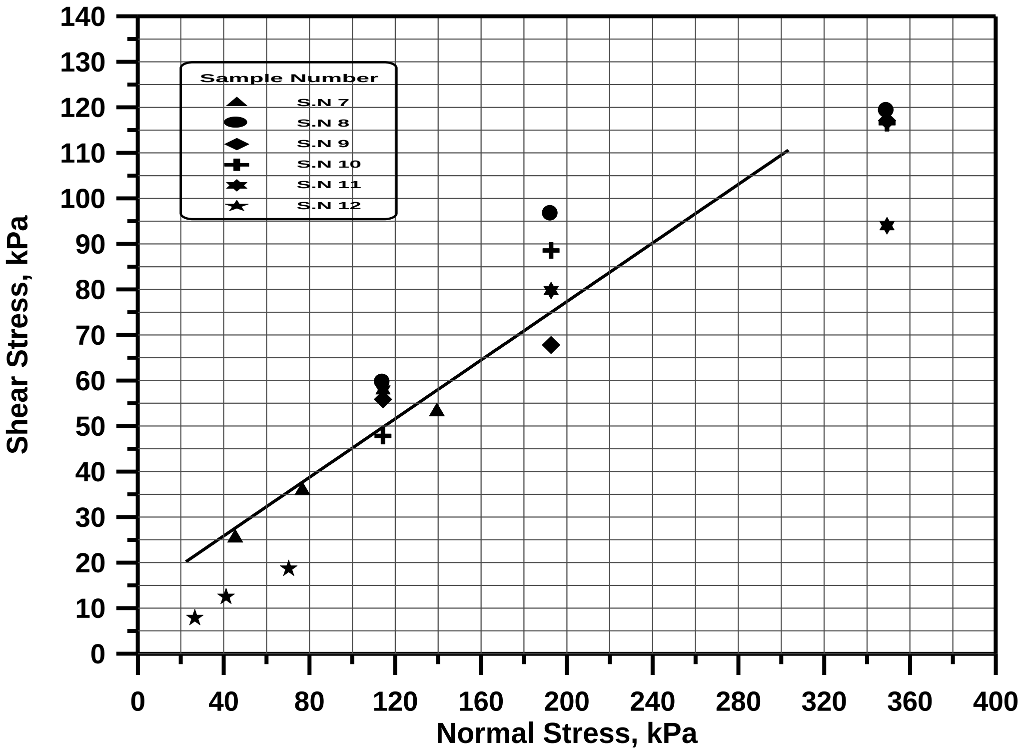

Fig. 6 Determination of Skin Friction of over Consolidated Clay – Precast Concrete in undrained Condition