Journal of the Korea Academia-Industrial cooperation Society
Vol. 13, No. 8 pp. 3713-3718, 2012

http://dx.doi.org/10.5762/KAIS.2012.13.8.3713

A Study on the Undrained Characteristics of Highly plastic soils I: Relations of Properties

Dae-Kyu Kim[1*]

[1]**Department of Civil Engineering, Sangmyung University**

고소성토의 비배수 특성에 관한 연구 I: 특성치간 관계

김대규[1*]

[1]상명대학교 건설시스템공학과

Abstract The relations of the various undrained geotechnical properties were, in depth, investigated for highly plastic soils using the numerous experimental testing results. The sensitivity is proportional to void ratio and OCR but inversely proportional to effective unit weight. The difference in Su(Un), Su(UU), and Su(FV) tends to increase or decrease with such sensitivity, void ratio, and OCR. The possibility of deducting the empirical equations denoting the correlations of various properties and the indicator for selecting appropriate testing method could be confirmed.

요 약 본 연구에서는 고소성토 비배수 특성치들의 관계에 대하여 다양한 현장 및 실내시험 결과를 활용하여 고찰하였다. 예민비는 간극비 및 과압밀비와 비례경향이었으나 유효단위중량과는 반비례 경향이 있는 것으로 나타났다.일축압축, 비압밀비배수 삼축압축, 현장베인실험에서 구한 비배수강도의 차이는 예민비, 간극비, 과압밀비 등과 비례, 또는 반비례 등 확실한 경향이 있음을 보여주었다. 다양한 특성치들 간의 경험식 및 적절한 실험방법의 선택을 위한 지표설정 등의 가능성이 확인되었다.

Key Words : Highly plastic, Undrained strength, Undrained property

1. Introduction

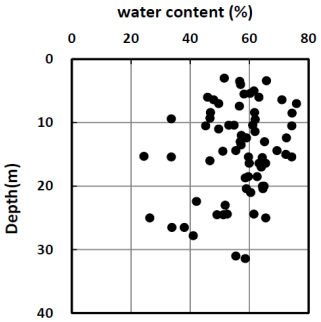
The safety and designing analyses in all geotechnical problems, with all engineering properties of soils, are grouped into two concepts: undrained or drained conditions[1,2,3]. The properties might have totally different values under undrained and drained conditions. This tendency is likely to be large for the highly plastic soil[4,5].

In this study, the relations of various geotechnical properties of highly plastic soils were, in detail, investigated using the numerous laboratory and field testing results.

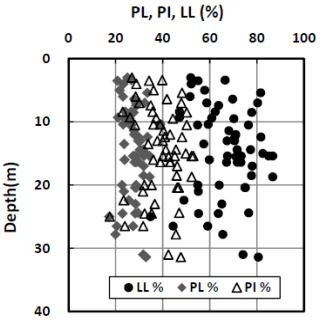
2. Characteristics with depth

The experimental results used in this study are the data obtained from the various testings, which have been conducted for the highly plastic soils at the offshore site in Gadeokdo, Busan[5]. The main geotechnical properties with depth are shown in Fig. 1 (a) to (h), where, Un, UU, FV respectively indicate the unconfined, unconsolidated and undrained triaxial, and field vane tests.

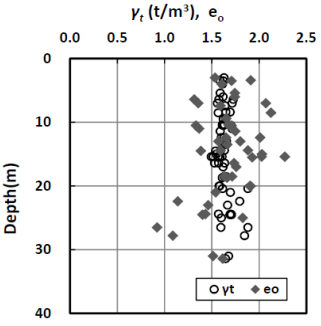
The author acknowledges the Dodam Engineering for providing the valuable test data.
*Corresponding Author : Dae-Kyu Kim
Tel: +82-41-550-5312 email: daekyu@smu.ac.kr
Received July 24, 2012 Revised August 7, 2012 Accepted August 9, 2012



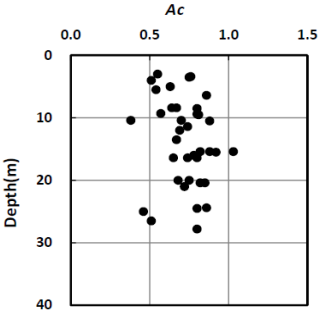
(a) Water content with depth



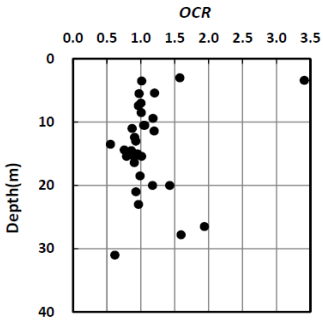
(b) Atterberg limits with depth



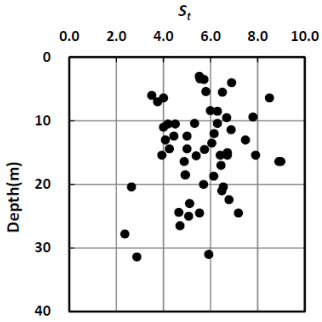
(c) Wet unit weight, void ratio with depth



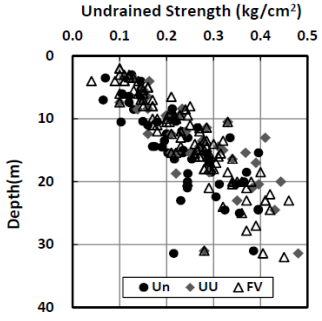
(d) Activity with depth



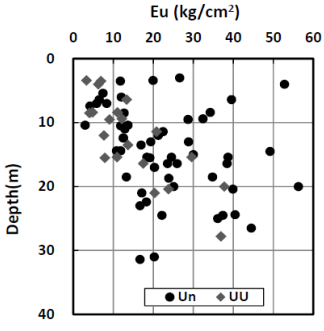
(e) OCR with depth



(f) Sensitivity depth



(g) Undrained strength with depth



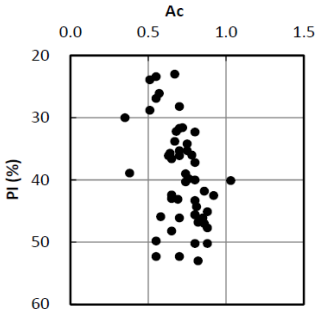
(h) Undrained elastic modulus with depth

[Fig. 1] Variations of geotechnical properties with depth

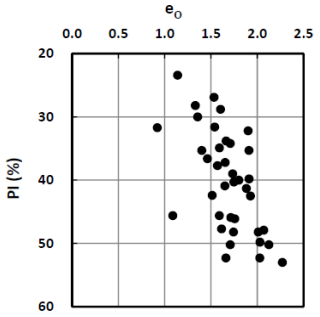
Most of the soil is regarded as normally consolidated, very soft and highly plastic silty clay(CH in USCS) considering the water content over the liquid limit, the activity near 0.8, the OCR near unity, the sensitivity over 4, and the undrained strength and undrained elastic modulus increasing with depth.

3. Relations of general properties

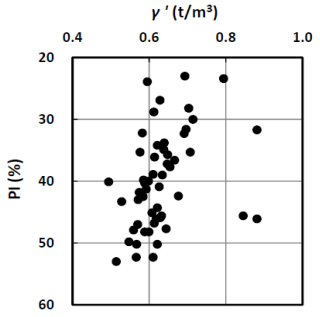
The plastic index PI and the sensitivity St are specially important for highly plastic soils. Fig. 2 (a) to (d) present the relations between PI and other properties.



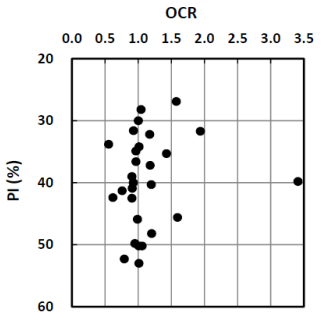
(a) PI and activity



(b) PI and void ratio



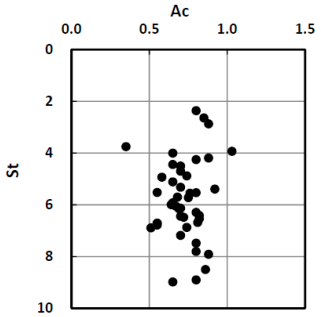
(c) PI and effective unit weight



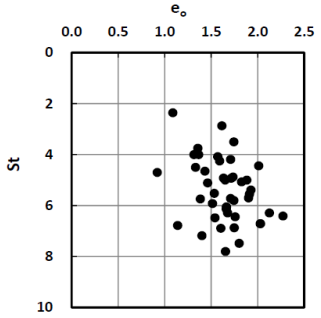
(d) PI and OCR

[Fig. 2] Variations of properties with PI

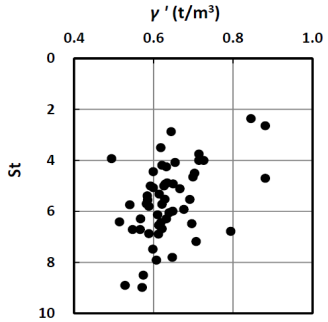
The observation that PI is in nearly direct proportion to Ac and void ratio results in that the fines of the soil consist of mainly clay and some silt, and vice versa. The PI does not show any special relation to the effective unit weight and the overconsolidation ratio OCR. The sensitivity relations to other properties are presented in Fig. 3 (a) through (d).



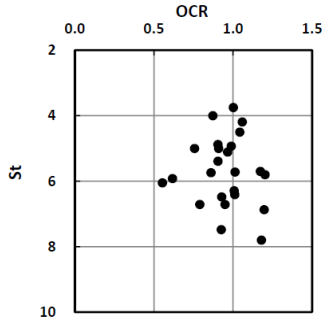
(a) Sensitivity and activity



(b) Sensitivity and void ratio



(c) Sensitivity and effective unit weight



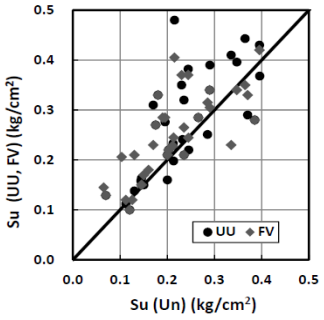
(d) Sensitivity and OCR

[Fig. 3] Variations of properties with St

It is observed that the sensitivity shows a tendency to increase in the increase of the void ratio and the OCR, on the contrary, decrease with the increase of effective unit weight. This indicates that the sensitivity could be an important indicator for the estimation of other geotechnical properties and the state of the soil.

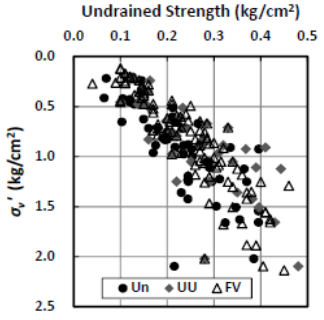
4. Discussions of Undrained Strength

The undreained strength Su is one of the most important properties for both practical work and research. The three kinds(Un, UU, FV) of undrained strengths with depth are described in Fig.1 (g). The Su values are compared with each other in Fig. 4. The Su variation with the effective vertical stress is presented in Fig. 5.



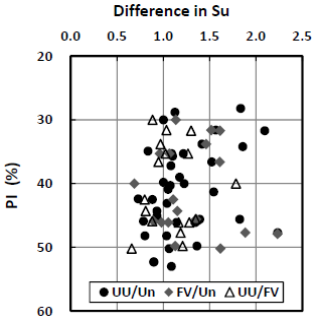
[Fig. 4] Undrained strengths from various tests

Both Su(UU) and Su(FV) are in general larger than the Su(Un) but are still within the reasonable range. This is since the confining stress is not applied in Un test other than in UU and FV tests. On the other hand, the Su(UU) is greater than the Su(FV). It is thought that the confining stress in UU test might be larger than that in field. The details on the effect of confining stress needs further research.

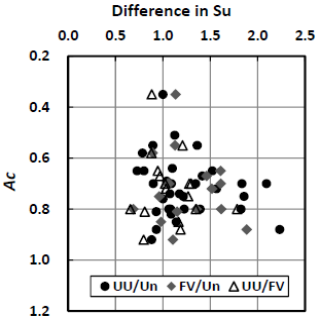


[Fig. 5] Effective vertical stress and undrained strengths

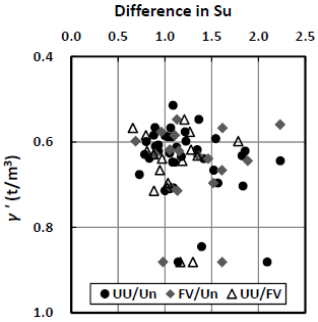
In Fig. 5, the undreained strength is proportional to the effective vertical stress, which may be natural since the soil looks in the typical range of normally consolidation as shown in Fig. 1 (e) and (g). Fig. 6 (a) to (h) describe the difference in Su(Un), Su(UU), Su(FV) with various properties. The water content showed no tendency to difference in Su so was excluded in Fig. 6. UU/Un designates Su(UU) divided by Su(Un).



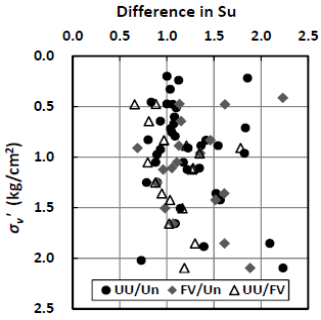
(a) Plastic index and Su difference



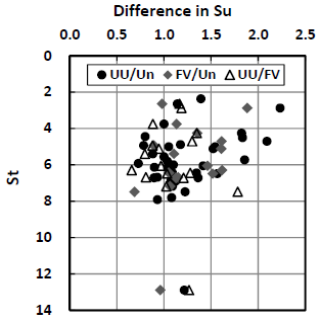
(b) Activity and Su difference



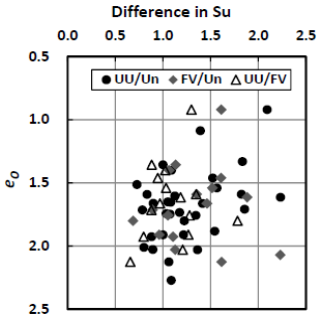
(c) Effective unit weight and Su difference



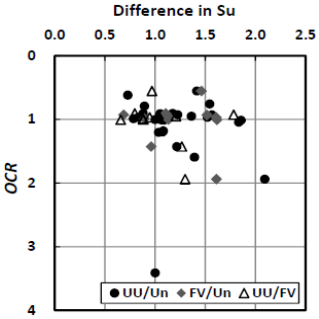
(d) Effective vertical stress and Su difference



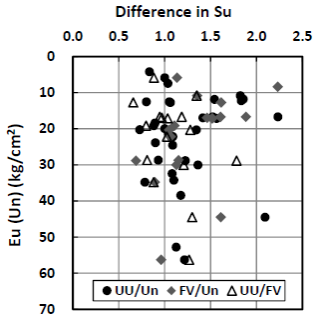
(e) Sensitivity and Su difference



(f) Void ratio and Su difference



(g) OCR and Su difference



(h) Undrained elastic modulus and Su difference

[Fig. 6] Variations of Su difference with properties

The relatively small difference in Su might be appreciated near PI 45%, effective vertical stress 1.3 kg/cm^2, Eu 25 to 40, and in less values than Ac 0.6. The difference in Su, to some degree, tends to decrease with the increase of sensitivity and void ratio but shows the opposite tendency to OCR.

5. Conclusions

In this study, the investigations of the relations of the undrained geotechnical properties for highly plastic soils in Gadeokdo, Busan, specially the undrained strengths from various testings, were made using the numerous experimental results. The following conclusions could be formed.

- The difference in Su obtained from Un(unconfined), unconsolidated and undrained triaxia(UU)l, field vane(FV) testings is likely to tend to increase or decrease with such soil properties as sensitivity, void ratio, and OCR.

- The sensitivity has a tendency to be proportional to void ratio and the OCR, on the contrary, inversely proportional to effective unit weight.

- It might be possible that the empirical equations, which denote the correlations of various properties, and a kind of indicator in selecting the appropriate testing method could be deducted.

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Dae-Kyu Kim [Regular member]

- Dec. 1999 : Louisiana State University, Ph.D.
- Mar. 2002 ~ current : Sangmyung University, Dept. of Civil Engineering, Associate Professor

<Research Interests>
Geotechnical Engineering, Soils and Foundations, Ground Exploration and Testing, Constitutive Relations, Numerical Analysis, Underground