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Study on the Relation Constant between OCR and Normalized Net Cone Tip Resistance

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정규화 콘팁저항치와 OCR의 관계상수에 관한 연구

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Abstract The relation constant method between OCR and normalized net cone tip resistance has been widely used to estimate OCR value in practice. In this study, the method was analyzed for the soft soils in the Bukmyun area in Changwon city and the northwestern area in Incheon city. The relation constant value was estimated in the range of 0.28～0.33 for the Bukmyun area in Changwon city and 0.49～0.6 for the northwestern area in Incheon city. The value was max. 90% larger than it from the foreign previous studies. This is not the conservative result so the previous methods should be used with great caution of determining the constant value.

요 약 본 연구에서는 현재 OCR(과압밀비) 값 결정을 위하여 실용적으로 많이 활용되고 있는 경험적 방법인 정규화 콘팁저항치과 과압밀비의 관계상수법에 대하여 분석하였다. 이를 위하여 창원 북면 및 인천 서북면 지역의 연약점토지반에 대하여 관계상수를 산정하고 고찰하였다. 연구결과, 관계상수 값은 창원북면의 경우 0.28～0.33, 인천 서북면의 경우 0.49～0.6으로, 해외의 기존 연구결과 보다 최대 90% 크게 비안전측으로 산정되어 향후 콘팁저항치와 과압밀비의 관계상수법 사용에 주의가 필요하다 하겠다.

Key Words : Piezocone, OCR, Normalized Net Cone Tip Resistance

1. Introduction

The semiempircal method for predicting OCR (overconsolidation ratio) value, utilizing PCPT(piezocone penetration test) data, for cohesive soils have been widely used on the strength of its simplicity and convenience for use(Lunne et al. 1997, Abu-Farsakh 2007)[1,2]. Such semiempirical methods usually adopt the relationship between OCR and net cone tip resistance normalized by effective vertical stress(Chen and Mayne 1994)[3]. The reliability of the methods is dependent on the relation constant between OCR and the normalized net cone tip resistance, and determining the value of the constant is a matter of great importance.

Previous researches have proposed the value of the relation constant, which is ranged 0.1 to 0.5 in general(Powell et al. 1988, Kulhawy and Mayne 1990, Lunne et al. 1997, Abu-Farsakh 2007)[1,2,4,5]. The relation constant value is actually site dependent but its study on Korea has been rarely performed[6].

In this study, the relation constant was estimated and investigated for the soft clayey soils in Bukmyun area in Changwon city and northwestern area in Incheon city.

2. Relationship between OCR and Normalized Net Cone Tip Resistance

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Such semiempirical relationship between OCR and cone tip resistance as Eq. (1) has been proposed for predicting OCR for clayey soils. Although Eq. (1) has simple form, it has been widely used with relatively high reliability.

$$OCR = k\left(\frac{q_t - \sigma_{vo}}{\sigma_{vo}'}\right) \quad (1)$$

where q_t indicates the cone tip resistance corrected for the unequal end area effect[1,2]. The σ_{vo} and σ_{vo}' mean the total and effective overburden stresses respectively. The k is the relation constant, whose value has been proposed by various researchers as in Table 1. The k values by Kulhawy and Mayne(1990) and Lunne et al.(1997) are based on the synthesized data mainly for the soft soils in US. The k value by Powell et al.(1998) and Abu-Farsakh(2007) are for the clayey soils in UK and Louisiana State respectively.

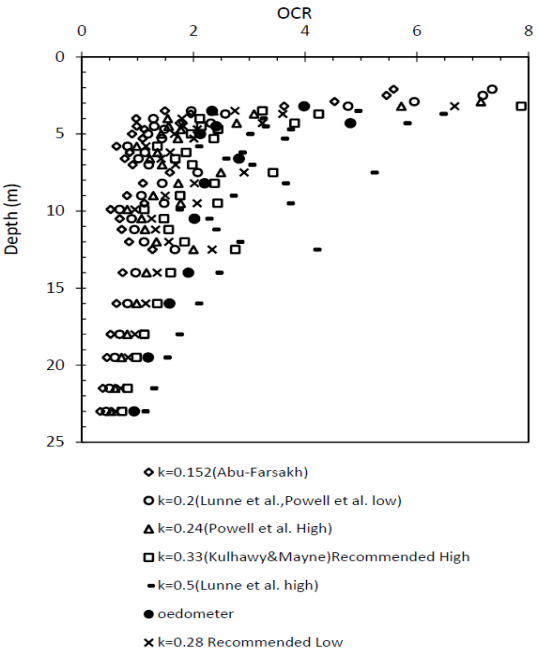
[Table 1] Relation Constant Values in Previous Researches

Previous Research	k value
Kulhawy and Mayne(1990)	0.33
Powell et al.(1988)	0.2～0.24
Lunne et al.(1997)	0.2～0.5
Abu-Farsakh(2007)	0.152

3. Estimation and Investigation of the Relation Constant Value

The OCR predicted through the k values by previous studies and oedometer test with depth, for the Bukmyun area in Changwon city, are presented in Fig. 1.

In the graphical consideration of Fig. 1, the oedometer result looks to lie generally between high boundary k=0.5 and low boundary k=0.28; however, more investigation and the possibility of the intrinsic experimental error in the oedometer testings might lead to narrow the space between the high and low boundaries. OCR values were predicted also using various k values other than in the previous studies. The best fit line of the predicted to the measured OCR(OCR_{fit}/OCR_m) by oedometer testing and the corresponding coefficients of determination R^2 were calculated and shown in Table 2 and Fig. 2. The low and high values of k could be recommended 0.28 and 0.33 respectively in around ±85～90% reliability.

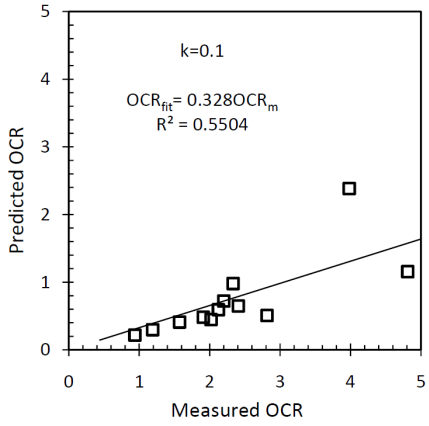


[Fig. 1] Measured and Estimated OCR (Bukmyun Area in Changwon City)

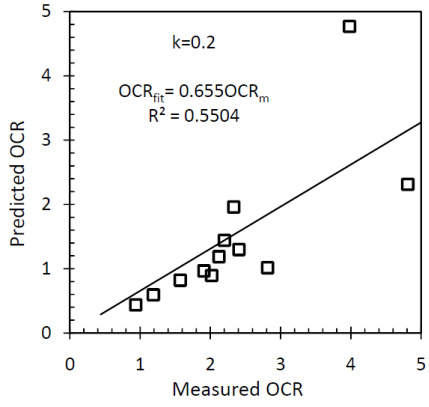
[Table 2] Best Fit Calculation with Various Values of Relation Constant k (Bukmyun Area in Changwon City)

k value	OCR_{fit}/OCR_m
0.1	0.328
0.152(Abu-Farsakh 2007)	0.498
0.2(Lunne et al.1997, Powell et al.1988's Low Boundary)	0.655
0.24(Powell et al. 1988's High Boundary)	0.786
0.28 (*Recommended Low Boundary*)	0.917
0.33(Kulhawy and Mayne 1990 *Recommended High Boundary*)	1.081
0.4	1.310
0.45	1.474
0.5(Lunne et al. 1997's High Boundary)	1.637

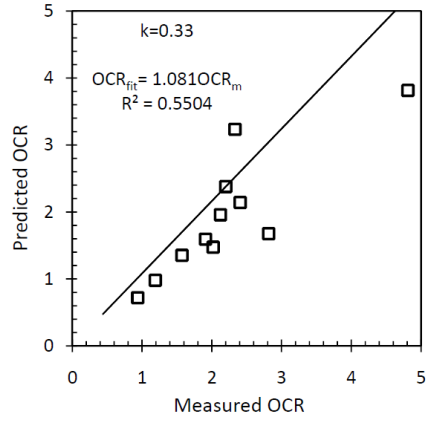
※ R^2=0.5504



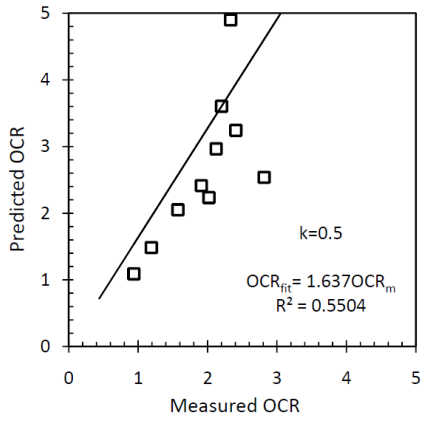
(a) k=0.1



(b) k=0.2



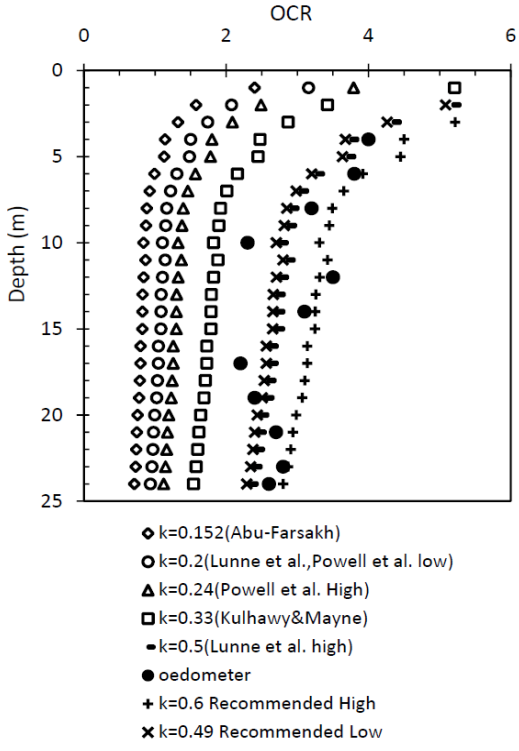
(c) k=0.33



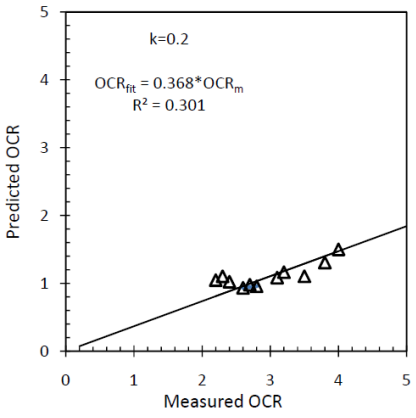
(d) k=0.5

[Fig. 2] Measured and Predicted OCR with Various Values of Relation Constant (Bukmyun Area in Changwon City)

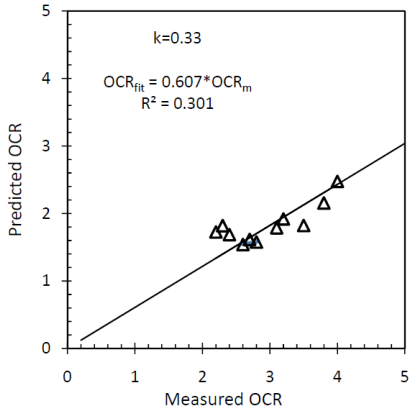
Figs. 3 and 4 and Table 3 present the measured and predicted OCR values together with their reliability analyses for the northwestern area in Incheon city.



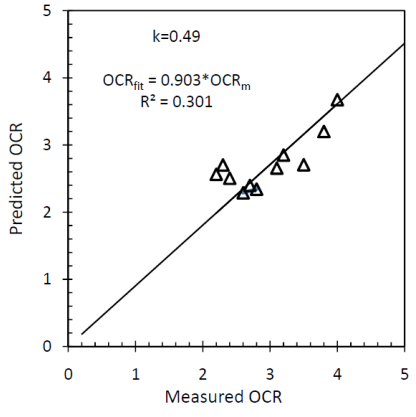
[Fig. 3] Measured and Predicted OCR (Northwestern Area in Incheon City)



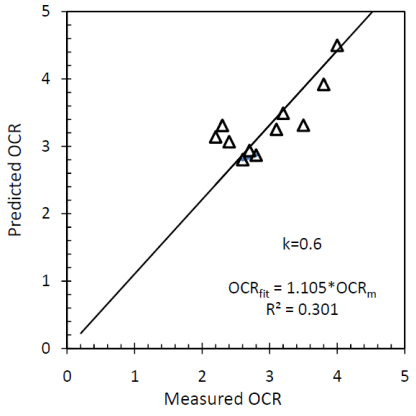
(a) k=0.2



(b) k=0.33



(c) k=0.49



(d) k=0.6

[Fig. 4] Measured and Estimated OCR with Various values of Relation Constant (Northwestern Area in Incheon City)

[Table 3] Best Fit Calculation with Various Value of Relation Constant k (Northwestern Area in Incheon City)

k value	OCR_{fit}/OCR_m
0.1	0.184
0.152(Abu-Farsakh 2007)	0.28
0.2(Lunne et al.1997, Powell et al.1988's Low Boundary)	0.368
0.24(Powell et al. 1988's High Boundary)	0.442
0.33(Kulhawy and Mayne 1990)	0.607
0.4	0.736
0.49 (Recommended Low boundary)	0.903
0.5(Lunne et al. 1997's High Boundary)	0.921
0.55	1.013
0.6 (Recommended High Boundary)	1.105
0.7	1.289
0.8	1.473

※ R^2=0.3014

The predicted OCR values in Fig. 3 are in good arrangement. This is due to the fact that the magnitude of the unit weight of soils, which is used to calculate the total and effective overburden stresses in Eq. (1), does not vary much at each depth. Contemplating the scattered measured data in Fig. 3 and the best fit calculation in Table 3 and Fig. 4, the low and high boundaries of k value could be respectively recommended 0.49 and 0.6

with about 90% reliability.

The recommended k value for the Bukmyun area in Changwon city, in a broad sense, can be said within the scope of previous studies, namely, between 0.24(Powell et al. 1988's High Boundary) and 0.33(Kulhawy and Mayne 1990). On the other hand, the recommended k value scope, 0.49～0.6, for the northwestern area in Incheon city is larger, max. 90%, than the normal scope. In other words, the existing k values, which have been widely used in practice, might underestimate OCR. This can produce unconservative geotechnical designing in part. It needs to be noted that k value varies with sites so k value should be determined with great caution.

In Eq. (1), the k value is influenced by such factors as the total and effective overburden stresses, the net cone tip resistance, and OCR. These factors are obtained from unit weight of soils and pore water pressure, which depends on plasticity of soils except for the ground water table itself. This may be the reason why inducing many geotecnical properties from piezocone test results is dependent on the plasticity[1,7]. The correlation between k value and plasticity, such as the strength increase ratio, needs future study. Table 4 indicates the summary of main soil properties of the investigated sites[1,2,4,5,8].

[Table 4] Soil Property Summary of the Investigated Sites

Site	Unit Weight t/m^3	plastic index %	water content %
Louisiana State (Abu-Farsakh 2007)	1.6～1.9	17～36	20～49
synthesized in US (Lunne et al.1997)	1.5～2.2	20～45	21～50
synthesized in UK (Powell et al. 1988)	1.6～2.1	14～40	20～48
synthesized in US (Kulhawy and Mayne 1990)	1.6～2.2	18～44	19～49
Bukmyun Area in Changwon City	1.7～1.9	19～39	22～60
Northwestern Area in Incheon City	1.7～2.1	23～45	22～46

4. Conclusions

In this study, the relation constant k between OCR and normalized net cone tip resistance was estimated and investigated for the soft clayey soils in Bukmyun area in Changwon city and northwestern area in Incheon city. The following conclusions could be made.

- The relation constant k value was estimated in the range of 0.28～0.33 for the Bukmyun area in Changwon city.
- The k value was relatively well matched with Kulhawy and Mayne(1990) method.
- The relation constant value was estimated in the range of 0.49～0.6 for the northwestern area in Incheon city.
- The k value was max. 90% larger than it from the existing representative methods.
- It was observed that the k value varies with sites so the k value should be determined with great caution for the appropriate prediction of OCR.

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