Shear Strength Assessment of Pile's Concrete Interface with different (Varying Moisture Content) Soil Layers

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Abstract - *This research is based on to investigating the shear strength interface between concrete and different soil layers like (Clay, Sand and lime mix with other soil), which is very important to ensure the safety and stability of geotechnical engineering structures. Deep foundations like pile and retaining walls heavily rely on the shear strength between these materials to withstand external loads and environmental conditions. In this paper, several types of soils including clay, sand and lime-treated clay are study to know their effect on the shear strength interface. Experimental trials and numerical simulations are supervised to analyze the behavior of the interface under different moisture content conditions. Components like, fine content, sand content, clay content, and moisture content are studied to obtain their impact on shear strength. The results gained give valuable insights into the behavior of the concrete-soil interface and its vulnerability to these factors. The findings of this research identify the important of comprehension the shear strength properties of the concrete-soil interface for designing and constructing safe structures. By identifying the crucial elements affect shear strength, designers and engineers can make decisions concerning material selection, construction techniques, and structural strength analysis. This research adds to the field of geotechnical engineering by increasing knowledge on the shear strength behavior of the Pile foundation concrete-soil interface. The findings can be utilized to increase the design and construction elements, ultimately leading to stable and more efficient civil engineering structures.*

Key Words: **Shear Strength, Soil Layers, Pile Foundation, Moisture content, Concrete.**

1.INTRODUCTION

Shear strength interface between concrete and soil is very crucial phenomena in the field of Geotechnical engineering. This phenomenon can be seen in deep pile foundations, retaining walls' back and backfill and foundation base and soil. It is important because it is that aspect of geotechnical engineering in which shear strength plays an important role in stability of the civil engineering structure. The shear strength of the interface is due to adhesion between two different materials like concrete surface and soil in pile foundations. This shear strength is expressed by Mohr-Coulomb law of shear strength shown in equation (1.1)

$\tau = c + \sigma_n \tan\phi$ .... (1.1)

Where: c is the cohesion of soil if any; σ_n effective normal stress on the shearing failure plane and $\tan\phi$ is the angle of internal friction of soil. In deep foundations of pile system, equation (1.1) takes the following shape shown in equation (1.2).

$\tau = c + \gamma hK \tan\delta$ .... (1.2)

Here γ is the unit weight of soil; h is the depth where skin friction, τ is measured; K is the coefficient of lateral earth pressure at h level which a function of ϕ and δ is the angle of adhesion at depth h. For pile foundation, when the soil is sand, the angle of adhesion for skin friction is reasonable in the range of 3/4th of ϕ, it is established fact that moisture content does not affect the angle of friction of sand to greater extent; but it is nominal as a worst condition of greater value of moisture content when the soil is clay. This will make the second term in equations (1.1) and (1.2) negligible in case of clay. Another scenario may also arise when the pile is upper layer of clay and the underlying layer of sand. During pile installation, the clay content may get sandwiched between the pile and sand layer, smear effect that will reduce the angle of adhesion to almost zero at higher moisture content. To try to reduce the effect of nominal adhesion between clay and concrete pile surface, the clay is treated with lime. The lime reacts with clay and Na and K ions in clay are replaced by Ca of the lime. This increases the angle of friction of lime-treated clay up to 40o and to some extent cohesion is increased but at mild rate (Szendefy, 2013). Pure clay and pure sand are also used as interfacing members with concrete surface for the determination of shear strength. Sand - clay mixture and concrete surface interface is also investigated for shear strength behavior. These results are compared with the interface shear strength of lime- treated clay and concrete surface. The internal resistance of soil mass per unit area that a soil mass can offer to resist sliding and failure along any plane inside it is called shear strength (τ). This is a very critical phenomena related to soil because it mostly fails in tension and shear. There are two important shear strength parameters considered for stability that are Cohesion (c) and angle of internal friction (Φ). The shear strength interface between Concrete and Soil is of unique properties and are mainly concerned with the bonding between Soil and concrete, the slipping action between these two and their stiffness behavior under Normal pressure and shearing velocity is very important to know for constructing safe and stable structures. Compacted Soils are analyzed in unsaturated state for the calculation of Effective stress or total stresses. In efforts of finding Shear strength interface phenomena many researchers have put their contribution in the field of Geotechnical engineering.

1.2 Review of Literature

Miller and Sower [1] stated that the shear strength of sand clay mix depends on the effect of sand content, sand content up to 67 percent no apparent change in strength is observed while increasing sand content in the range of 67 to 74 percent decrease in cohesion and fast increment in frictional angle was reported. The mixture was dominated by sand when sand is more than 67 percent in place of clay. Liu, R.H (2004) [2] studied "Soil-structure interface with ideas of soil mechanics having critical states and presented a constitutive model". He Use numerical simulation and appropriate modeling of the soil and structure interface. The critical case of soil mechanics has been used in his studies, and this model is used to compress in the case of stiffness, softening, while natural expansion also emphasizes the pathways. Adunoye (2014) [3] performed "Study of the lateritic soil having fine content with internal angle friction angle". He reported the following points from his research: The frictional angle of soil sample considered decreased as the fine content increases. He expressed a polynomial equation between the fine contents and cohesion of the soil. He expressed his empirical equation for his research made on different collected soil samples. Akayuli D.C and O. Bernard (2013) [4] conducted research on "Impact of clay content on the shear strength and compressibility of sandy soils". He publishes his work in Journal of Engineering Research and applications Vol.3, July-August 2013. He concluded that there is a very strong relation between shear strength and amount of clay content and the compressibility of sandy soil. Ahmed and Jahangir (2008) [5] supervised 12 series of direct shear strength trials on the interface between undisturbed OC silty clayey soil and concrete. With strain rates of 0.2 mm/min and 0.3 mm/min, they noticed the inventiveness of shear resistance strength at a strain of 10%, gave valuable insights into the interface friction angle between cohesive soil and concrete. The research also added the collection of soil samples from different depths in Babel Province Iraq, increasing the concern of natural soil characteristics in the tested area. Gan and Rahardjo [6] conducted direct shear tests on unsaturated dry soil, finding that matric suction affects shear strength parameters. Failure envelopes for unsaturated soil nonlinearly follow matric suction values from 0-500 kPa. Hammoud and Boumekik (2006) [7] stated that the shear strength between the interfaces of cohesive soil-solid material depends on the roughness at interface and soil properties. Increase in roughness increasing interface shear strength. Lavanya (2014) [8] studied "Interface Behavior between carbon fiber reinforced polymer and gravel soils" in his work he used concrete specimen wrapped in reinforced carbon polymer and gravels for the determination of shear strength properties. He concluded that there is a marked decrease in the angle of the interface with CRP wrapping. It means the conclusion was that friction angle with the well graded gravel is higher than poorly graded gravel. Pakbaz and Moqaddam (2012) [9] studied "way of Behaving and properties of clay-sand medium with sand of different gradations" in this study he used clay-sand interface with varying gradation of sand and fines percentage. He noticed consolidated drained Conditions through his trials performed he made the following observations from his analysis: There is a basic difference when fine content reaches 30%. Thus, the characteristics of the shear stress-strain curve are significantly change at this rate of fines and Fine content mixture depends on the sand gradation. He noticed that for soil used in his work with cement grout in suction range of 0-300 kilo pascal curve was not linear. Changes in surface adhesions are about same to the angle of the friction interface. Potyondy J. G. [10] performed his studies regarding "Experimental data with modified form of direct shear test" The test was carried out on a steel interface with different roughness conditions such as a smooth surface whiles the other coarse surface. The results show that the friction angle is connected at a 24 ° angle at the smooth surface while 34 ° for the rough steel surface. No roughness limits were determined. Also with varying normal loads, slight variations were observed in the values of shear on dry and wet sand. The friction angle of the sand used ranges from 39° to 44°, while the sand density was not discussed by the author. Uesugi and Kishida [11] Conducted research on "Influential factors of friction between steel and dry sands". They Conducted Series of many laboratory tests on friction between air dry sand steel, he examined significance of many factors by analyzing experimental data. Sliding displacement was obtained on the contact surface and displacement due to the deformation of the shear of the sand block. Shear deformation was found for the sand mass that is not affected by the roughness of the surface of the steel. Chen and Schreyer [12] studied "A constitutive model for simulating soil-concrete interfaces". He emphasized that due to Earth's movement due to earth's earthquake and explosive material, the importance of soil and concrete interface behavior can be studied due to structural failure. He said that Coulombs law may not be applicable as slipping doesn't occur to the border interface. He concluded that no slip occurs at interface between Concrete-soil and a shear band appeared at interface. After his testing and numerical calculation, he presented a new non local model that can judge the behavior of softening for various construction materials knowing appropriate properties for material used during consideration. Shakir and Zhu (2009) [13] studied "The shear strength properties of interface between clay and concrete".in his research work he used two categories of concrete that are surface roughness and smooth surface. interface shear strength test performed for clay with concrete having smooth surface generally showed larger displacements, shear deformations continue till a point where ultimate shear strength is achieved and shear deformation become ceased. Test was conducted on rough concrete interface surface and increased moisture condition shear deformation was seen more than shear displacement with a normal load of 150kpa. Moisture content plays a vital role for the determination of increased or decreased interface shear strength. Wang. D and J. X. Zhang (2011) [14] Conducted "Research on the shear strength test by using various soil-pile medium/interface". To determine the frictional properties of the interface between the soil and pile, experiments were performed three laboratory experiments were carried out in three different groups at interface. The first was soil-concrete, and second was soil-steel, and third group was soil-HDPE. For analysis of shear strength properties six normal loads were applied and it was seen that by increasing normal load the shear strength increased as like the case studied for soil-pile interface under constant normal load. Minor variation observed for shear deformation and shear stress.it was also observed for change in normal load change in shear stress at interface was less. For Pile-HDPE case changes in the normal load increased shear strength. Peng and L. Jian Kun (2013) [15] conducted "Tests on interface between soil and concrete while the soil is frozen to study the dynamic shear resistance". He concluded from his research that, deformation modulus and shear strength of frozen soil are greater than unfrozen soil. Slip resistance of the frozen concrete-soil remains lower than shear stress of unfrozen soil. Wang, L.C and W. Long (2014) [16] conducted his research "Variation of shear strength on remolded dry clay, with different voids ratio and moisture content by adding different proportions of sand". Purpose of the remolding was to prepare a sample for direct shear test, after controlling moisture content. Specific margin ratios in addition to the sand content of the clay sample were added in order to determine the effect of these parameters on the transfer of shear strength properties to the clay. Laboratory tests were performed using four vertical load values of 100 to 400 kPa using 100 kPa increments for each test. The higher the moisture content, the less friction angle in addition to the cohesion c was observed. Results were same for increasing ratio of the voids and sand content fraction, so the shear strength limits i.e., c, φ for dry remolded clay decreased with increase in water content. Nie and Wang (2015) [17] did experiments on "study of interface between soil and pile by performing interface shear strength tests" Slippage on shearing in soil and the concrete interface is the main problem of piling. As the load increases in the upper part of the pile, shear stress increases, so that after the friction forces are overcome, the system's eventual failure will occur at the bottom and sides of the pile surrounding the soil. So, in order to get a safe mechanism study of the interface is essential. For this purpose, a medium shear test was conducted for the soil and concrete interface. He further elaborated his research work on the following observations: Concrete interface and ultimate shear stress of soil has a vivid linear proportion under various normal stresses that follow Mohr coulomb failure envelop. Cohesive forces exist in case of clayey soil and he showed a particular case of bond strength 30 KPA with angle of internal friction (18°) responsible for shear strength. Test results indicated that shear strength of sand is greater due to angle of friction. Hong-Fa Xu and Ji-Xiang Zhang 2020 [18] have analyzed the influence laws of parameters u and m on the pile soil system characteristics by written MATLAB program for the analytical model. And wrote the back-analysis method and steps of the pile-soil system characteristics were proposed. Accordingly analytical model. Parth Akbari and Hardik Patel [19] studied some research articles and made a review on pile foundation concealing with different soils, they did experiments on numbers of pile like 2, 3, 5, 6 and 9 piles together in triangular, square and rectangular group shapes. In The result declared the ultimate bearing capacity affected by different soils when piles concealing with different type of soils. Ghazi Abou El Hosn 2015 [20] did details thesis how to improve pile capacity and used hooks cast-in-place piles with and without hook system in soft clay and sand. And increased apparent adhesion from 19 KPA to 34 KPA by testing a series of pile-load tests at field cast-in-place in soft clay and sand for investigating the effect passive inclusion on pile bearing capacity. All the researchers did not work on pile foundation Concrete concealing/ Interface with different soils layers varying different moisture content (5, 15 and 25 Percent) like (Concrete interface with clay, Sand, Clay + lime, sand + lime) at ratio (1:1) respectively. This paper is based on Pile's Concrete interface with different soils layers in the presence of different moisture content.

1.3 EXPERIMENTAL APPARATUS, MATERIALS AND PROCEDURE

This paper is on the interface between Soils to pile foundation Concrete under varying moisture content at laboratory. in this research work selected are clay and sand, both of them has been collected from district Nowshera. Different cases have been selected which are described such as (1) Concrete interface with Clay at 5, 15 and 25 percent moisture content (2) Concrete interface with Sand at 5, 15 and 25 percent moisture content (3) Concrete interface with Sand + Clay mix (1:1) at 5, 15 and 25 percent moisture content and (4) Concrete interface with Clay + lime mix (1:1) at 5, 15 and 25 percent moisture content. Direct shear test apparatus is used in the laboratory on undisturbed soil specimen collected from field and consolidated undrained conditions will be applied during performing test under different moisture content and normal loads. As the shear strength at interface varies with moisture content, so under different moisture conditions results is compared for different cases in this research. Precast Concrete sample is tested against soil. The concrete specimen used in the direct shear test is having nearly smooth surface, however field conditions were not simulated. Disturbed soil samples were used in performing direct shear tests. Interface shear tests for concrete-sand/clay were tested under constant normal load.

Following tasks is done for achieving the above-mentioned objectives

- Clay, sand and lime (unheated, quick) samples are collected from tehsil Pabbi District Nowshera KPK Pakistan.
- Concrete (1:2:4) cast in steel boxes of 60mmx60mmx25mm for facing.
- Preparation of sample and precast Concrete specimen and testing against soil.
- Disturbed Soil samples are used during research work
- Direct shear strength test is conducted to evaluate the shear strength properties at interface between concrete-sand clay and concrete-clay lime mix in equal proportion, under different moisture contents at 5, 15, 25 %.
- Constant Normal loads are maintained during direct shear strength test

1.4 Materials used

1.4.1 Sand

Sand used in this research work was brought from district Nowshera and tests were being conducted as per ASTM standards such as (Basic Properties of Sand) Unit Weight of sand sample (natural moisture content), Specific gravity of sand using ASTM D 854-00, Voids ratio of Sand (under natural moisture content), Natural moisture/water content using ASTM-D2216-10, it was placed in oven for 24 hours. And then Index Properties of sand analyzed. For Gradation of sand (ASTM D 2487-00) test procedure method was applied for the gradation of sand. Relative density (Dr. %) test was performed to find out the relative density based on standard ASTM D 4254. before subjecting it for interface phenomena with concrete. The Index properties were found for the purpose of identification and classification after that Engineering properties were also sorted out. Sand is a frictional material and its interface with concrete is very important to be properly analyzed for calculating best results.

1.4.2 Clay

The clay was also collected from district Nowshera tehsil Pabbi which mostly expand so much when come in contact with water, the color is mostly red. All the tests were being conducted as per ASTM such as (Basic Properties of Clayey Soil) Natural moisture/water content using ASTM-D2216-10 standard, Unit Weight of soil sample under different moisture content, Specific gravity of soil solids under ASTM D 854-00 standard, and Voids ratio of soil in natural moisture content. For Index Properties of soil ASTM standard (ASTM D 2487-00) test procedure method was applied for the gradation of sand obtained from District Nowshera. And for Determination of Liquid limit (LL), Plastic limit (PL) and Plasticity index (PI), The Atterberg above limits were determined by using ASTM D4318-10, based on the moisture content of sample soil. in order to find the Index properties as well as engineering properties. The natural moisture content of the clay was also evaluated.

1.4.3 Lime

The lime was brought from District Nowshera which mostly came from marble industries located near to Attock Bridge.

1.4.4 Concrete

Sample of concrete was prepared according to ASTM C109 standard method. The ratio of the sample was 1:2:4 and the strength were 3000 psi for 28 days. The sand used in concrete mold preparation for tests was the same as used under consideration for interface shear strength that is Concrete-soil. Cement used in concrete was available in market while 3/8" down aggregates were also used for concrete mold preparation.

1.5 Procedure for small scale interface test

Sand specimen was first poured in the upper part of shear box; it comes in full contact to the concrete surface. The sand was then compacted in order to attain the same density with natural moisture content that is 5%. Screws of shear box was loosed in order to allow the shearing between sand, Concrete and normal vertical stress that was applied with help of U-frame. Initially the loading was applied on the sample, after sample placement and setting out of machinery, shear gauge (displacement/shear strain) and proving ring gauge (Shear stress measuring) device was fixed to a reading of zero. Both of the dial gauge readings were noted until maximum shear stress was attained. Same procedure was then followed for other loads under same moisture conditions. Shear stress was then plotted versus the shear displacement. And then shear stress was plotted versus vertical stress then the failure envelop was obtained by the help of Mohr's Coulomb Criteria. Now procedure was repeated for same sample of the sand with same density, but the moisture content was 15%, poured in shear box and test data was then plotted. Similar procedure was repeated for 25% moisture content, and the result curves was then plotted. Now after finding basic and index properties for clayey soil the curves were plotted for 5%, 15%, and 25% moisture contents with same procedure. Further modification was made by enhancing interface of Soil-Concrete, Clay was mixed with sand in (1:1) and clay with lime was also mixed in (1:1). Similar procedure was adopted by maintaining 5%, 15%, and 25% moisture content conditions.

1.6 Objective of the Study

The objectives of this study are to analyze interface shear strength at different moisture contents for the following combinations and to see the effects of lime and sand addition with clay. And for the future what to add for better shear strength with pile foundation concrete. Shear strength of the interface between different materials are:

- Pile Foundation's Concrete interface with Clay at 5, 15 and 25 percent moisture content.
- Pile Foundation's Concrete interface with Sand at 5, 15 and 25 percent moisture content.
- Pile Foundation's Concrete interface with Sand + Clay mix (1:1) at 5, 15 and 25 percent moisture content.
- Pile Foundation's Concrete interface with Clay + lime mix (1:1) at 5, 15 and 25 percent moisture content.

2. Methods and Materials

2.1 General

This section will cover the estimation of shear strength exists on the interface between Soils to Concrete under varying moisture content at laboratory, as this type of phenomena will simulate actual field conditions. Soils in this research work selected are clay and sand, both of them has been collected from district Nowshera. Different cases have been selected which are described below and shown in table 3.1:

Table 1: Nature of interface in direct shear tests.

Case no	Interface Nature
1	Concrete interface with Clay at 5, 15 and 25 percent moisture content.
2	Concrete interface with Sand at 5, 15 and 25 percent moisture content.
3	Concrete interface with Sand + Clay mix (1:1) at 5, 15 and 25 percent moisture content.
4	Concrete interface with Clay + lime mix (1:1) at 5, 15 and 25 percent moisture

Direct shear test apparatus will be used in the laboratory on undisturbed soil specimen collected from field and consolidated undrained conditions will be applied during performing test under different moisture content and normal loads. As the shear strength at interface varies with moisture content, so under different moisture conditions results will be compared for different cases in this research.

2.2 Limitations of the Research

Following are the limitations for research conducted:

- Precast Concrete sample will be tested against soil
- The concrete specimen used in the direct shear test is having nearly smooth surface, however field conditions were not simulated
- Disturbed soil samples were used in performing direct shear tests.
- Interface shear tests for concrete-sand/clay were tested under constant normal load.

2.3 Research Methodology

Following tasks are to be done for achieving the above-mentioned objectives.

- Clay, sand and lime (unheated, quick) samples are collected from tehsil Pabbi District Nowshera.
- Concrete (1:2:4) cast in steel boxes of 60mmx60mmx25mm for facing.
- Preparation of sample and precast Concrete specimen and testing against soil.
- Disturbed Soil samples are used during research work
- Direct shear strength test is conducted to evaluate the shear strength properties at interface between concrete-sand clay and concrete-clay lime mix in equal proportion, under different moisture contents at 5, 15, 25 %.
- Constant Normal loads are maintained during direct shear strength test

2.4 Materials used

2.4.1 Clay

The clay was also collected from district Nowshera tehsil Pabbi which mostly expand so much when come in contact with water, the color is mostly red. All the tests were being conducted as per ASTM in order to find the Index properties as well as engineering properties. The natural moisture content of the clay was also evaluated. Basic properties of clay are:

2.4.2 Natural moisture/water content

For determination of the in-situ moisture content the following ASTM-D2216-10 standard test method was applied, weight of the sample was determined first and then it was placed in oven for 24 hours in order to make to it completely dry. Following calculations were used in order to find the dry weight of sand.

Procedure:

- The container should be clean and dry its weighs is (W1). "After the balance was tarred"
- Take specimen of sample in container and weight it with lid (W2).

- Keeps container in oven with lid being removed. Make the specimen dry to a constant weight by maintaining the temperature in between 105 ºC to 110 ºC for period varying from 16 to 24 hours.
- Record final reading that is constant weight (W3) of container with dried sample of the soil.

$$W (\%) = W_2\text{-}W_3 / W_3\text{-}W_1 * 100 \quad ... (2.1)$$

2.4.3 Unit Weight of soil sample under different moisture content

For evaluation of the unit weight of soil sample under consideration, it was placed in a sampler and it was graduated for taking its weight. Then measured weight was divided by the volume of sample. The required value for unit weight was then noted.

Procedure

- Make drying of the Pycnometer and weigh it combinedly with cap (W1).
- Take 200 to 300 g of oven dry soil that is passing through the 4.75mm sieve into Pycnometer with weighing it again as (W2).
- Add some amount of water in order to cover the soil.
- Pycnometer should be shake well and connect it with the vacuum pump in order to remove the entrapped air. 10 to 20 minutes are required for this process.
- After removal of air, fill Pycnometer with the water and weigh it as (W3).
- Clean the Pycnometer with water thoroughly.
- Cleaned Pycnometer should be filled completely with the water up to the top with a cap on screw.
- Weight Pycnometer after making it dries thoroughly (W4).
- The Specific gravity of the soil solids (Gs) are calculated by using following equation.

$$G_s = (W2 – W1) / [(W4–1) \text{-}(W3\text{-}W2)] \quad .... (2.2)$$

2.4.4 Voids ratio of soil in natural moisture content

The voids ratio (e) is defined as, ratio between volumes of voids to the volume of solids. Numerically; e = Vv / Vs: Vv = Volume of Voids, Vs = Volume of soil solids, it is generally abbreviated (Dimensionless) and expressed in number.

2.3.5 Gradation of soil

ASTM standard (ASTM D 2487-00) test procedure method was applied for the gradation of sand obtained from District Nowshera. The sample of sand was first oven dried and 500 gram of sample was then taken. The sand sample was placed in a series of different sieve sizes and shake properly by shaking machine. The retained weight on all sieves was measured and the accumulative mass for each sieve was measured. Then graph was then plotted by writing mesh size at x-axis and percent finer on y-axis. co-efficient of curvature, Uniformity co-efficient and the effective sizes D10, D30, D60 were then evaluated from resulting curve.

2.4.6 Determination of Liquid limit, Plastic limit and Plasticity index

The Atterberg limits are: Liquid limit (LL), Plastic limit (P), Plastic index (PI). The mentioned limits were determined by using ASTM D4318-10, based on the moisture content of sample soil. The water content on which it changes from semi solid state to plastic state and the specific water content on which it changes from plastic to viscid condition is called as liquid limit. Following are the equipment used in laboratory. Casagrande apparatus/liquid limit tool, grooving tool, moisture cans, weighting balance, spatula, washed flask filled with purified water, oven and glass plate. Soil sample was then oven dried on 105°C and then passed on sieve #40. 200 gram of soil sample was taken and a small amount of the distilled water was then added to soil sample and mixed thoroughly. Portion of the mixed soil was then placed in Casagrande apparatus and surface became leveled with the help of a spatula. Soil surface was then leveled in such fashion that lower surface become in same height to the lower edge of cup. Cut was made on the center of soil sample with a grooving tool. The crank of the tool was turn on and the blows was given to sample in such a manner so that 2 blows per second were given under two halves should touch each other along the distance of 13mm (1/2 in). Number of the blows was noted down as N-1. The soil sample was then placed in the cane and dried in oven for 16 hours, moisture content in some amount was added and number of blows that touching the groove decreased from a range of 25-35, in another trail for 20-30 and for 15-25 was also executed. We obtained 4 reading of blows that are Na, Nb, Nc, Nd also we get 4 moisture contents Wa, Wb, Wc, and Wd, a graphical relation was plotted between water content and number of blows. The point plotted on y-axis was corresponding to the 25 numbers of blows and was noted that will gives us liquid limit for the soil sample, 50 gram of the soil specimen was then measured and the distilled water was mixed into the soil sample so that it will roll without sticking to the hand. After thoroughly mixing water to the soil, a piece of the soil was taken in hands and transformed into elliptical shape with the help of fingers. The elliptical shape was then converted into uniform threads with the help of applying sufficient pressure. The thread was rolled in backward and forward movement so that thread of soil gets converted into a 3mm diameter thread, then it crumbled into pieces. The crumbled portions were united and same process was continued till thread gather into pieces and no longer crumbled. Now the gathered pieces were collected into moisture can and then it was placed in oven for 16 hours at 105°C, performing this experiment it was continued for 3 trials and then the average moisture content was noted as

P.L of the soil sample. Plasticity index was calculated by using formula: Plasticity index = liquid limit – plastic limit

2.5 Sand

Sand used in this research work was brought from district Nowshera and tests were being conducted as per ASTM standards before subjecting it for interface phenomena with concrete. The Index properties were found for the purpose of identification and classification after that Engineering properties were also sorted out. Sand is a frictional material and its interface with concrete is very important to be properly analyzed for calculating best results. Basic properties of sand are:

2.5.1 Unit Weight of sand sample (natural moisture content)

In order to evaluate the unit weight for the sand sample under consideration, it was placed in a sampler and then it was graduated taking its weight. The measured weight was then divided by the volume of sample and then the required value of its unit weight was note down for further necessary procedure.

2.5.2 Specific gravity of sand

In order to find the specific gravity of sand sample it can be evaluated with the help of a test that use Pycnometer device. It can be defined as the ratio of unit weight of a soil at specific temperature to the weight of equivalent volume filled with distilled water at that specified temperature. Following steps was carried out in order to determine the specific gravity of sand by using ASTM D 854-00 which is the standard procedure for determination of the specific gravity.

2.5.3 Voids ratio of Sand (under natural moisture content)

The voids ratio (e) is defined as, ratio between volumes of voids to the volume of solids. Numerically $e = V_v / V_s$, V_v = Volume of Voids, V_s = Volume of soil solids, it is generally abbreviated (Dimensionless).

2.5.4 Natural moisture/water content

For determination of the in-situ moisture content the following ASTM-D2216-10 standard test method was applied, weight of the sample was determined first and then it was placed in oven for 24 hours in order to make to it completely dry. Following calculations were used in order to find the dry weight of sand.

2.5.5 Gradation of sand

ASTM standard (ASTM D 2487-00) test procedure method was applied for the gradation of sand obtained from District Nowshera. The sample of sand was first oven dried and 400 gram of sample was then taken. The sand sample was placed in a series of different sieve sizes and shake properly by shaking machine. The retained weight on all sieves was measured and the accumulative mass for each sieve was measured. Then graph was then plotted by writing mesh size at x-axis and percent finer on y-axis. Co-efficient of curvature, Uniformity co-efficient and the effective sizes D10, D30, D60 were then evaluated from resulting curve.

2.4.6 Relative density (Dr. %)

This test was performed to find out the relative density based on standard ASTM D 4254.Mold was filled with sand as loosely as possible. The mass of sand and mold was determined as and noted as M1. The guide sleeves were attached with mold, and additional weight was lowered on base plate after which vibration of 8 minutes duration was given to the assembly, following by taking the final reading Rf. using the same procedure in previous step. The mass was determined as M2.The size of mold is measured to have the dimensions of mold, i.e., height and diameter of mold, so that volume was calculated as Vc and also, thickness of the base plate used as surcharge, Tp was carried out, So that Ms1= mass of dry sand = (mass of loose sand + mold) – (mass of mold), Vc= Calibrated volume of mold, Ms2 = mass of dry sand = (mass of sand after vibration) – (mass of mold), V = Dry sand volume = Vc – (Ac * H), Ac = cross sectional area of mold after calibration.

2.6 Lime

The lime was bought from District Nowshera which mostly came from marble industries located near to Attock Bridge.

2.7 Concrete

Sample of concrete was prepared according to ASTM C109 standard method. The ratio of the sample was 1:2:4 and the strength were 3000 psi for 28 days. The sand used in concrete mold preparation for tests was the same as used under consideration for interface shear strength that is Concrete-soil. Cement used in concrete was available in market 3/8" down aggregates were also used for concrete mold preparation.

2.8 Concrete sample preparation

A sample of concrete was prepared by using standard technique ASTM C109, which is Standard test procedure for the compressive strength of the hydraulic cement mortars.

Procedure:

- For preparing Concrete mortar specimen mixing was made on 1:2:4 ratios. 1 part of cement and 2 parts of sand was mixed with 4 parts of the crushed aggregate collected.

- Spatula was used to level the concrete surface the concrete was then placed into wooden mold whose size is equal to the half portion of direct shear box that is square in size of 6cm x 6cm x 1cm.
- After concrete casting proper curing was made for the sample that is 28 days in order to achieve its complete strength. After completing curing period Sample was collected and made air dried for 24 hours.
- The said sample was handled carefully so that its sides should not get rough so much in order to perform direct shear test on it.

2.9 Procedure for small scale interface test

Sand specimen was first poured in the upper part of shear box; it comes in full contact to the concrete surface. The sand was then compacted in order to attain the same density with natural moisture content that is 5%. Screws of shear box was loosed in order to allow the shearing between sand, Concrete and normal vertical stress that was applied with help of U-frame. Initially the loading was applied on the sample, after sample placement and setting out of machinery, shear gauge (displacement/shear strain) and proving ring gauge (Shear stress measuring) device was fixed to a reading of zero. Both of the dial gauge readings were noted until maximum shear stress was attained. Same procedure was then followed for other loads under same moisture conditions. Shear stress was then plotted versus the shear displacement. And then shear stress was plotted versus vertical stress then the failure envelop was obtained by the help of Mohr's Coulomb Criteria. Now procedure was repeated for same sample of the sand with same density, but the moisture content was 15%, poured in shear box and test data was then plotted. Similar procedure was repeated for 25% moisture content, and the result curves was then plotted. Now after finding basic and index properties for clayey soil the curves were plotted for 5%, 15%, and 25% moisture contents with same procedure. Further modification was made by enhancing interface of Soil-Concrete, Clay was mixed with sand in (1:1) and clay with lime was also mixed in (1:1). Similar procedure was adopted by maintaining 5%, 15%, and 25% moisture content conditions.

3. Results and Analysis

3.1 Clay – Concrete interface Shear strength

Shear strength determination is carried out in the laboratory direct shear test apparatus for the clay – concrete interface in different moisture contents. These moisture contents are zero, 5, 15 and 25 %. The consistency is found to be soft. Results are shown in figures 3.1, 3.2 and 3.3. They show that the shear strength of this clay is dependent on the moisture content. It is maximum for dry state but decreases with increase in moisture content. the shear strength is maximum for dry soil when the normal stress is more than 40kPa but wet clay at 25% moisture content dominates this resistance below 40kPa of normal stress due to sticking.

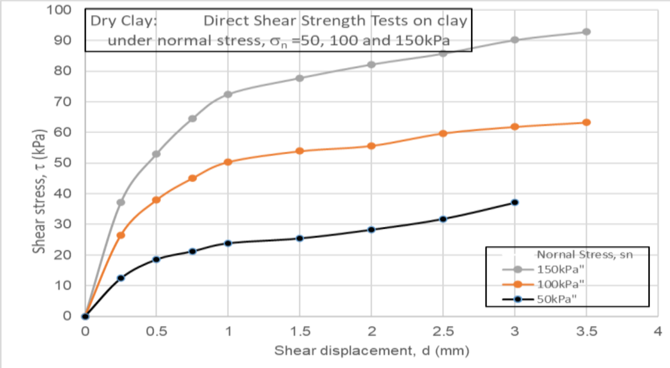

Figure 3.1: Shear stress v/s shear displacement of clay-Concrete interface at 0% moisture content

The maximum of the shear stresses is plotted against normal stress to determine the shear strength parameters of the pure clay in dry state. This is shown in figure 4.2. Since it is normally consolidated, therefore, its shear strength at zero normal stress is zero, which is cohesion intercept is absent.

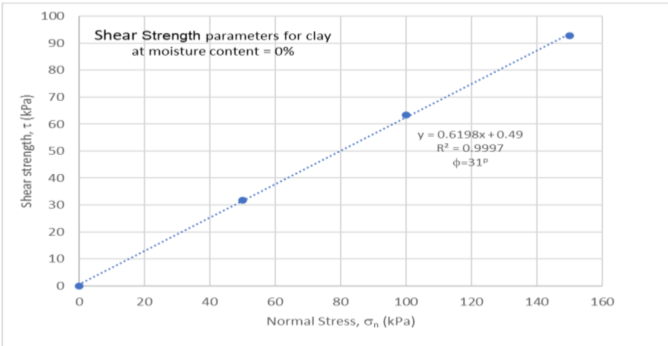

Figure 3.2: Shear strength parameters of clay-Concrete interface at 0% moisture content

The rest of the shear strengths under 5, 15 and 25 % of moisture contents are shown in figures 3.3 and 3.4.

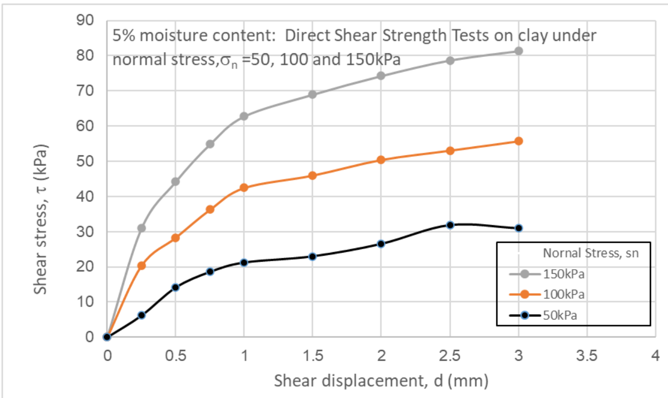

Figure 3.3: Shear stress v/s shear displacement of clay-Concrete interface at 5% moisture content

It can be seen from figure 3.4 that some cohesion develops with moisture content.

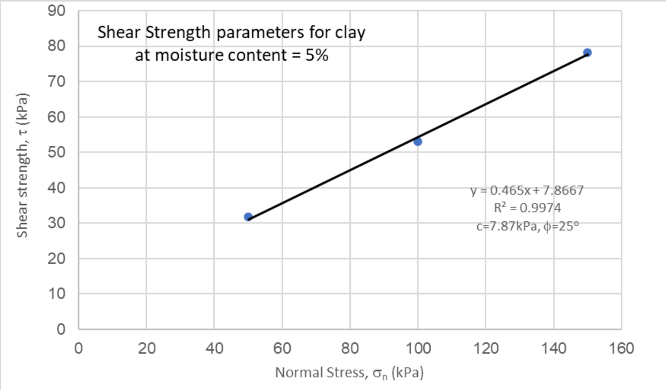

Figure 3.4: Shear strength parameters of clay-Concrete interface at 5% moisture content

With 5% moisture content, the shear strength parameters of the clay are that cohesion, c is 7.87kPa and angle of internal friction, ▯ is reduced to 25o, 15% moisture content behavior of clay in direct shear test is shown in figures 4.5 and 4.6.

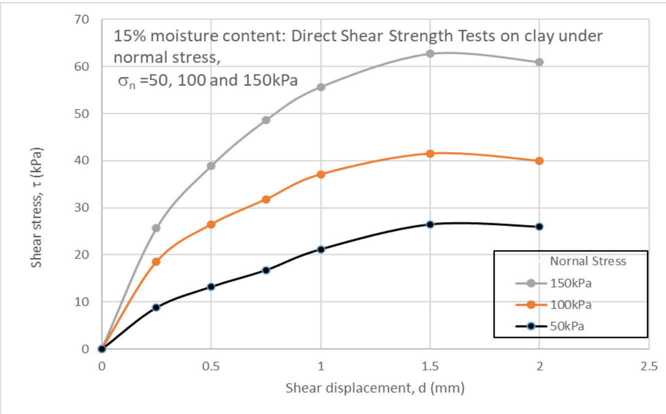

Figure 3.5: Shear stress v/s shear displacement of clay-Concrete interface at 15% moisture content

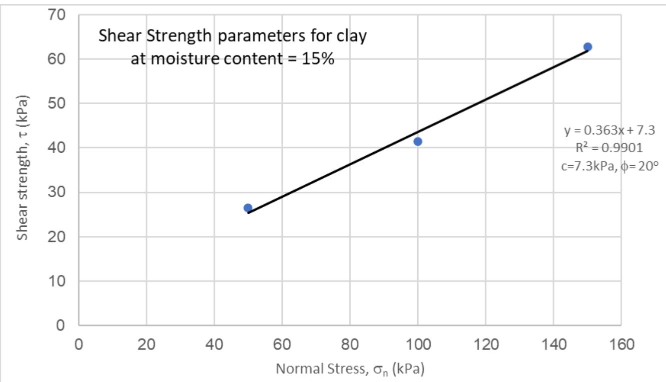

Figure 3.6: Shear strength parameters of clay-Concrete interface at 15% moisture content

The new cohesion, c is 7.3 kPa and the angle of internal friction of moist clay is reduced to 20o. 25% moisture content engineering behavior of the clay is shown in figures 3.7 and in figure 3.8.

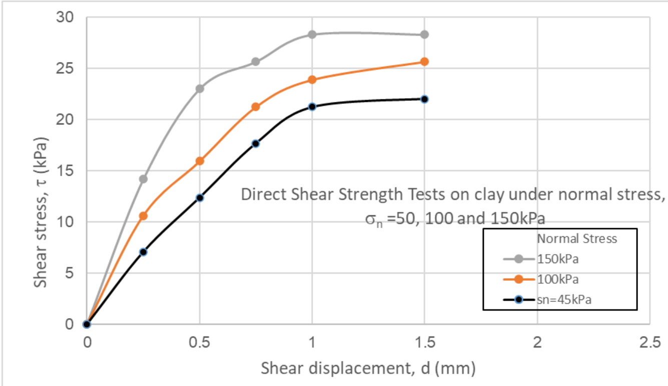

Figure 3.7: Shear stress v/s shear displacement of clay-Concrete interface at 25% moisture content

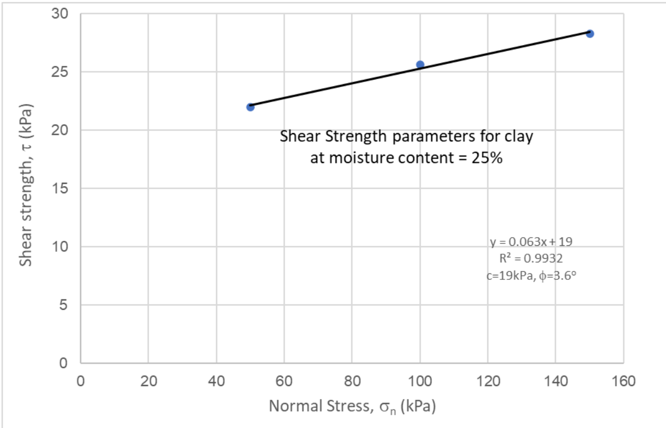

Figure 3.8: Shear strength parameters of clay-Concrete interface at 25% moisture content

From the observation of figures 3.7 and 3.8, it is seen that increase in moisture content drastically changes the shear strength behavior of clay. Cohesion, c increases to 19kPa and angle of internal friction reduces to 3.6o. The overall shear behavior of clay with moisture content is accumulated in figure 3.9.

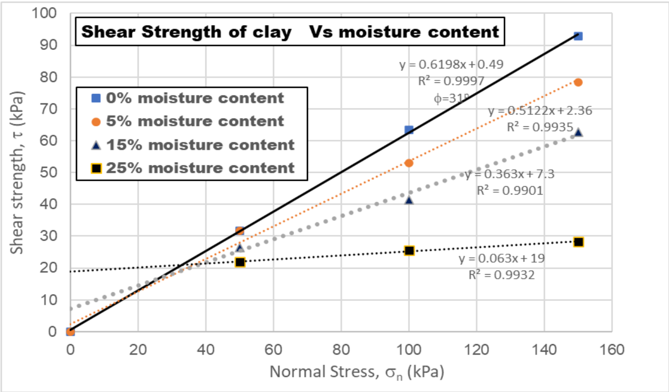

Figure 3.9: Combine Effect of moisture content on shear strength parameters of clay-concrete interface

3.2 Direct Shear test results for soil-concrete interface

Interface test for shear strength on small scale was conducted for concrete-soil interface in soil mechanics laboratory at GSK Consultants Peshawar, by using the Direct Shear test apparatus a Pre- cast concrete sample was placed on lower half portion and soil was also placed above concrete specimen. Soil was also compacted to same density by introducing full contact with the concrete interface. Tests was performed on 5%, 15%, and 25% moisture content, by application of different normal stresses we got different Results from series of tests conducted, resulting shear strength at different moisture contents and normal stresses as shown in Figure given below. Graphs showed that as shear stress increases, the shear deformation (z) also increases until a maximum shear stress value is reached. Reaching the ultimate stress, the shear strain also increases at a constant shear stress and straight portion of the line is obtained beyond this point. Results also show that there is decrease in the shear strength of interface as moisture content (%) is increased, Soils include clay, sand, clay-sand mix, clay-lime mix. The interface of concrete was tested with these mentioned soils.

3.3 Sand – concrete interface Shear strength

For the determination of shear strength properties of the interface, direct shear test apparatus is used in the laboratory. Four moisture conditions of zero, 5, 15 and 25% are selected too, like clay in the previous section, as shown in figures 3.1 to 3.9. The state of packing is loose as can be seen from the shear stress vs shear displacement data and plots.

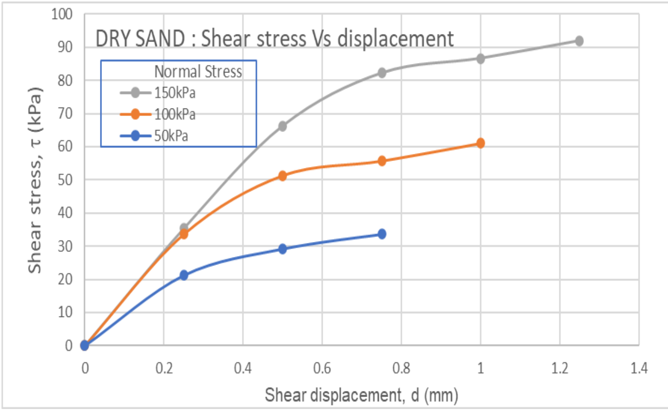

Figure 3.10: Shear stress v/s shear displacement of sand-Concrete interface at 0% moisture content

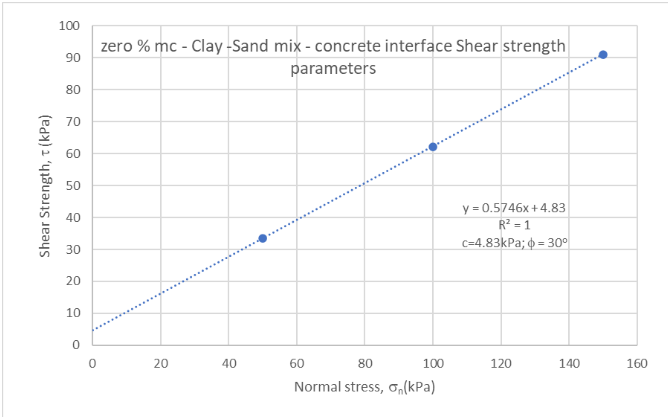

Figure 3.11: Shear strength parameters of clay, sand mix-Concrete interface at 0% moisture content

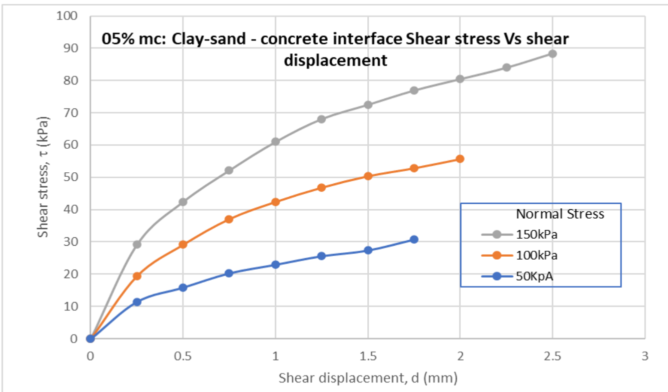

Figure 3.12: Shear stress v/s shear displacement of clay, sand mix-Concrete at 5% moisture content

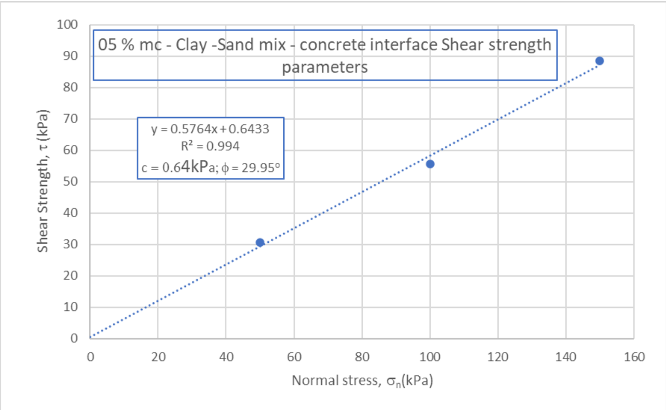

Figure - 3.13: Shear strength parameters of clay, sand mix-Concrete interface at 5% moisture content

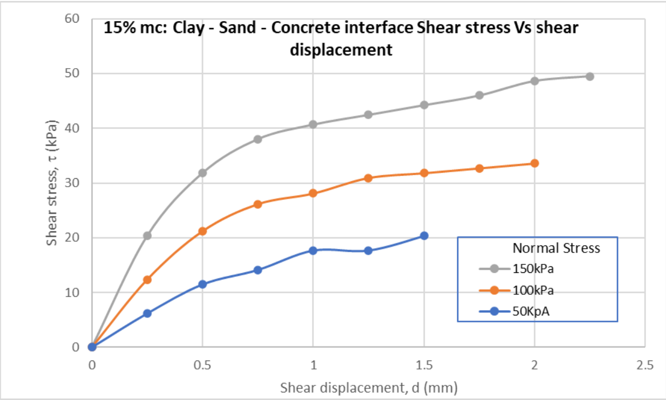

Figure 3.14: Shear stress v/s shear displacement of clay, sand mix-Concrete at 15% moisture content

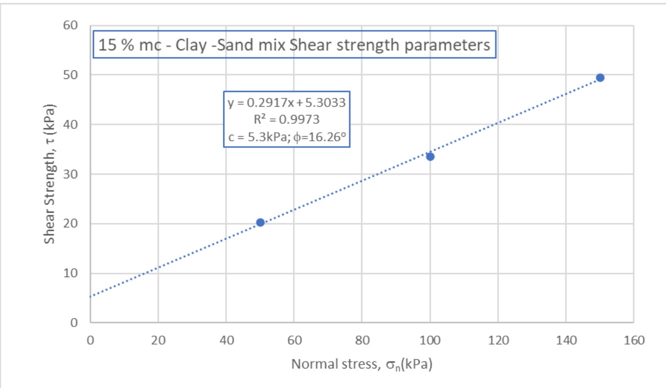

Figure 3.15: Shear strength parameters of clay, sand mix-Concrete interface at 15% moisture content

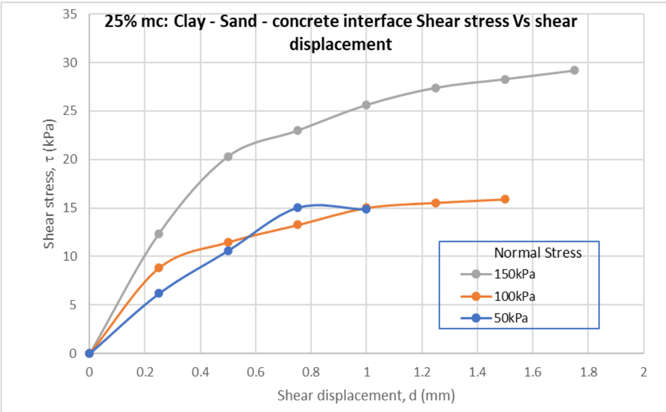

Figure 3.16: Shear stress v/s shear displacement of clay, sand mix-Concrete at 25% moisture content

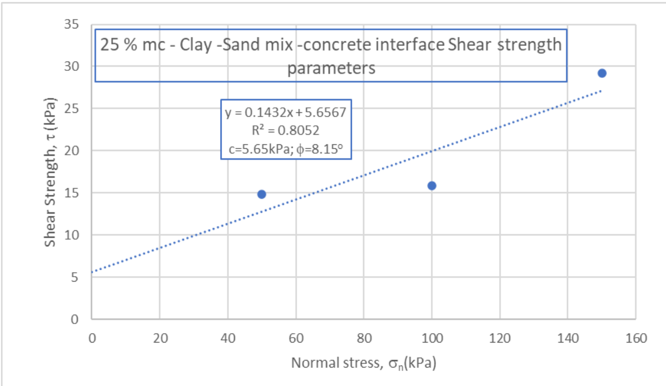

Figure 3.17: Shear strength parameters of clay, sand mix-Concrete interface at 25% moisture content

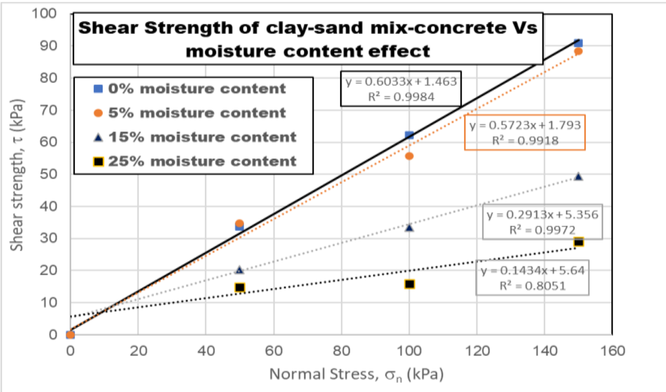

Figure 3.18: Combine Effect of moisture content on shear strength parameters of clay, sand mix-concrete

From the figure that shows the combined results of the tests, it is seen that the effect of moisture content on the shear strength of the interface between the clay-sand-concrete is large beyond 05%. This strength drastically decreases when the moisture content is more than 05% due to the reduction of frictional properties of the system of clay-sand-concrete. It widens as the normal stress increases seen in the figure

3.4 Clay – Lime – Concrete interface shear strength properties

As Clay-lime Mix interface was tested through direct shear test apparatus under different moisture contents and graphs has been plotted for different moisture conditions. Following below results has been made:

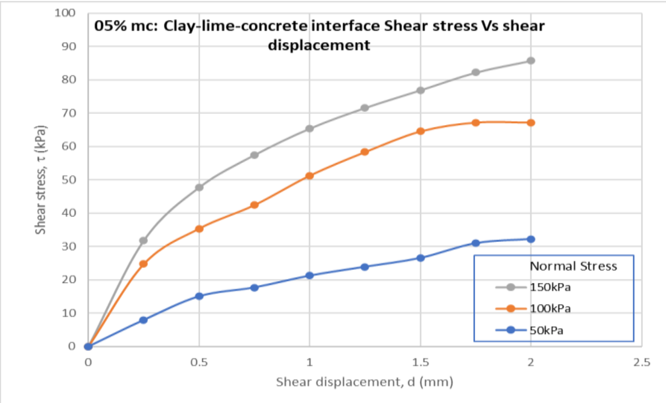

Figure 3.19: Shear stress v/s shear displacement of clay, lime mix-Concrete at 5% moisture content

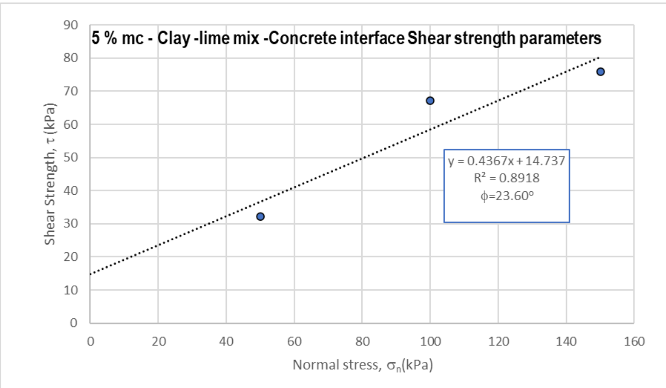

Figure 3.20: Shear strength parameters of clay, lime mix-Concrete interface at 5% moisture content

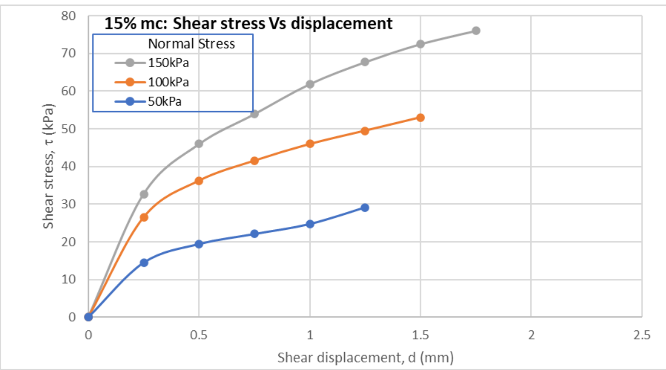

Figure 3.21: Shear stress v/s shear displacement of clay, lime mix-Concrete at 15% moisture content

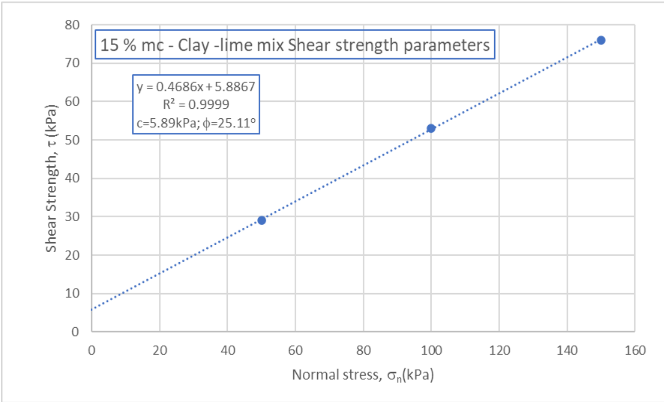

Figure 3.22: Shear strength parameters of clay, lime mix-Concrete interface at 15% moisture content

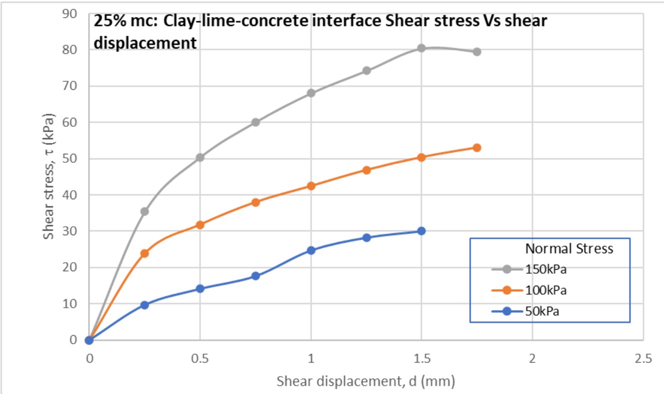

Figure 3.23: Shear stress v/s shear displacement of clay, lime mix-Concrete at 25% moisture content

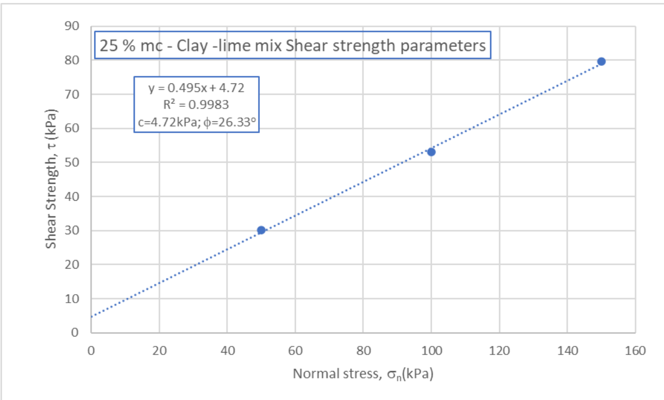

Figure 3.24: Shear strength parameters of clay, lime mix-Concrete interface at 25% moisture content

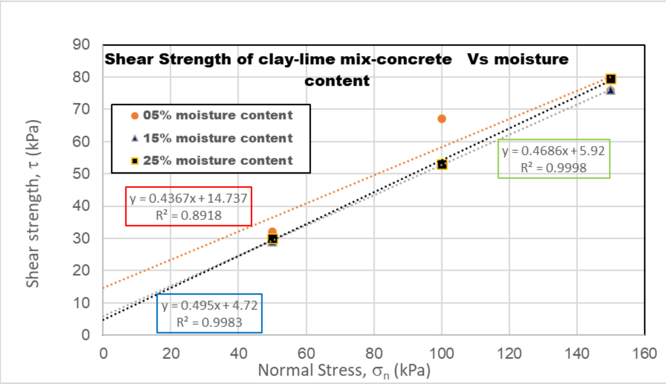

Figure 3.25: Combine Effect of moisture content on shear strength parameters of clay, lime mix-concrete interface in direct shear test results.

3.6 Comparison and discussion on different interface shear Strength results

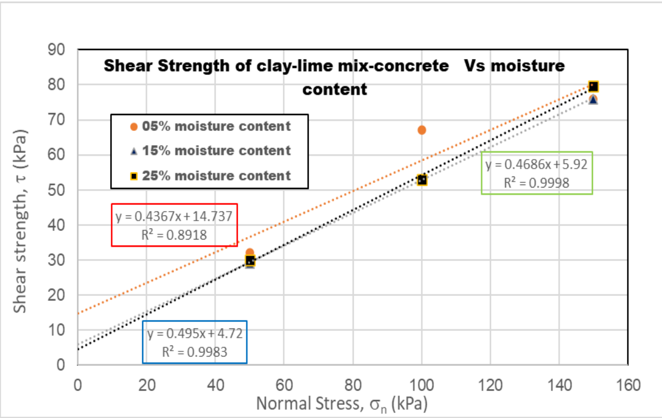

Figure 3.26: Combine interface Shear strength parameters for clay, lime mix v/s concrete at different % age of Moisture contents

The combined plot of the effect of the moisture content on the shear strength shows that there is little bearing of moisture content on the shear strength behavior of the clay-lime- concrete interface. However, a slight increase in the angle of internal resistance of the system can be seen with increase in moisture content which might be due to reaction with clay exchange ions, cation exchange capacity (CEC) – sodium ion (Na+) being replaced by calcium (Ca+). According to Bell (1996), clay soil can be stabilized by the addition of small percentages, by weight, of lime, thereby enhancing many of the engineering properties of the soil and producing an improved construction material.

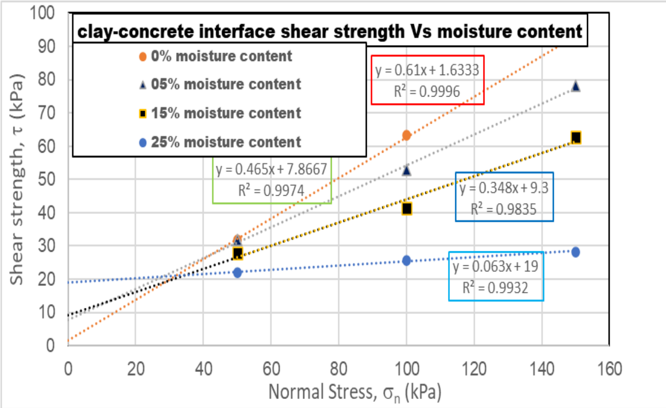

Figure 3.27: Interface Shear strength parameters for clay v/s concrete at different % age of Moisture contents

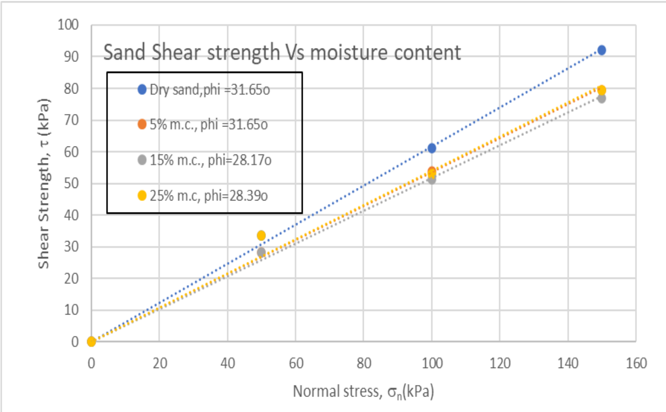

Figure 3.28: Interface Shear strength parameters for sand v/s concrete at different % age of Moisture contents

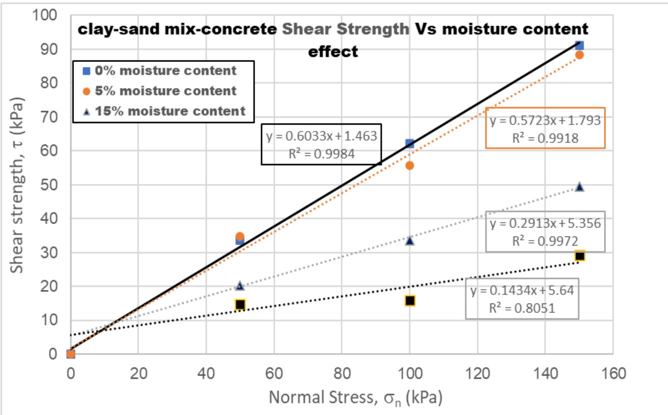

Figure 3.29: Interface Shear strength parameters for sand, clay mix v/s concrete at different % age of Moisture contents

The overall scenario of the effect of moisture content on the shear strength of the interface is collectively shown in table 3.1 The interface between the sand and concrete is seen to give good results provided that it is not tarnished by clay.

When a trace of clay is found in sand from any means reduces the skin friction efficiency of the system.

Table 3.1: Effect of moisture content on the shear strength of each interface.

Moisture content- M.C. (%)	Mohr – Coulomb, $\tau = c + \sigma_n \tan\phi$, Shear strength parameters (c kPa, ϕ^o) Interface in direct shear tests – Concrete vs Different soil type.							
	Clay		Sand		Clay - sand		Clay-lime	
	c (kPa)	ϕ^o	c (kPa)	ϕ^o	c (kPa)	ϕ^o	c (kPa)	ϕ^o
0	1.63	31.4^o	0	31.7	1.46	31.1		
5	7.87	25	0	28.4	1.8	30.8	14.74	23.59
15	9.30	19	0	27.3	5.4	16.24	5.92	26.33
25	19.00	3.6	0	28.4	5.6	8.16	4.72	25

4. Summary

This research work was carried for evaluating results of interface shear strength between Concrete-soil interfaces under different moisture content conditions through experimental observations, for this purpose the Concrete interface was tested against clay, sand, clay and sand mix, plus clay and lime mix. Experimental work was carried out on small scale “Interface shear test apparatus” at laboratory. Concrete surface was smooth despite occasional irregularities and constant normal loadings were applied. Clay properties were founded first and then it was subjected to interface test on small scale with concrete. Similar procedure for sand and Blends of soil (Clay-sand mix and clay-lime) was carried out for interface testing with concrete.

5. Conclusions and Recommendations for future work

Following conclusions are made from this research study

1. Shear resistance of the interface between sand and concrete is maximum and variation in moisture content is not effective

2. The interface resistance between the concrete and clay is heavily moisture dependent; maximum for dry state and minimum for 25% moisture content due to which frictional properties are almost lost with increase in moisture content. The cohesion at 25% moisture content is maximum but creep type of behavior leads to maximum settlement.

3. The sand-clay-concrete interface behavior is controlled by both clay content and moisture content. Increase in both decreases shear resistance. In case of piling, the smear effect of clay going down to mix with sand deteriorated frictional properties. But if sand goes down to mix with clay, increases frictional properties of clay with concrete pile surface.

4. Clay-lime-concrete interface shear strength is little affected; however, frictional properties are enhanced but not very much.

Recommendations for future work

Following recommendations are suggested for future work in this specific area

1. Clay mix should be carried out with fly ash, Cement, in order to analyze interface shear strength behavior with concrete sample.

2. Sand mix should be carried out with fly ash, Cement, and bitumen in order to analyze interface shear strength behavior with concrete sample.

3. Different moisture conditions are suggested for interface shear strength phenomena other then used in this research work.

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