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Determination of Compressibility Parameters for Indian Soils

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Abstract
Compressibility of a soil mass is its susceptibility to decrease in volume under pressure and is indicated by soil characteristics like coefficient of compressibility, compression index and coefficient of consolidation. It is one of the most important engineering properties of soils and is used for the determination of rate of settlement and total amount of settlement of soil masses. However,the determination of soil compressibility characteristics in the laboratory is a cumbersome and time consuming process. On the other hand, determination of soil index properties such as particle sizes, Atterberg Limits etc. is relatively simpler and less time consuming. There are several existing models in literature which predict the compressibility characteristics of soils as a function of its index properties. In the present study, seven different models have been selected from literature. Six of these models have been in practice in geotechnical engineering field and the seventh model was proposed for the Indian soils in 2023. All of these models predict compression index as a function of Liquid Limit of soils. A total of 64 nos. of soil samples collected from different Indian water resources projects were analysed. The collected samples were subjected to laboratory investigations for the determination of geotechnical parameters namely liquid limit and compression index. An empirical model was developed to estimate the compression index as a function of liquid limit. The model results were compared with the actual compression index values, as determined by laboratory tests, and were found to be in good agreement. The compression index values for the collected samples were also determined using the available models in literature, and the results indicate that the present model can predict the soil compressibility with a good degree of accuracy. The predictions made by the proposed model are more accurate than 6 of the 7 models in literature and are very close to the most accurate model in literature i.e. Singh et. al (2023).

Keywords: *soil compressibility characteristics, compression index, Indian water resources projects, liquid limit, correlation models, proposed model.*

Disclaimer: *The views expressed in this paper are strictly individual views of the authors and do not, in any way, represent the views of the department/organization where they are presently working.*

I. Introduction

Shear strength, compressibility and permeability are considered to be the three most important properties of a soil mass applicable in areas such as in the design and analysis of dams, retaining walls, soil foundation systems and in other applications pertaining to geotechnical engineering practice. Among these three, compressibility isthe most significant parameter while evaluating the settlement of soil under the load of an infrastructure constructed on that soil mass (Tiwari and Ajmera, 2012). Compressibility of a soil mass is its susceptibility to decrease in volume under pressure and is indicated by soil characteristics like coefficient of compressibility, compression index and coefficient of consolidation. Although coefficient of volume compressibility is the most suitable, and most popular, of the compressibility coefficients for the direct calculation of settlement of structures, its variability with confining pressure makes it less useful when quoting typical compressibilities or when correlating compressibility with some other property. For this reason, the compression index of soils is generally preferred as its value does not change with the change in confining pressure for normally consolidated clays (Carter and Bentley, 1991, Gulhati and Datta, 2005). However, the determination of compression index in the labs is a cumbersome and time consuming process. Hence several attempts have been made in the past to correlate the value of compression index of soils with index properties of soil which are relatively easier to determine and take lesser time.

II. Literature Review

In the literature several correlations have been proposed whereby compressibility characteristics like compression index have been evaluated using liquid limit, natural moisture content, initial void ratio, plasticity index, specific gravity, void ratio at liquid limit, and several other properties of soil. Skempton (1944) and Terzaghi and Peck (1967) have given equations correlating compression index with the liquid limit of soils. Wroth and Wood (1978) used critical state soil mechanics concepts to deduce a relationship between compression index, plasticity index and specific gravity of remoulded clays. Nagaraj and Murthy (1983) proposed equations to evaluate the valueof compression index with specific gravity and void ratio at liquid limit of soils. Di Maio et al. (2004) conducted one dimensional consolidation tests on the mixtures of bentonite and kaolin as well as other natural clays and observed a good correlation between compression index and void ratio at liquid limit of soils. Tiwari and Ajmera (2012) prepared 55 different soil specimens in the laboratory by mixing various proportions of montmorillonite, illite, kaolinite, and quartz at initial moisture contents equal to the liquid limit and proposed two different equations to estimate the compression indices of remoulded clays with liquid limit, one for soils with activities less than one and the other for soils with activities greater than one. Establishing empirical equations for quantifying relationship between C_C and index properties is a practical and quick solution to predict C_c (Fan et al. 2021).

In the present study, seven different models have been selected from literature. Six of these models have been in practice in geotechnical engineering field and the seventh model was proposed for the Indian soils in 2023. All of these models predict compression index as a function of Liquid Limit of soils.
These seven models have been given below:

Table 1: List of Models Linking C_C with LL

S. No.	Equation	Reference
1.	C_c = 0.007(LL-7)	Skempton (1944)
2.	C_c = 0.046(LL-9)	Cozzolino (1961)
3.	C_c = 0.009(LL-10)	Terzaghi and Peck (1967)
4.	C_c = 0.006(LL-9)	Azzouz et al. (1976)
5.	C_c = (LL-13)/109	Mayne (1980)
6.	C_c = 0.0014 LL-0.168	Park and Lee (2011)
7.	C_c = 0.004(LL-7)	Singh et. al (2023)

III. Methodology of the Present Study

In the present study, an attempt has been made to estimate Compression Index as a function of soil index properties. A total of 64 nos. of soil samples collected from different Indian water resources projects were analysed. The collected samples were subjected to laboratory investigations for the determination of geotechnical parameters namely liquid limit and compression index. An empirical model was developed to estimate the compression index as a function of liquid limit. The model results were compared with the actual compression index values, as determined by laboratory tests, and were found to be in good agreement. The compression index values for the collected samples were also determined using the available models in literature, and the results indicate that the present model can predict the soil compressibility with a good degree of accuracy. The predictions made by the proposed model are more accurate than 6 of the 7 models in literature and are very close to the most accurate model in literature i.e. Singh et. al (2023).

Proposed Model

To predict the compression index (Cc), several regression analysis were carried using the different variables and accuracy of each model was tested by comparing the predicted values with actual values and calculating the statistical parameter root mean squared error (RME). The following proposed models were the best fit to the data.

Cc = 0.0038*(LL-3.8)

IV. Conclusions

The comparison of the proposed model with the seven available models towards prediction of Compression Index of Indian Soils based on the Liquid Limit values has been carried out and the results have been shown below:

Table 2: Comparison of Accuracy of Models Linking C_C with LL

S. No.	Model	Mean Value Difference (Absolute Value)	RME Values
1	Proposed Model	0.016	0.00039
2	Skempton (1944)	0.104	0.013
3	Cozzolino (1961)	0.019	0.00056
4	Terzaghi and Peck (1967)	0.148	0.027
5	Azzouz et al. (1976)	0.058	0.004
6	Mayne (1980)	0.126	0.0213
7	Park and Lee (2011)	0.281	0.0981
8.	Singh et. al (2023)	0.016	0.00037

V. Discussions

A perusal of the above table shows that the proposed model can predict the Compression Index values with a good degree of accuracy. The predictions made by the proposed model are more accurate than 6 of the 7 models in literature and are very close to the most accurate model in literature i.e. Singh et. al (2023). Hence, Singh et. al (2023) can predict the Compression Index values most accurately with the least deviation in the mean estimated values and the least value of Root Mean Squared Errors. On the other hand, the model proposed by Park and Lee (2011) is the least accurate as it gives maximum deviation in the mean estimated values and the highest value of Root Mean Squared Errors. However, it may be mentioned here that the prediction of engineering properties using the index properties is a dynamic process and in the light of more results obtained, the accuracy of the models shall change considerably.

The scatter plot for both these models is displayed below.

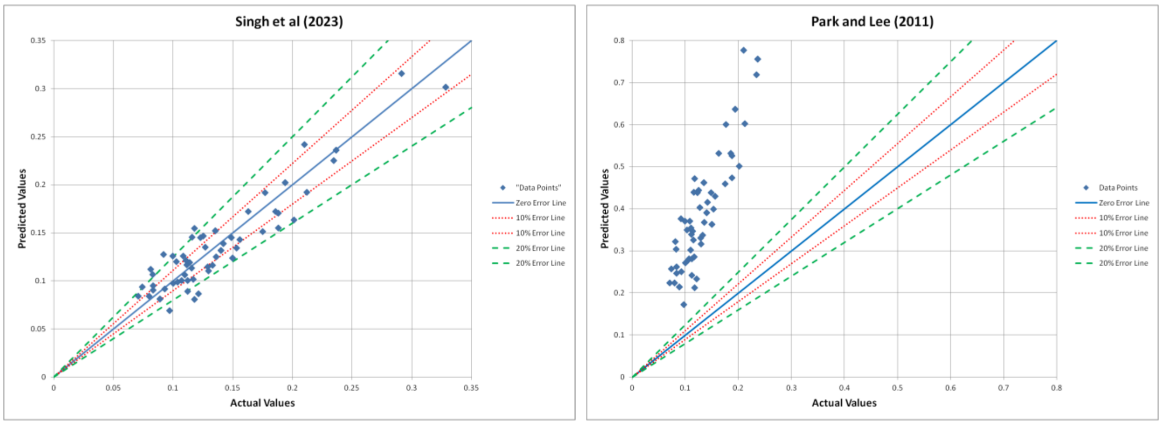

Fig. 1 Actual Compression Index, C_c versus predicted Compression Index C_c obtained by Singh et al Model (2023) and Park and Lee Model (2011)

It is clear from the scatter plots that 90.6 percent of the values lie within 20% error envelope as predicted by Singh et al (2023). Moreover, the coefficient of determination for Singh et al (2023) model is 0.88 which shows that the model is capable of accurately predicting the compression index values.

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