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PREDICTION OF UNCONFINED COMPRESSIVE STRENGTH FROM INDEX PROPERTIES OF SOILS

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ABSTRACT: *Experimentation is very important to determine the engineering properties of soils in Geotechnical Engineering. Special expertise and care are required to perform these tests. The unconfined compression test is also one of them. Thus, there is a need to develop models to quickly predict the unconfined compression test of soils. The authors made an attempt to develop correlations to predict the unconfined compressive strength from index properties of soils, which are easier and quicker to determine. Samples were collected from different areas of Pakistan. All the basic tests and unconfined compression test were performed on soil samples as per ASTM standards. According to USCS soil samples were classified as CL, ML, CH and CL-ML. The unconfined compression strength of these soil samples was in the range of 16-495 KN/m^2. Finally, relationships were drawn between unconfined compressive strength and index properties of soil. Best possible prediction models were developed using a statistical approach. Validity of developed models is also checked on a separate set of soil samples. Developed models predicted the unconfined compressive strength of soil with very less deviation from experimental results.*

KEY WORDS: Unconfined Compression Test, Index Properties, Prediction Models

INTRODUCTION

Infrastructure plays an important role in the development of any country. It includes roads, highways, buildings and all other civil structures. The characteristics of ground on which all these structures are build very important to determine. To evaluate the strength of soil unconfined compression test is widely used. The unconfined compressive strength of soil is a load per unit area at which an unconfined cylindrical specimen of soil will fail in the simple compression test. This test requires time, precision and expertise. UCS test gives the shear strength of the soil that is useful parameters for computing Safe bearing Capacity of soil as well as strength of soil. In comparison to parameters evaluated by UCS tests, index properties of soils such as moisture content, Atterberg's limit, soil particle distribution and compaction characteristics are easier, quicker and economical to determine [1]. To quickly characterize the strength parameters there is need to identify the quickest methods to determine these parameters. One very famous method to quickly characterize such parameters is to develop models correlating them with quickly characterized parameters such as index properties of soils. Such prediction models are very rare for unconfined compressive strength of soils. For the quick prediction of unconfined compression strength of soils there is need of development of prediction models. This study is an attempt towards this direction

EXPERIMENTAL INVESTIGATION

To develop valid correlations proper testing program was adopted. Soil samples were acquired from various places in Pakistan. Total 85 undisturbedsoil samples were collected. Special care was carried out to preserve the natural moisture content and density of soil samples. Figure 1 shows the map of soil sample collection. All the basic soil tests like natural moisture content determination, grain size distribution analysis and Atterberg's limit tests were performed in accordance with ASTM standards [2-6]. After performing basic tests soil classification and index properties of soil samples were determined. The unconfined compression test was then performed to evaluate the unconfined compression strength of soil samples [6,7].

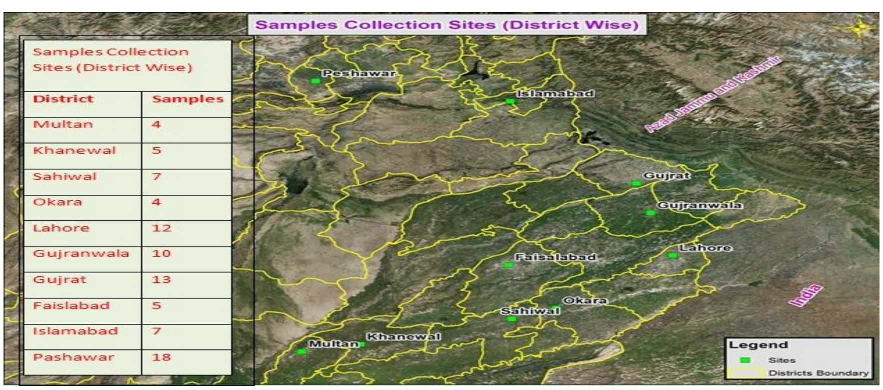

Figure 1: Soil Sample Collection Map.

TEST RESULTS AND DISCUSSION

All the tests were performed as per ASTM standards. Summary of all test results are presented in table 1.on the basis of test results following observations were made:

1. Particle size distribution analysis results showed that among all soil samples gravel was varying from 0-38%, sand 0-48%, silt 40-78% and clay 8-46 %.
2. Based on Atterberg's limit test it was observed that Liquid limit was varying from 19 to 56 % and plasticity index was in range none plastic to 28%.
3. All Soil samples were classified as fine grained soil as per USCS. Among 85 soil samples it was observed that there were 51 samples of CL, 18 ML, 13 CL-ML and 3 samples of CH nature [5].
4. Specific gravity of all soil samples was in range of 2.63 to 2.79.
5. Natural moisture content of soil samples was observed to be in range of 16 to 24.4%.
6. Natural dry unit weight was determined to be in range of 13.5 to 22.5 KN/ m^3.
7. Series of unconfined compression test was then performed to observe the unconfined compression strength of soil samples. Unconfined compression strength of soil samples was found in range of 16-495 KN/ m^2.

Table 1: Summary of test results

Classification Symbols	**No. of Samples**	**Grain Size Distribution**				**LL**	**PI**	**G_s**	**Natural Moisture Content**	**Natural Bulk Unit Weight**	**Natural Dry Unit Weight**	**Unconfined Compressive Strength**
USCS		**Gravel (%)**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**(%)**	**(%)**		**w_n (%)**	**γ_{bn} (KN/m^3)**	**γ_{dn} (KN/m^3)**	**q_u (KN/m^2)**
CL	51	0-28	1-37	42-78	15-35	22-45	8.0-21	2.63-2.79	5.8-28.4	16.6-24.4	14-22.5	16-490
ML	18	0-26	1-48	46-76	8-22	19-40	N.P-19	2.66-2.75	1.1-21.7	17-24	14-22.5	35-495
CL-ML	13	0-38	2-12	40-71	15-25	25-35	4-7	2.63-2.77	7.5-28.5	16-22	13.5-19	19-230
CH	3	0-3	0-4	49-54	44-46	50-56	26-28	2.65-2.73	15.5-26	19.7-20.8	15.5-18	56-190
Overall Range	*85*	*0-38*	*0-48*	*40-78*	*8-46*	*19-56*	*N.P-28*	*2.63-2.79*	*1.1-28.5*	*16-24.4*	*13.5-22.5*	*16-495*

DATA ANALYSIS AND MODEL DEVELOPMENT

To develop valid prediction models relationships were drawn between unconfined compression strength and index properties of soils. These index properties like moisture content, liquid limit, bulk density and particle size distribution are easier and quicker to determine. Keeping this in view relationships was drawn between unconfined compression strength and the formerly mentioned index properties of soil. The health of relationships drawn was checked based on R^2 value as it is better indicator to check the health of any correlation.

When the relationship was drawn between unconfined compressive strength and Liquid limit large scatter in data point was observed. R^2 value 0.021 indicates very poor strength of relationship as shown in figure 2 (a.). Similarly the relationship between Soil particle sizes and unconfined compressive strength showed higher scattering of data points. R^2 value for the relationship between percentage of sand particles and unconfined compressive strength is as low as 0.089 while similar trend was observed in case of fine particles passing sieve no 200 (F_{200}), R^2 value was 0.036 in this case as shown in figure 3 (a,b). In case of relationship between moisture content and unconfined compressive strength less scattering of data was observed as shown in figure 2 (b.). Similar trend was followed by the relationship between unconfined compressive strength and dry unit weight of soil as shown in figure 4 (a,b). R^2 value of 0.64 and 0.86 for moisture content and dry unit weight respectively showed strong relationships.

While observing relationships between different engineering properties and unconfined compressive strength of soil it was observed that predictive models can be developed using moisture content and dry unit weight of soils.

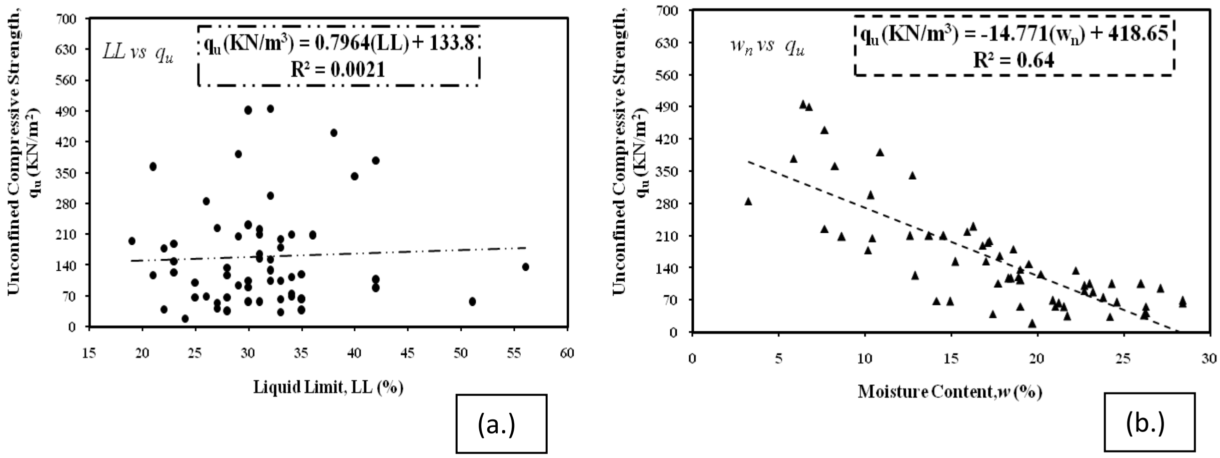

Figure 2: Relationship between unconfined compression strength, (a.) liquid limit and (b.) moisture content

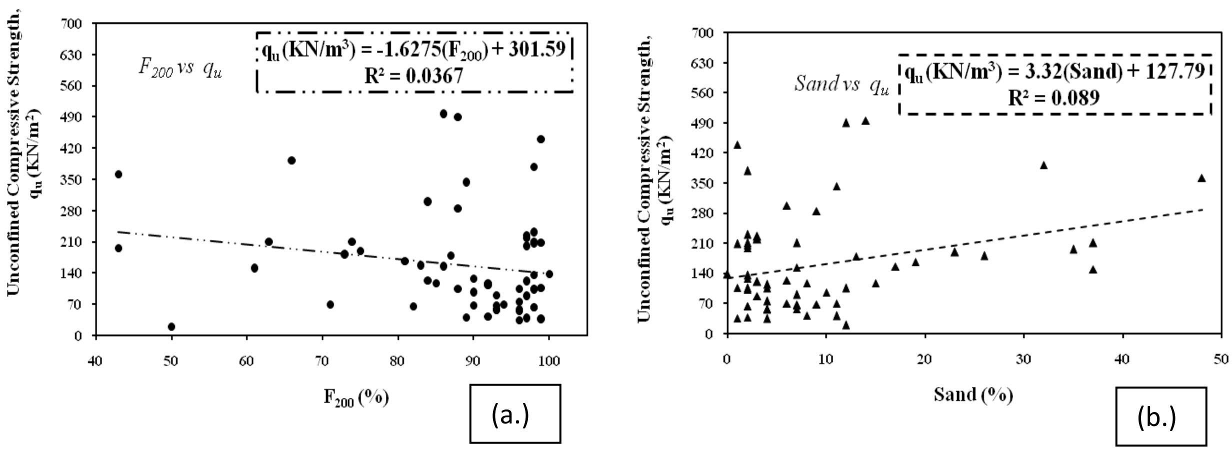

Figure 3: Relationship between unconfined compression strength, (a.) Fines (F_{200}, %) and (b.) Sand (%)

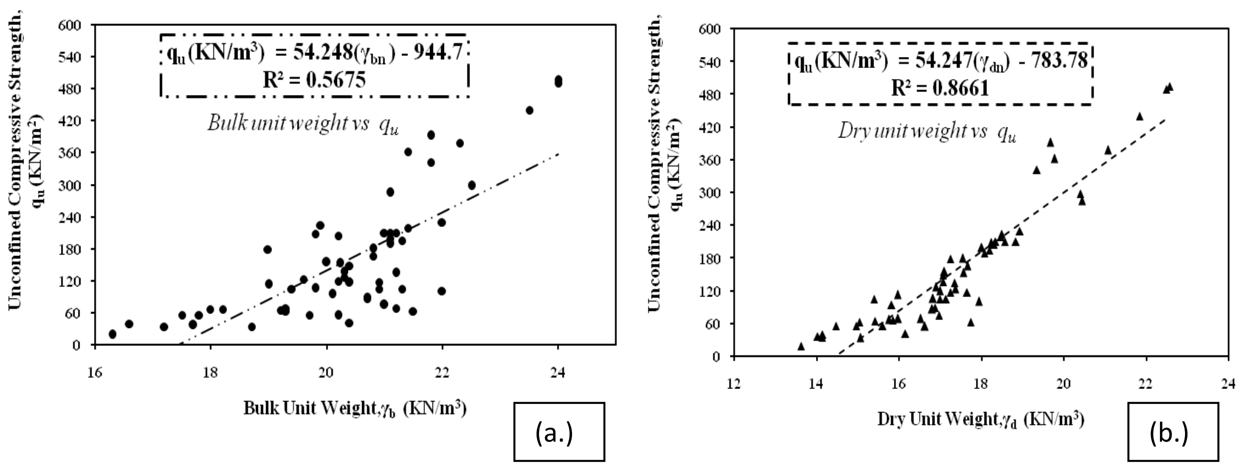

Figure 4: Relationship between unconfined compression strength, (a.) bulk unit weight and (b.) dry unit Weight of soils

Predictive models were developed using single and multiple linear regression in SPSS software. Following three models were developed after analysis.

$$q_u (KN/m^2) = 54.247(\gamma_{dn}) - 783.78$$

[R² = 0.87] *eq.1*

$$q_u (KN/m^2) = -14.771(w_n) + 418.65$$

[R² = 0.64] *eq. 2*

$$q_u (KN/m^2) = 44.4(\gamma_{dn}) - 4.12(w_n) - 540.25$$

[R²=0.89] *eq. 3*

It is always very important to check the validity of predictive models on real scale data. To check the validity of developed models separate set of real scale soil samples were tested. All the soil samples were tested in accordance with ASTM standards. To check the validity of developed models Experimental values of q_u obtained from these samples were compared with the predicted value of q_u. The scatter around equality line shows the error in prediction of developed models. It was observed that for present study equation 3 shows the least error in prediction as shown in figure 5.

Therefore the equation 3 predicts the value of unconfined compressive strength more accurately than other two equations. To easily predict q_u value from equation 3 an interactive curve was developed as shown in figure 6.

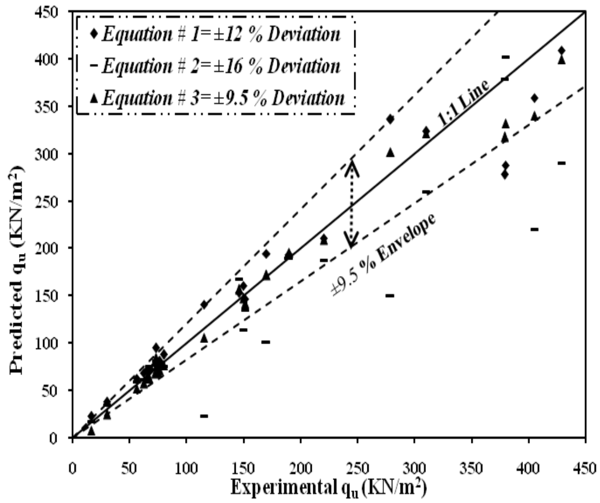

Figure 5: Validity of developed models

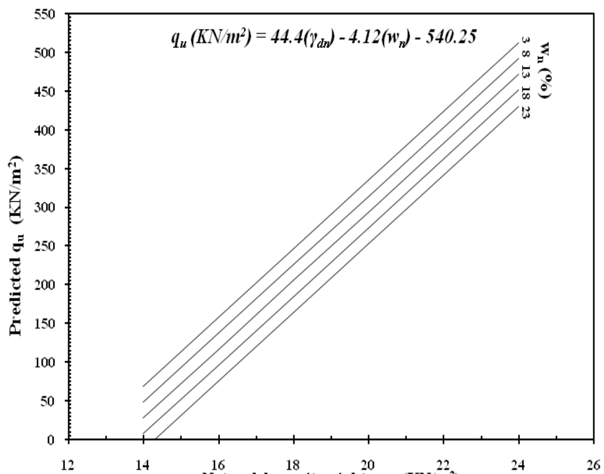

Figure 6: Predictive Curves

CONCLUSION

Unconfined compressive strength can be best predicted using moisture content and dry unit weight.

A multi linear regression model was developed to predict the unconfined compressive strength with percentage error ±9. 5 %.

A curve was also developed for quick and easy prediction of unconfined compressive strength of soils.

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