Indian Geotechnical Journal, 38(3), 2008, 355-362

TECHNICAL NOTE

Empirical Correlations for Compressibility Parameters of Alluvial Deposits

C. H. Solanki[*], M. D. Desai[**] and J. A. Desai[***]

Introduction

The total settlement of foundation is the sum of immediate, consolidation and secondary compression settlements. Consolidation settlement usually refers the primary consolidation and this component is significant in the case of saturated clayey soil. Typically the consolidation settlement is estimated using the compressibility parameters derived from one dimensional consolidation tests on representative undistrubed soil samples. In some cases the time rate settlement prediction is required. Performance of consolidation test in the laboratory requires good quality undisturbed samples and considerable time.

Researchers have suggested various empirical correlations for determination of consolidation parameters. Even though such empirical correlations cannot be generalized for all clayey soils, those are useful for a preliminary analysis of consolidation settlement. Results of laboratory tests including index and one dimensional consolidation tests on alluvial soils of south Gujarat region of Surat and surroundings are subjected to a statistical study for developing useful correlations between the index properties and consolidation parameters.

Subsoil Characteristics of the Study Area

Most of the area in Surat and SUDA (Surat Urban Development Authority) have stratified alluvial deposits formed under the alternate floods and tides. The range of soil index properties to a depth of about seven metres in different zones of Surat and SUDA are presented in Table -1(a) & 1 (b).

The typical ranges soil properties are; Liquid limit 40-60 %, Plastic limit 20-30 %, Plasticity index 15 - 35 %, Dry unit weight 14 - 16 kN/m^3, Fines smaller than 75 microns 70 - 100 %, Natural moisture content 20 - 30 %, Clay content 20 - 40 %. Both montmorillonite and kaolinite are found in the mineralogy.

* Lecturer, Department of Applied Mechanics, SVNIT, Surat, Gujarat, chs@amd.svnit.ac.in, chandresh1968@yahoo.co.in

** Geotechnical Consultant, B-004, Heritage Apartment, City Light Road, Surat earthmdd@yahoo.co.in

*** Professor & Head, Department of Applied Mechanics, SVNIT, Surat, Gujarat, jatinadesai@yahoo.com, jad@amd.svnit.ac.in

Table 1(a) Subsoil Characteristics of Different Zones of Surat and SUDA

Property	*Central Zone, Surat*	*East Zone, Surat*	*North East SUDA*
Liquid Limit (w_L) %	35 – 60	40 -60	30 – 60
Plastic Limit (w_P) %	20 – 30	20 – 30	15 – 35
Plasticity Index (I_P) %	10 – 40	15 – 30	10 – 30
Void Ratio (e_o)	0.62 – 0.84	0.70 – 0.85	0.64 – 0.90
Dry Unit Weight (γ_d) kN/m^3	15-16	15-15.5	14 – 16
Water Content (w) %	10 – 20	15 – 25	15 – 30
% fines <75 microns	80 – 100	70 – 95	70 – 100
Compression Index (C_C)	0.19 – 0.385	0.21 – 0.33	0.175 – 0.34
Compression Ratio (C_C') = $Cc/(1+e_o)$	0.11 – 0.19	0.12 – 0.17	0.11 – 0.175

Table 1(b) Subsoil Characteristics of Different Zones of Surat and SUDA

Property	*North West SUDA*	*South West SUDA*	*South East SUDA*
Liquid Limit (w_L) %	30 – 60	30 – 65	40 – 70
Plastic Limit (w_P) %	20 – 30	15 – 30	20 – 30
Plasticity Index (I_P) %	15 – 30	15 – 40	15 – 35
Void Ratio (e_o)	0.67 – 0.83	0.64 – 0.95	0.54 – 0.94
Dry Unit Weight (γ_d) kN/m^3	14 -16	15.5 -16.5	14 -16
Water Content (w) %	15 – 25	20 – 30	15 – 30
% fines <75 microns	70 – 90	60 – 100	75 – 100
Compression Index (C_C)	0.19 – 0.33	0.19 – 0.39	0.22 – 0.38
Compression Ratio (C_C') = $Cc/(1+e_o)$	0.13 – 0.17	0.12 - 0.19	0.13 – 0.18

Pre-consolidation Pressure and Over Consolidation Ratio

The stress history and present state of stress which influences settlement computation is reflected by over consolidation ratio. The ratio of maximum pre-consolidation pressure to the present average effective overburden pressure is presented as the over-consolidation ratio (OCR). The maximum pre-consolidation pressure is generally determined from laboratory procedures on undisturbed samples. There are several methods for computing the pre-consolidation pressure from laboratory one dimensional consolidation tests in the laboratory, [Casagrande method,1936; Schmertmann,1955; Janbu, 1969; Butterfield, 1969; Tavenas,1979; all referred by Senol et al (2000)] The graphical method proposed by Casagrande is widely used for the determination of maximum pre-consolidation pressure. Senol et al (2000) suggested that strain energy - log stress method shows better computation with a higher value of correlation coefficient. Similarly the compressibility parameters such as compression index (C_C), Recompression index (C_r), coefficient of volume change (m_v) and the consolidation coefficient (C_v) are also computed from the laboratory consolidation tests.

There were several attempts to develop universal correlations between the above compressibility and consolidation parameters. (The correlations to obtain pre-consolidation pressure and OCR by Nagaraj, et. al. (1994), Chetia and Bora (1998), etc.)

In the present study, the authors attempt new empirical correlations for the alluvial deposits of South Gujarat region using statistical software and the available soil index and consolidation test data for shallow depths.

The authors derived the following empirical correlations for the OCR by regression analysis of the data.

$$OCR = 1.85 - 0.007\, p_o - 0.255\, (e/e_L) \qquad (1)$$

where,

p_0 = Existing over burden pressure in kN/m^2, e = Initial void ratio (in-situ) and e_L = Void ratio at liquid limit

The figure 1 shows reasonably good value of correlation coefficient 0.793 while comparing with measured data base and the predicted data of over consolidation ratio.

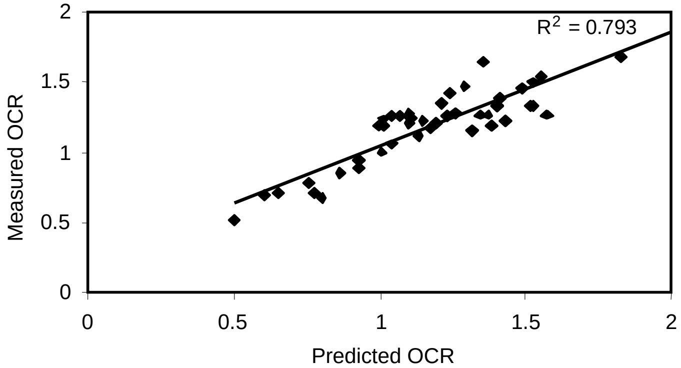

Fig.1 Measured vs Predicted OCR

Time Rate Settlement

Coefficient of consolidation C_v derived from one dimensional consolidation tests by curve fitting methods such as log time and square root time. Both these computations produce varied results.

Several correlations between the coefficient of consolidation and the index properties like liquid limit and plasticity index are available in the literature. The correlation coefficients are not far from the variations from different curve fitting methods.

New empirical correlations are derived using the same index properties of the alluvial soil of present study. Detailed statistical study of the available data suggest that the correlation with plasticity index is more realistic. Equations 2 & 3 are derived by regression analysis for C_v (for loading range up to 200 kN/m^2) with liquid limit and plasticity index.

$$C_v = 10^8 \ (w_L)^{-6.7591} \text{ in cm}^2/\text{sec} \quad (2)$$

$$C_v = 7.7525 \ (I_p)^{-3.1021} \text{ in cm}^2/\text{sec} \quad (3)$$

The correlation coefficient of C_v with the liquid limit is 0.7867 (figure 2), whereas the correlation coefficient with the plasticity index is 0.9156 (figure 3). This correlation of plasticity index was verified with other test data of study area which produced a correlation coefficient R^2 = 0.9484 as shown in Figure 4.

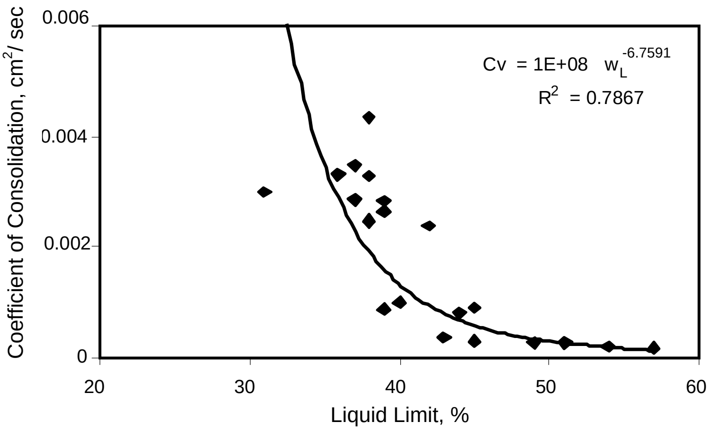

Fig. 2 C_v vs Liquid Limit

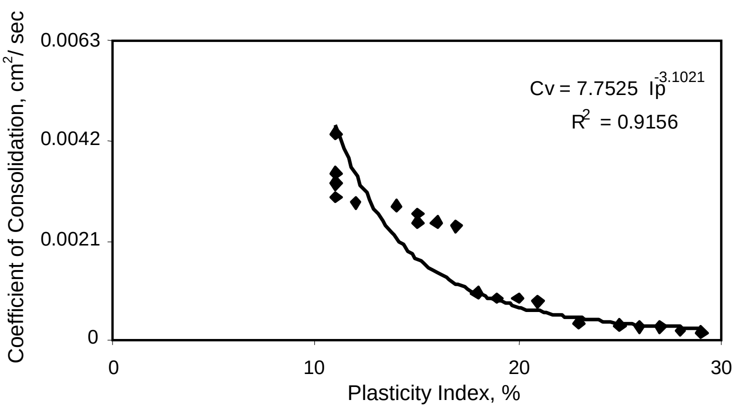

Fig. 3 C_v vs Plasticity Index

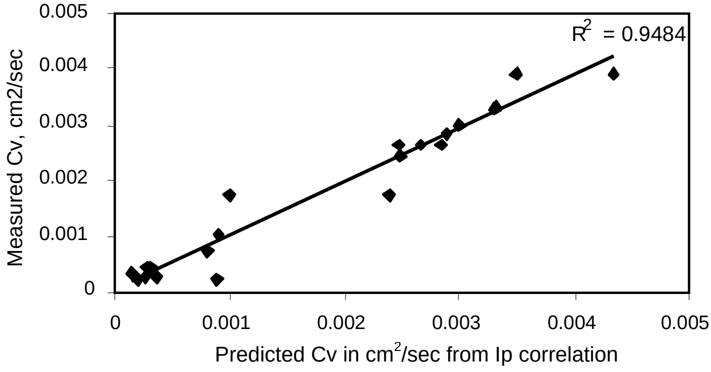

Fig. 4 Predicted vs Measured C_v

Consolidation Settlement

The compression index C_c is measure directly from the e-log p curves derived from one dimensional consolidation tests. The recompression index (C_r) is the slope of e - logσ rebound curve. Typically Cr is 10 -20% of C_C. The compression ratio C_C' is represented as the ratio between Cc and (1+e_0).

The Several researchers have suggested empirical correlations for C_C and m_v with liquid limit (w_L), void ratio (e_0), plasticity index (Ip), natural moisture content (w), shrinkage index (I_S) etc. In the present study, compression ratio Cc' of soil is correlated with plasticity characteristics of soil such as liquid limit and plasticity index. The following correlations were developed.

$$Cc' = 0.0032\, w_L + 0.0004 \quad (4)$$

$$Cc' = 0.002\, w_L + 0.001\, Ip + 0.037 \quad (5)$$

The correlation of compression ratio Cc' with the liquid limit alone is shown in Figure 5 with correlation coefficient 0.8588.

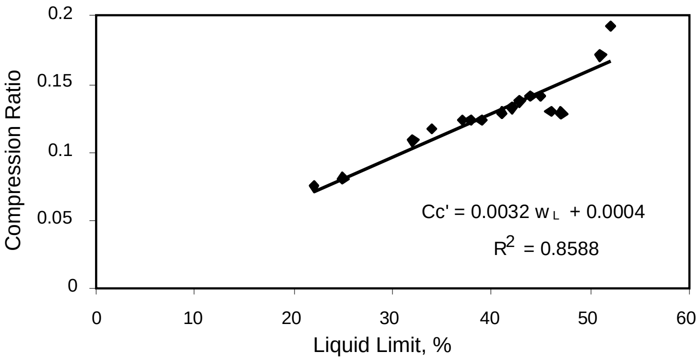

Fig. 5 Compression Ratio vs Liquid Limit

Comparison with the measured datasets produces correlation coefficient equal to 0.7178 (Figure 6) for Eqn 4. Comparison with the measured datasets produces correlation coefficient equal to 0.880 as shown in Figure 7 for the correlation given in Eqn. 5.

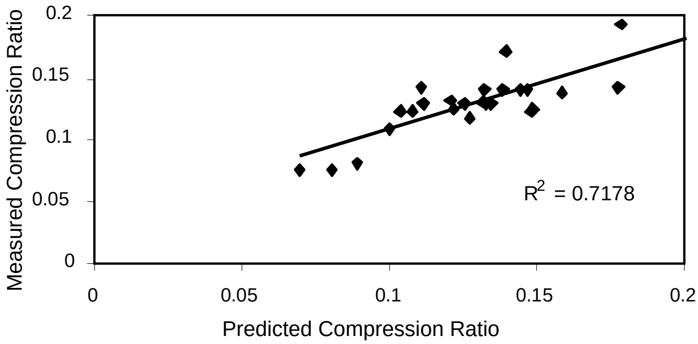

Fig. 6 Measured vs Predicted Compression Ratio with w_L

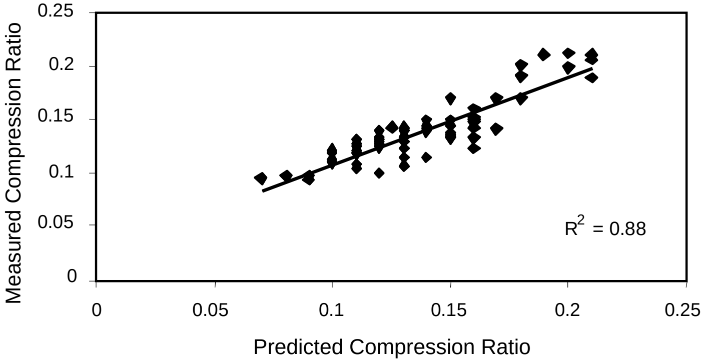

Fig. 7 Measured vs Predicted C_c' with w_L & I_p

Validation of Correlations with other Alluvial Soil Data Sets

A database from literature (Crumley, 2003) on alluvial deposit is used to verify the new empirical correlations for compression ratio. The coefficient of correlation for Eqn 4 using liquid limit alone is 0.7868 (Figure 8), while a marginally better correlation ratio of 0.7986 is produced for the Eqn 5 using both the liquid limit and the plasticity index (Figure 9).

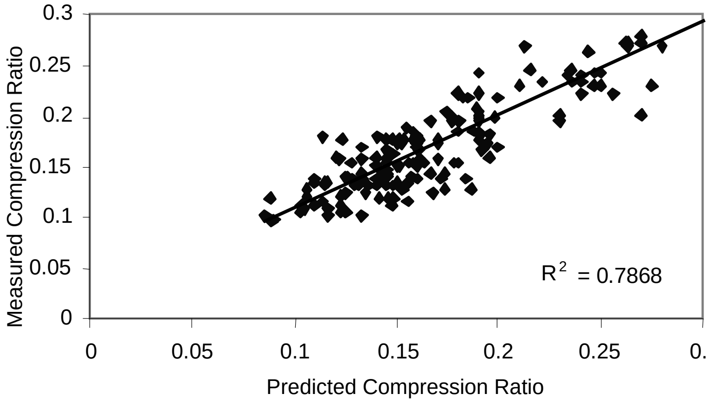

Fig. 8 Measured vs Predicted C_c' with w_L

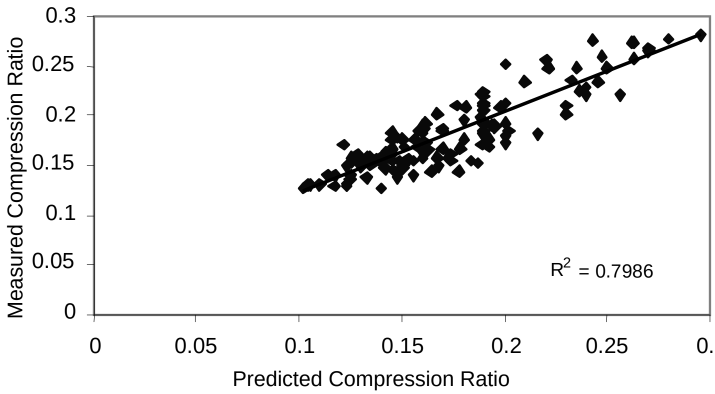

Fig. 9 Measured vs Predicted C_c' with w_L& I_p

The summary of statistical analyses of compression ratio from measured and predicted values are shown in Table 2. The coefficient of variance observed from the statistical data shows that compression ratio estimation using both the liquid limit and the plasticity index is preferable.

Conclusions

A dataset containing index and consolidation parameters are used to conduct a statistical study to derive new empirical correlations for estimating compressibility and consolidation characteristics of alluvial deposits in different zones of Surat and SUDA. It is found that soil plasticity characteristics gives better correlation coefficient with soil compressibility parameters. The following correlations are suggested.

$$OCR = 1.85 – 0.007\ p_o - 0.255\ (e / e_L) \quad (p_o \text{ in kN / m}^2) \qquad (6)$$

$$C_v = 7.7525\ (Ip)^{-3.1021} \quad (C_v \text{ in cm}^2 / \text{sec}) \qquad (7)$$

$$Cc' = 0.002\ w_L + 0.001\ Ip + 0.037 \quad (Cc' = Cc / 1+ e_0) \qquad (8)$$

Table 2 Statistical Summary of C_c' from Literature Test Data and the Present Correlation

Parameter	*from test data*	*From w_L*	*From w_L & Ip*
Count	135	173	135
Mean C_c'	0.175	0.174	0.178
Median C_c'	0.167	0.167	0.172
Std Error	0.004	0.004	0.003
Std Dev.	0.043	0.051	0.039
Coeff. Var.	24.391	29.397	21.312
Sum	23.609	30.095	24.582
Minimum	0.103	0.096	0.126
Maximum	0.296	0.356	0.280
Range	0.193	0.259	0.154
Skewness	0.678	0.935	0.823
Kurtosis	-0.151	0.659	-0.151

References

Chetia, M. and Bora, P. K. (1998): 'Estimation of Over Consolidation Ratio of Saturated Uncemented Clays from Simple Parameters', *Indian Geotechnical Journal* 28(2), pp. 177 – 194

Crumley, A. R.(2003): 'Compressibility Relationships for Soils in Puerto Rico', *12th Pan-American conference on soil Mechanics and Geotechnical Engineering* Massachusetts Institute of Technology, Boston. pp. 1-5

Nagaraj T. S., Shrinivasa Murthy B. R. and Vatsala A (1994): *Analysis and Prediction of Soil Behaviour*, Wiley Eastern Limited

Senol, A and Seglamer, A (2000): 'Determination of Pre-consolidation pressure with a new strain energy – log stress method', *The Electronic Journal of Geotechnical Engineering* pp 1-11