Indian Journal of Science and Technology, *Vol 10(32), DOI: 10.17485/ijst/2017/v10i32/106232, August 2017*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Suggesting a Formula to Calculate the Compression Index in Ahvaz

Mohsen Farzi*

Azad University of Abadan, Iran; Mohsen.Farzi@gmail.com

Abstract

Objective: The compression index is one of the most important parameters in soil mechanics to calculate the settlement of different geotechnical structures, which can be achieve by spending much time and expense through one dimensional consolidation test, therefore this study tries to provide a relation for determining compressibility coefficient by the help of soil parameters. **Methods:** A great number of experiments were conducted before to use simple and applicable formula for calculating the compression index in different types of soil. This study is resulted from 130 geotechnical studies, carried out in 2 years on the soil of different parts of Ahvaz which after providing the Undisturbed samples from different depths, the one dimensional consolidation, the Atterberg limits, the in situ humidity specification, specifying the specific dried weight, and the gradation tests were carried out on all samples. **Findings:** After analyzing the whole results obtained from consolidation test, a relation was achieved between compression index and initial void ratio, which can very accurately estimate the compression index. **Application:** By the help of the obtained relation which is $C_C = 0.506\,e_0 - 0.1$ compressibility coefficient can be estimated with high accuracy to determine the soil settlement at the site of project in Ahvaz city.

Keywords: Ahvaz Soil, Compression Index, Consolidation Test, Initial Void Ratio, Settlement

1. Introduction

Previously, some studies and researches have been carried out to specify the relation among primary consolidation indices including the compression index, swelling index, and soil's physical parameters. To expand one formula to different construction sites doesn't seem to be rational, considering each construction site owns its specific conditions in terms of soil's mechanical and hydrological parameters. The relation between the compression index, CC, and soil's physical parameters such as natural humidity, liquid limit humidity, and plastic limit humidity, initial void ratio, and etc. which all can be measured easily, was determined in many previous empirical studies.

The soil's mechanical experiments are of most expensive experiments in construction industry, which many expenses get spent on it annually. Besides high expenses, when it comes to performing experiments and analyzing results much time and high accuracy will be required, which will thus make it essential to employ experts.

The construction site where this study was carried out at is Ahvaz city, the capital of Khuzestan province which is located at south-west of Iran. Ahvaz soil has different stratifications in terms of material, grading and generally in terms of soil classification in such way that the substrate layer lies in different depths of city, in other words first one the soil profiles from north half of the route mainly consisted of fine grain clay and silty layers over the bedrock formation consisting of red marl, siltstone and sandstone at a shallow depth. Second part, the soil profiles from the south half of the route on which the bedrock formation falls below a depth of 40 m under young alluvial despites due to the presence of the ahvaz fault. The young alluvail despite consists of layers of fine to medium sand. Clay and silt with low to medium density and thus at different part of city we will observe different resistance and

**Author for correspondence*

settleability[1]. As it mentioned before, the geotechnical studies require a great deal of time and expense, thus an estimation of compression index can greatly help projects' initial calculations. The empirical studies on estimating the compression index are given in Table 1.

Table 1 some of empirical relations presented by various scientists are given.

Table 1. Empirical equations to estimate the coefficient of compressibility

Reference	Equation
2	Cc = 1.15(e - e0)
3	Cc = 0.28e0 -0.015
5	Cc = -0.002FF+0.276 FF(the percentage fine fraction content)
6	Cc = 0.28e0 -0.054
7	Cc = 0.0115wn
7	Cc = 0.208e0 + 0.0083
7	Cc = 0.156e0 + 0.0107
7	Cc = 0.156e0 + 0.0107
7	Cc = 0.048(LL - 10)
8	Cc = 0.008(LL - 12)
8	Cc = 0.007(SI + 18)
8	Cc = 0.014(PI + 3.6)
8	Cc = 0.008(LL - 12)
9	Cc = 0.29(e0 - 0.27)
9	Cc = 0.35(e0 - 0.5)
9	Cc = 0.29(e0 - 0.27)
9	Cc = 0.35 (e0 - 0.5)
10	Cc = 0.009wn+ 0.005LL
0	Cc = 0.01wn
11	Cc=0.302(e0-ep)+0.064
12	Cc=0.0048*Wc.Gs-0.096
13	Cc = 0.01(wn - 7.549)
14	Cc = 0.063(LL - 10)
15	Cc = 0.007(LL - 10)
6	Cc = 0.01(wn - 5)
16	Cc = 0.006(LL - 9)
16	Cc = 0.037(e0 + 0.003LL - 0.34)
6	Cc = 0.048(e0 + 0.001wn - 0.25)
6	Cc = 0.37(e0 + 0.003LL+ 0.0004wn - 0.34)
17	Cc = 0.009(LL - 10)
17	Cc = 0.009(LL - 10)

According to Table 1 which listed relations based on different parameters for estimation of compressibility coefficient, after investigation of different soil parameters for estimation of compressibility coefficient, no specific relationship was observed between these parameters and compressibility coefficient.

According to Table 1, most researchers have studied different parameters of soil. For example In[2] theoretically proved the relation between compressibility index and initial void ratio while others worked on experimental specimens. Regarding the presented formulas, there is mostly a relation between compressibility index and initial void ratio, and they mostly offered a linear relation.

A considerable fact about suggested relations is that almost all of them are suggested to all types of soil, while there is much difference between relations and one can't surely apply one relation for estimating the compression index. To calculate the compression index[3] in Ahvaz soils presented a relation which had examined a few number of samples. So we have tried to cover two major subjects in this study which has lasted over two years and has provided more than 130 undisturbed specimens from Ahvaz city soil, first to present a formula for calculating the compressibility index, then investigating the accuracy of relation suggested by Ahadian, which has been obtained through fewer specimens. It must be mentioned that as all the districts of Ahvaz city were sampled, and regarding the nature of the city which was mentioned before; in some places of the city Mudstone and sandstone were found in depths less than 2 m. therefore no undisturbed samples were provided from these sites and hence, they were not used in samples calculations.

2. Materials and Methods

Lots of empirical relations has been suggested on soil's potential in terms of estimating consolidation settlement, but they can't be employed for all the areas, but in this study we have examined more than 130 undisturbed specimens obtained from different depths which are results of two years geotechnical studies. This distribution of samples indicates in the Figure 1. All the standard tests have been conducted on samples, including one dimensional consolidation, in-situ humidity, determining the Atterberg limits, determining specific dried weight, and grading.

Figure 1. Distribution of samples in Ahvaz City.

After excavation which has been done by drilling machine (Figure 2) and extracting the undisturbed sample from different depths, the sample's Shelby was completely covered by a thick plastic bag and then was taken to laboratory to execute the experiments (the Shelby was made of PVC tube with diameter of 2.15 inch and length of 20 inch). After that the Shelby was taken to the lab and the sample was brought out of it, some of the soil was taken for humidity test and some was taken and put in the consolidation cell (Figure 3) to execute the one dimensional consolidation test.

The standard oedometer test is carried out on a cylindrical specimen of saturated soil with the dimension of around 50 mm diamater and 20 mm thick. The soil sample is enclosed in a metal ring and is placed on a porous stone. The loading cap has also a porous stone, so the sample is sandwiched between two porous stones. When preparing the sample, filter papers are added between the soil and the porous stones. The sample is then mounted in the consolidation cell and the loading unit. Water is added into the cell around the sample, so the sample remains saturated during the test. The two porous stones at the top and bottom of the sample allow a two-way drainage of the sample.

The test involves applying increments of vertical static load to the sample and recording the corresponding settlement. Increments of vertical static load are usually applied using dead loads and a static loading system. The change in the thickness of the sample against time is recorded during each loading increment. The duration of the application of each load depends on the soil and its consolidation characteristics. Once equilibrium reached for a loading step, the next increment is applied. The load is doubled at each increment until reaching the maximum required load, 0.25, 0.50, 1.00, 2.00, 4.00, 8.00 kg/cm^2. The range of applied stress depends on the range of effective stress which is needed in the consolidation analysis of the case under consideration[4].

When the full consolidation at the maximum applied load is reached, the sample is unloaded in one or several stages and the swelling of the sample is recorded. At the end of the test, the sample is carefully removed and its thickness and water content is measured[4].

Figure 2. Excavation which has been done by drilling machine.

Figure 3. One Dimensional Consolidation test and Hydrometer test.

After consolidation test, the grading, hydrometer, and determining the Atterberg limits including determining the percentage of plastic and liquid limits humidity tests were carried out on all specimens. According to the obtained results of the samples, it can be observed that almost all the studied soil samples could be classified as clay with low plasticity according to unified CL classification. The results about classification can be seen in Figure 4.

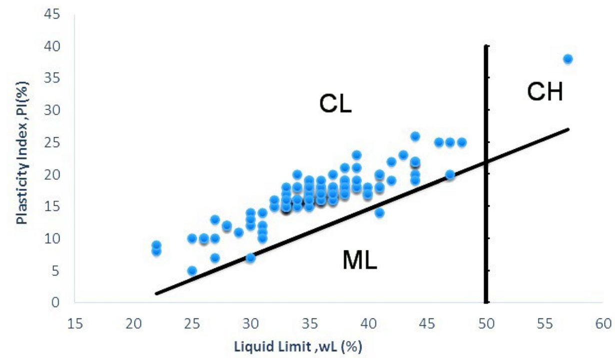
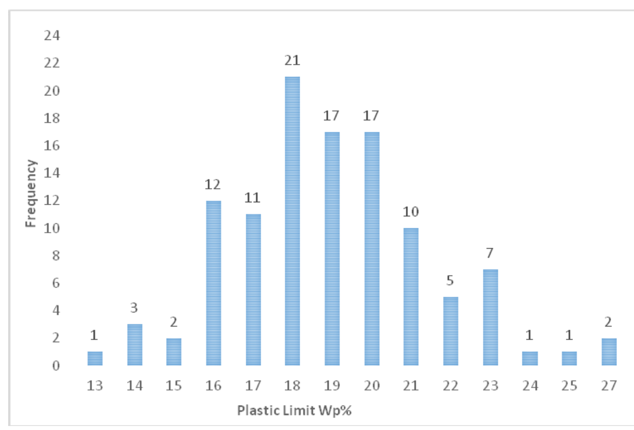
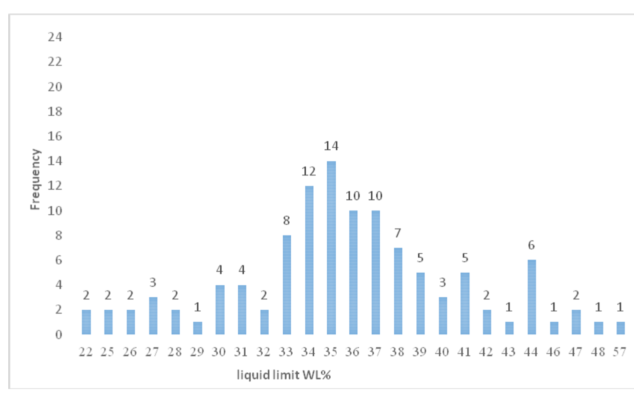


Figure 4. Samples classification based on Unifid soil classification method.

After all mentioned tests were completely carried out; the obtained data was analyzed by Nova Studio software. The results are given in Figures 5 and 6.





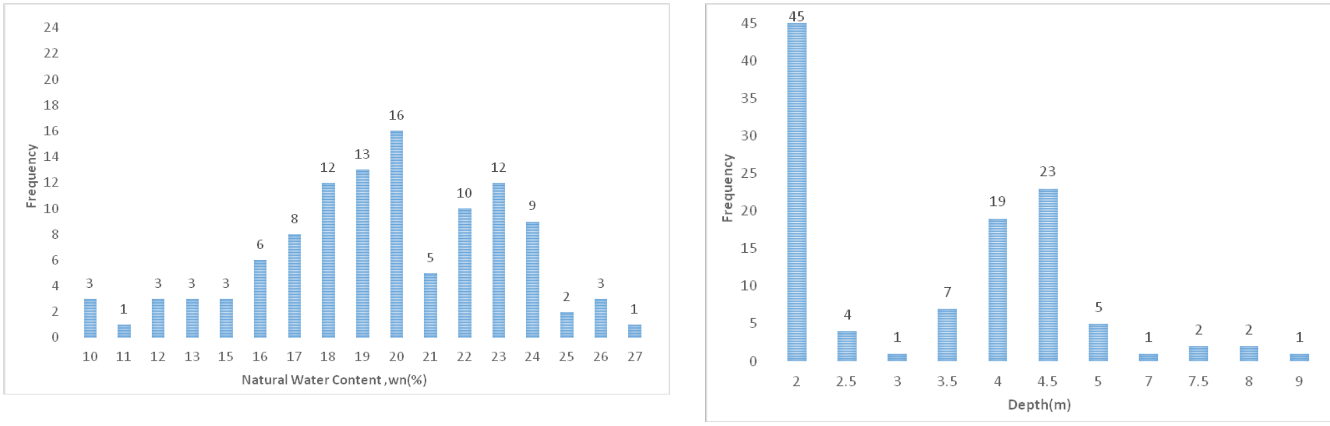


Figure 5. Frequency of all samples, Depth, PL, LL, Wn.

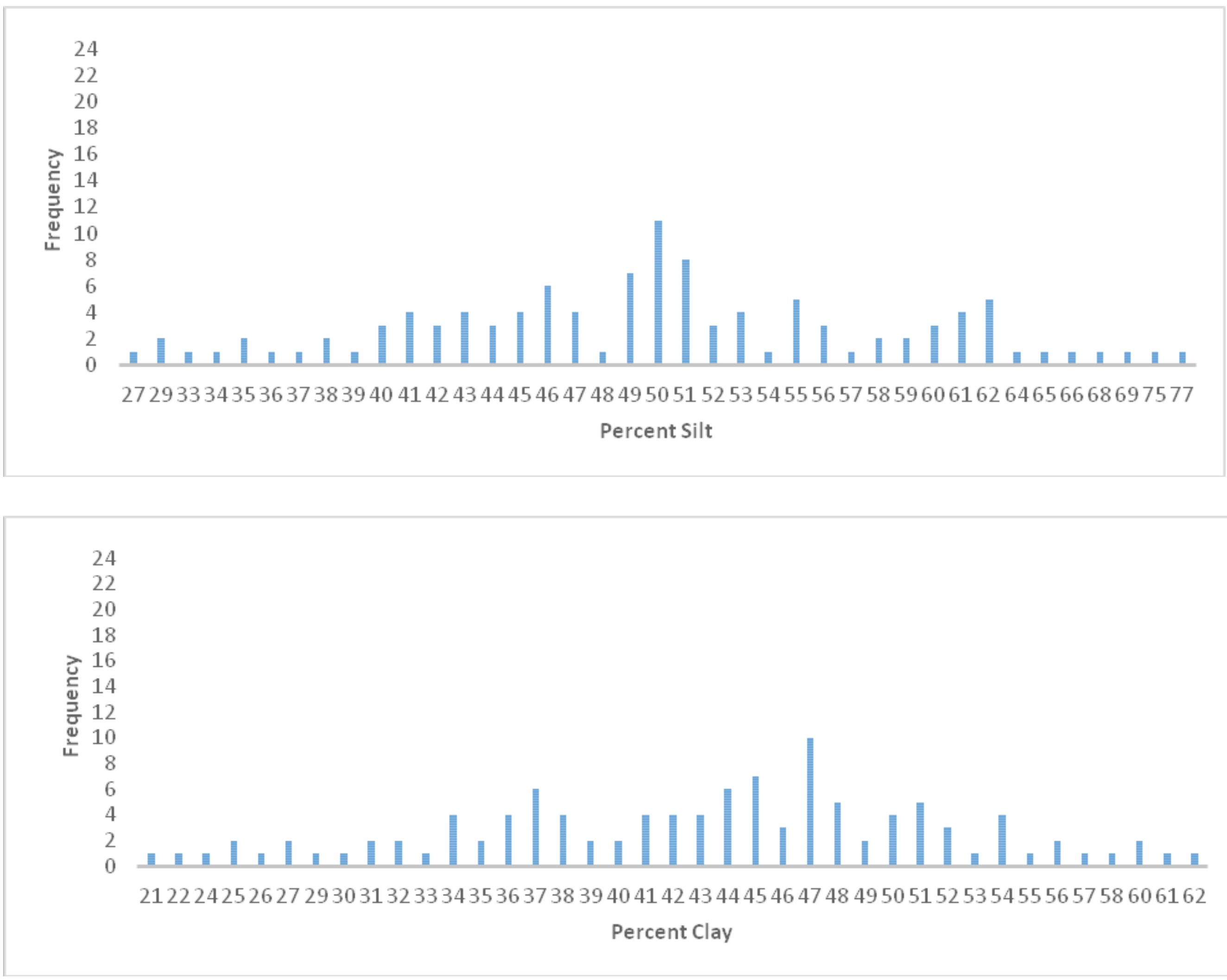


Figure 6. Frequency of all samples the percentage of fine fraction.

Based on the obtained results shown in Figures 5 and 6, it can be said that more than 90% of the undisturbed samples were prepared from depths less than 5 m; therefore these results can be used for more accurate estimation of settlement. More than 80% of samples had plastic limit in range of 16% to 21% and moreover, more than 50% of samples had liquid limit of 33-39%. The natural humidity of more than 80% of the studied samples were less than 20% and as it was in the plastic limit range of the samples, it showed relative hardness and stiffness of the soils.

3. Results and Discussion

The results include calculations on indices of laboratory settlement of consolidation test, and also determination of statistical correlation between the compression index and soil's physical parameters.

After conducting all the tests and analyzing results, the compression index and initial porosity ratio of all samples were calculated. Results are given in Table 2. According to this table, the initial void ratio varies from 0.41 to 0.78, and the compression index also varies from 0.108 to 0.32, for all samples. Distribution of these two indices is shown in Figure 7. According to frequently chart shown in Figure 7. The highest number of samples' void ratio lies within 0.5 to 0.6, and the highest number of compression index is in 0.15 to 0.2.

To investigate the initial void ratio of samples and compression index more and to find a reasonable relation between them, they were drawn in one diagram and the best line was fitted so in case it's possible, the relation between these two is derived. The result is shown in Figure 8. We have tried to present a linear relation to estimate the compression index so that deriving conclusions be done shortly as well as easily.

Regarding Figure 8 and the drawn line, a good correlation can be seen between mentioned formula and changes of initial void ratio and compression index. One thing we

Table 2. Results of initial void ratio and compression index for all soil samples

Cc	e.	Cc	e.	Cc	e.	Cc	e.	Cc	e.
0.192	0.62	0.152	0.5	0.158	0.596	0.154	0.562	0.32	0.78
0.2	0.61	0.16	0.54	0.244	0.651	0.244	0.651	0.168	0.519
0.22	0.64	0.158	0.58	0.244	0.651	0.25	0.668	0.152	0.557
0.18	0.54	0.268	0.68	0.146	0.517	0.21	0.639	0.142	0.511
0.158	0.59	0.156	0.564	0.19	0.611	0.136	0.471	0.156	0.473
0.158	0.58	0.25	0.67	0.244	0.651	0.16	0.565	0.12	0.447
0.17	0.54	0.162	0.58	0.156	0.573	0.152	0.557	0.152	0.496
0.274	0.69	0.158	0.596	0.124	0.454	0.162	0.511	0.13	0.467
0.18	0.52	0.156	0.576	0.19	0.527	0.16	0.565	0.152	0.558
0.2	0.61	0.244	0.651	0.114	0.445	0.156	0.478	0.2	0.639
0.158	0.59	0.28	0.73	0.18	0.535	0.16	0.57	0.112	0.437
0.122	0.45	0.154	0.562	0.156	0.517	0.188	0.602	0.13	0.467
0.16	0.6	0.144	0.517	0.264	0.676	0.19	0.611	0.16	0.517
0.158	0.59	0.16	0.507	0.13	0.467	0.16	0.583	0.156	0.595
0.16	0.6	0.156	0.576	0.158	0.552	0.21	0.639	0.148	0.543
0.15	0.55	0.172	0.583	0.124	0.454	0.142	0.512	0.2	0.639
0.22	0.64	0.188	0.611	0.156	0.576	0.196	0.526	0.108	0.411
0.18	0.48	0.248	0.644	0.164	0.519	0.208	0.639	0.112	0.437
0.16	0.51	0.154	0.559	0.156	0.488	0.158	0.488	0.148	0.543
0.18	0.6	0.19	0.609	0.172	0.536	0.148	0.543	0.272	0.684
0.17	0.48	0.156	0.576	0.15	0.511	0.15	0.502	0.16	0.587
0.186	0.6	0.212	0.639	0.172	0.536	0.15	0.551	0.15	0.546

can mention about the formula is that this relation is able to accurately estimate the compression index in samples with initial void ratio less than 0.45. But at higher initial void ratios (up to 0.55) the accuracy of formula decreases, so that the highest error recorded of initial void ratio between0.454 and 0.55, is about 17%. After this range, and up to void ratio of about 0.65, the formula acts rather conservatively, and estimates higher amounts for the compression index; however it is less than 17%. Passing initial void ratio of 0.65, the formula suggests even less amount for compression index, the error is about 10%. To determine the suggested formula's applicability compared to previously suggested formulas which had similar

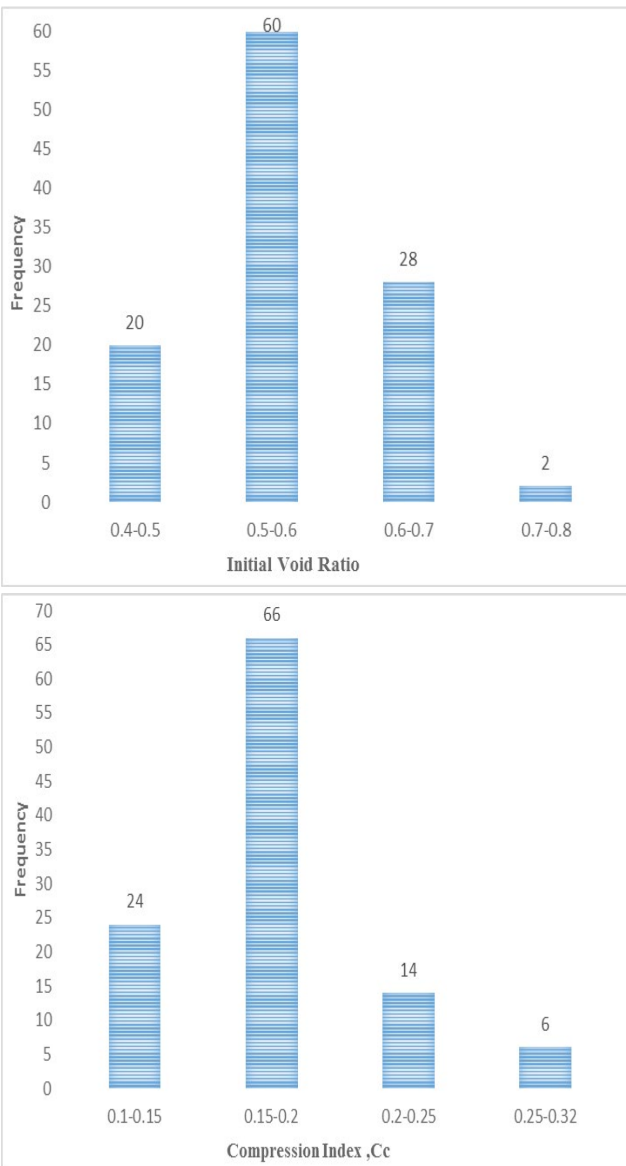


Figure 7. Distribution of Compression Index and Initial Void Ratio.

parameters, the accuracy of formula will be assessed as follows. Therefore, $C_C = 1.15(e_0 - 0.35)^2$ formula: due to theoretical bases of relation between two indices, $C_C = 0.40(e_0 - 0.25)$:[16]due to large number of samples (around 700), $C_C = 0.28e_0 - 0.054$ formula[6]: due to suggesting a formula for Iran's soils, and $C_C = 0.28e_0 - 0.015$ formula[3]: due to suggesting a formula for estimating the compression index of Ahvaz's clay have been used, which the result can be seen in Figure 9.

Table 3. Calculation of the statistical error of empirical relations on estimating the compression index

References	Equation	RMSE
2	$C_C = 1.15(e_0 - 0.35)$	0.09
16	$C_C = 0.40(e_0 - 0.25)$	0.05
6	$C \ \ = 0.28e \ - 0.054$	0.08
3	$C_C = 0.28e_0 - 0.015$	0.04
suggested formula this Study	$C_C = 0.506e_0 - 0.11$	0.02

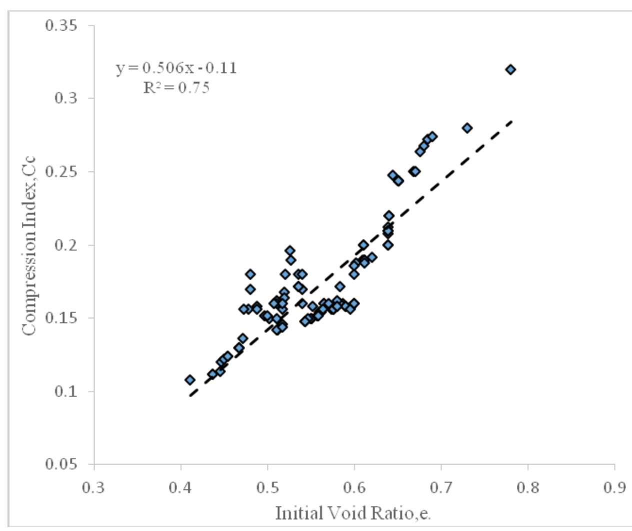


Figure 8. Relation between initial void ratio of samples and compression index.

According to the results shown in Figure 9, none of all equation, cannot accurately estimate the compression index of tested soils and only $C_C = 0.28e_0 - 0.015$

formula[3] can reach a rather acceptable estimate in initial void ratios less than 0.47 and between 0.55 and 0.6, and for all initial void ratios estimates a less amount of compression index than real amount.

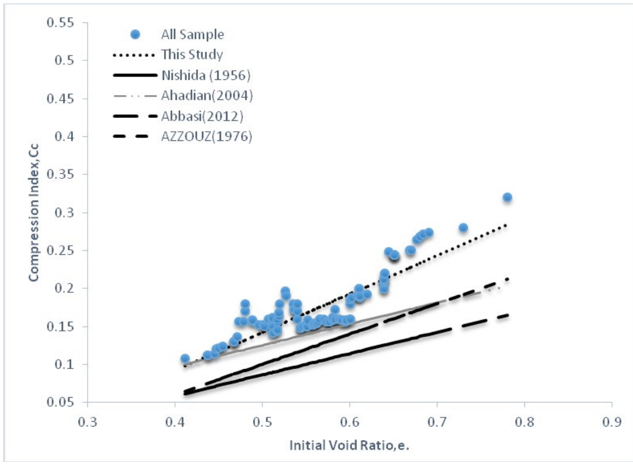


Figure 9. Comparisons between previously suggested formulas and current formula to estimate the compression index.

To examine different empirical formulas capability of estimating the compression index of Ahvaz city soils, we have used the statistical parameter RMSE. The parameter's calculated values are shown in Table 3.

The best relation for estimating the compression index of Ahvaz soil is one with least RMSE (the closer RMSE gets to zero, the better can the formula estimate). According to Table 3, the relation suggested in this study shows lowest statistical error, and thus meets the required accuracy to estimate the compression index.

4. Conclusion

Results obtained from this study, include:

- In current study, regarding the theoretical relation between compression index and initial void ratio, the statistical relation between these parameters has been studied for samples extracted from Ahvaz soil.
- The best relation to estimate the compression index of Ahvaz city soil, is $C_C = 0.506\,e_0 - 0.1$ which uses the initial voidratio.
- The highest error obtained in this study is about 17%.

5. References

1. Pakbaz MS, Vafaeian MM, Bagherinia K. Numerical prediction of subway induced vibrations: case study in Iran-Ahwaz City. Journal of Applied Sciences. 2009; 9(11):2001-15. Crossref.
2. Nishida Y. A Brief Note on Compression Index of Soil. Journal of the Soil Mechanics and Foundation Engineering Proceedings of the American Society of Civil Engineers. 1956; 82(3):1-14.
3. Ahadian J, Bajestan SHM, Abn Jalal R. Estimate fourmula for compression index in ahvaz soil's. University of Tabriz Journal. 2004; 35(2):66-73.
4. ASTM D2435 - 04 Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading.
5. Chandra B, Solanki CH, Vasanwala SA. Influence of Fine Fraction on Shear Parameters and Consolidation Behavior of Tropical Residual Soil. Indian Journal of Science and Technology. 2016; 9(41):1-7.
6. Abbasi N. Prediction of Compression Behaviour of Normally Consolidated Fine-Grained Soils. World Applied Sciences Journal. 2012; 18(1):06-14.
7. Bowles JW. New York: McGraw Hill: Physical and Geotechnical Properties of Soil. 1979; p. 1-10. PMid:456581.
8. Sridharan A, Nagaraj HB. Compressibility behaviour of remoulded, fine-grained soils and correlation with index properties. Canadian Geotechnical Journal. 2000; 37(3):712-22. Crossref.
9. Hough B. Basic soil Engineering. New York: Ronald Press. 1957; 12:319-35.
10. Koppula SD. Statistical Estimation of compression Index. Geotechnical Testing Journal.1981; 4(2):68-73. Crossref.
11. Ozer M. A statistical and neural network assessment of the compression index of clay-bearing soils. Bulletin Engineering Geology and the Environment. 2008; 67(4):537-45. Crossref.
12. Papke M. Studying Consolidation Characteristics of Ohio Geo-Frontiers Conference Dallas: ASCE. 2011; p. 2838-46.
13. Herrero RO. Universal Compression Index Equation. Journal of Geotechnical Engineering. 1983; 109(5):755-61.
14. Abdrabbo FM, Mahmud MA. Correaltions beetwen index test sand compressibility of egyptian clays. Soils and Foundations. 1990; 30(2):128-32.
15. Skempton A. Notes of the compressibility of clays. Quarterly Journal. 1944; 100:119-35. Crossref.
16. Azzouz. Regression Analysis of Soil Compressibility. Quarterly Journal of the Soil and Foundations. 1976; 16(2):19-29. Crossref.
17. Terzaghi K. New York: John Wiley and Sons: Soil Mechanics in Engineering Practice (2nd Edition). 1967.