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Research on predictive model of C_c compressibility index of clay in Thai Nguyen

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Abstract: *Using the geological data collected statistically and combining the actual experimental survey of soil and rock samples in the area. The authors tested the correlation functions used to predict the compression index C_c from e_0, W_L through the univariate regression analysis method available for geological data in Thai Nguyen. The results show that all four models predict that the C_c compression index has a very low correlation with the true value (less than 60%). At the same time, the authors conducted regression analysis for a dataset of 500 samples to find out the relationship between the compression index (C_c) and e_0, W_L and w_n of the sticky soil in Thai Nguyen. They have proposed three functions to predict the compression index C_c with the correlation R^2 between experimental data and forecast data both above 0.6.*

Keywords: *Correlation function, Geology, Compression index, Thai Nguyen, Sticky soil.*

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I. INTRODUCTION

Thai Nguyen city is located in the center of Thai Nguyen province, 80 km north of Hanoi's capital. The total natural area is 18,970 ha, of which 2,382.67 ha of construction land. The administrative unit includes 18 wards and 10 communes, limited to To the North: Dai Tu district, Phu Luong district, Dong Hy district. The South borders: Song Cong town. The West borders: Dai Tu district. The East borders: Phu Binh district. Thai Nguyen city has 28 administrative units, wards, and communes. 18 wards including: Tan Long, Quan Trieu, Quang Vinh, Hoang Van Thu, Tuc Duyen, Dong Quang, Quang Trung, Phan Dinh Phung, Trung Vuong, Gia Sang, Cam Gia, Huong Son, Tan Thanh, Trung Thanh, Tan Lap , Phu Xa, Tan Thinh, Thinh Dan. And 10 communes: Luong Son, Tich Luong, Thinh Duc, Quyet Thang, Tan Cuong, Phuc Triu, Phuc Xuan, Phuc Ha, Cao Ngan and Dong Bam.

In the region, there is a system of tributary streams, which mainly flow in the North-South direction, into the Cau River. Cau River is the main river of the province and almost divides Thai Nguyen province into two equal halves in the north-south direction. The river begins to flow into Thai Nguyen from Van Lang commune, Dong Hy district, and reaches Nga Mi commune, Phu Binh district. The river becomes the natural boundary between Thai Nguyen and Bac Giang provinces and then completely exits the province in Thuan Thanh commune, Pho Yen district. In addition, Thai Nguyen has a number of other rivers and streams, but most of them are tributaries of the Cau River.

The terrain of Thai Nguyen City is quite flat. However, this land still has the character of midland appearance with alluvial terraces and artificial stairs, new alluvial terraces, and mixed-layer terraces (sloping land) with gentle hills, upside-down bowls. each other occupying 50.2% of the natural area. The average agricultural land area of the city is 425.55 m2/person, concentrated mainly in the western and southwestern communes: Phuc Xuan, Phuc Triu, Tan Cuong, Thinh Duc, Luong Son.

In the field of construction in general and soil mechanics in particular, experimental work often takes a lot of time and is expensive in terms of costs. Therefore, it is necessary to use easily identifiable physical parameters to predict the mechanical properties of soil. Compression index C_c is mentioned in many standards and regulations of Vietnam and the world as the most basic criteria used in calculating settlement of soil and building foundations. Therefore, it is extremely important to evaluate and build models used to predict soil compaction indexes from basic physical criteria.

Soil settlement is a rather complicated issue. The sandy soil that is compacted in a short period of about a few years is a stable construction. But clay compaction process can take up to decades. Wherever there's a problem with the foundation, it's usually the clay. Clay often has a diverse structure. Clay layers from soft to hard and non-tight have very different load-carrying capacities. The phenomenon of settlement of clay is an issue to consider when calculating the structure of the foundation.

For clay, the initial moisture content (w_n) and the initial void ratio (e_0) have a great influence on the properties of the soil, especially the soil state. Besides, many studies also show that the compressive index of soil depends on the liquid limit (W_c) and plastic limit (W_L) of the soil [2; 3; 4; 6; 7; 8; 9; 10].

II. METHODOLOGY

The authors use statistical collection methods, actual surveys, analysis of documents, and data related to the research problem. Conduct soil and rock sampling experiments and analyze soil and rock samples. Additional engineering geological survey drilling. Based on scientific theories, as well as practical situations, comments, evaluations, and practical applications. The authors have conducted experiments in combination with data collection to evaluate the reliability of some compression index prediction functions widely used in the world for Thai Nguyen soil. Currently, in the world, there are many correlation functions used to predict the compression index Cc from e0, WL through univariate regression analysis. The authors test the existing models for geological data in Thai Nguyen. Proposing predictive functions based on single and multivariable linear regression methods for clay soil in the Thai Nguyen area.

The collection of engineering geological survey documents already in the study area serves as a justification for the research task to reduce the workload of the engineering geological survey. On the other hand, this work brings economic efficiency, avoiding waste due to duplication between geological exploration works. The collected documents are guaranteed to be complete, accurate, and clear. The collected documents include all documents related to geotechnical conditions in the study area, specifically:

- Documents on geology, stratigraphy, topography, hydrogeology of the area, map of the current state of the study area.
- Documentation of geological survey works that have been and will be built in the study area.
- Documentation of soil sample testing of drilled holes at construction sites.
- Collecting experimental data of soil and rock samples of 510 boreholes, each drill hole is 10-50m deep.

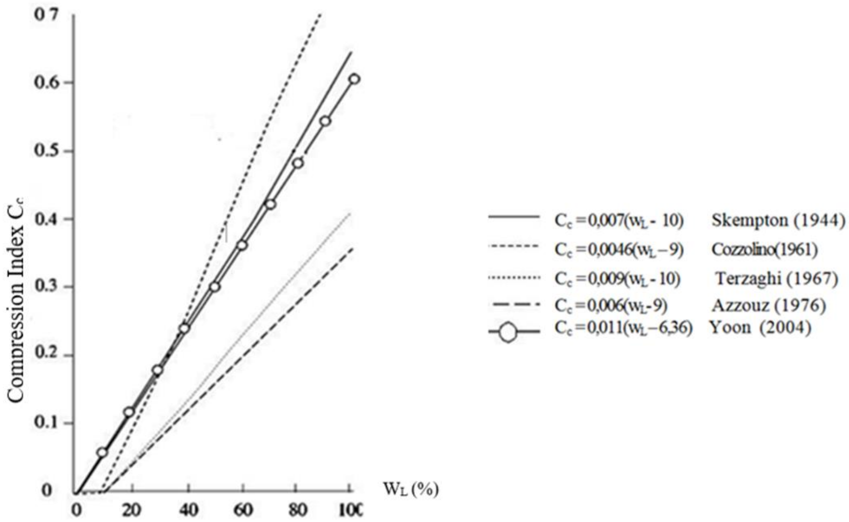

Figure 1. Compression index (C_c) forecast from yield strength (W_L)

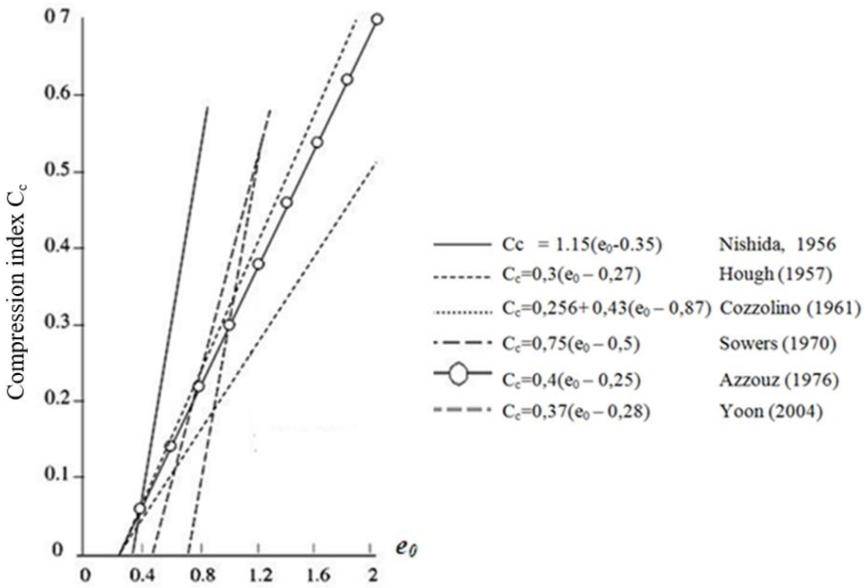

Figure 2. Compression index prediction chart (C_c) from initial void ratio (e_0)

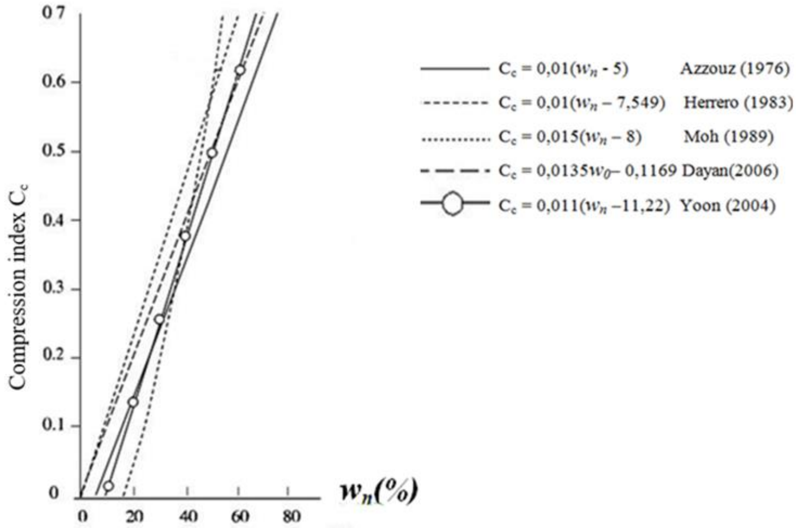

Figure 3. Compression index prediction graph (C_c) from initial void coefficient (w_n)

Table 1. Some models to predict compression index (C_c) from many criteria (w_n);(e_0);(w_L)

Authors	Formula	Note
Azzouz and associates (1976)	$C_c = 0,37(e_0 + 0,003W_L + 0,0004\ w_0 – 0,34)$	All clay
Koppula (1986)	$C_c = 0,009\ w_0 + 0,005W_L$	All clay
Yoon and associates (2004)	$C_c = 0,0038\ w_0 + 0,12\ e_0 + 0,0065\ W_L –0,248$	West Korea

Evaluation of correlation: Sample correlation coefficient R^2 is a variable from -1 to +1 evaluated according to Kalomexki as follows:

If 0< $R^2 \leq$ 0,5$\rightarrow$ correlation is very weak.

If 0,5 < $R^2 \leq$ 0,7$\rightarrow$ weak correlation.

If 0,7 < $R^2 \leq$ 0,9$\rightarrow$ degree of close correlation.

If 0,9< $R^2 \leq$ 1$\rightarrow$ correlation is very tight.

Testing existing models for geological data in Thai Nguyen: Evaluation results of predictive models of compression index C_c from W_L, e_0, w_n based on experimental data set [1,5].

C_c compression index prediction from W_L: The results show that the model Yoon et al (2004) has the highest correlation coefficient corresponding to the correlation R^2 = 0.41. The above correlation shows that the models proposed in Figure 1 are not suitable for the soil in the Thai Nguyen area.

Table 2. Comparison between the compression index C_c predicted from W_L and experimental data

Authors	**Standard deviation (%)**	**Absolute Standard Deviation (%)**	**Correlate R^2**
Azzouz (1976)	32,0	45,2	Very low
Cozzolino (1961)	13,2	42,5	
Skempton (1944)	28,3	43,5	
Terzaghi & Peck (1967)	7,2	39,7	
Yoon and associates (2004)	29,7	49,6	0,41

Forecast of compression index C_c from e_0:

The results show that the model Yoon et al (2004) gives the best prediction results with the correlation coefficient between experimental data and forecast R^2 = 0.69. Other models show very low correlation coefficients.

Table 3. Comparison between the compression index C_c predicted from e_0 and experimental data.

Authors	**Standard deviation (%)**	**Absolute Standard Deviation (%)**	**Correlate R^2**
Nishida (1956)	31,7	39,7	Very low
Cozzolino (1961)	35,8	37,8	
Hough (1957)	11,5	30,1	
Azzouz (1976)	76,7	74,0	
Sowers (1970)	70,5	69,5	
Yoon and associates (2004)	13,1	26,5	0,69

C_c compression index prediction from w_n:

The results show that two models: Azzouz et al. (1976) and Yoon et al. (2004) have the best prediction of compression index C_c with the correlation coefficient between experimental data and prediction of R^2 respectively. = 0.76 and 0.82. Other models give much lower correlation coefficients.

Table 4. Comparison between compression index C_c predicted from w_0 and experimental data

Authors	**Standard deviation (%)**	**Absolute Standard Deviation (%)**	**Correlate R^2**
Azzouz and associates (1976)	16,1	26,6	0,76
Herrero (1983)	24,8	30,3	0,51
Moh and associates (1989)	71,2	72,2	Very low
Dayal and associates (2006)	49,9	52,1	
Yoon and associates (2004)	11,9	23,1	0,82

Prediction of compression index C_c by multivariable model from W_L, e_0 , w_n:

Table 5. Comparison between compression index C_c predicted from multivariable model and experimental value

Authors	**Standard deviation (%)**	**Absolute Standard Deviation (%)**	**Correlate R^2**
Azzouz and associates (1976)	23, 1	28,8	Very low
Koppula (1986)	96,9	97,5	
Yoon and associates (2004)	3.1	25,2	0,53

The results show that all four models predict that the C_c compression index has a very low correlation with the true value (less than 60%). Therefore, these models are not suitable for the soil in the Thai Nguyen area.

From the above results, it shows that the predictive models of C_c compression index all show a very low correlation with real experimental data, except for the models: Azzouz et al (1976) and Yoon et al (2004). Based on the univariate linear regression method [10], the authors conducted regression analysis for a dataset of 500 experimental samples to find out the relationship between the compression index (C_c) and: w_L; e_0 and w_n.

III. RESEARCH RESULTS

The results of the regression analysis are shown in Figures 4 to 6 below.

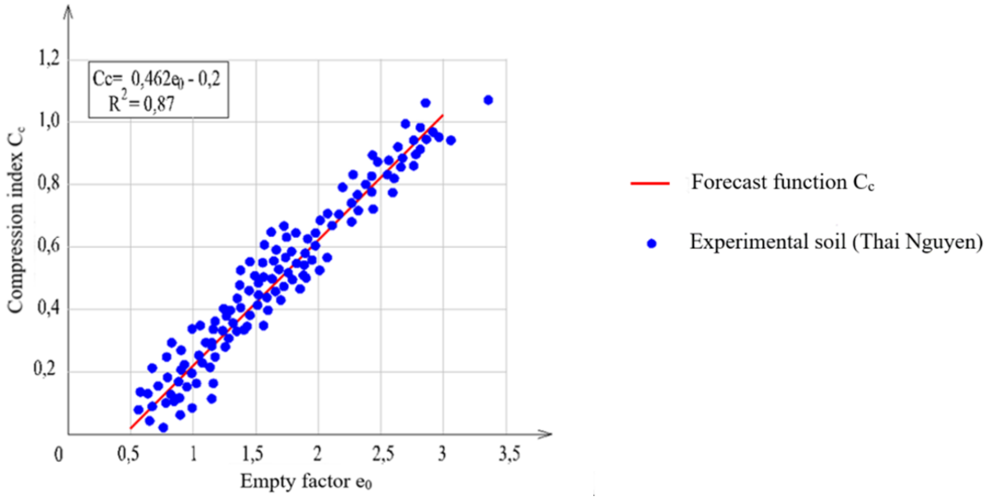

Figure 4. Relationship between compaction index (C_c) and initial void ratio e_0 for 200 soil samples tested.

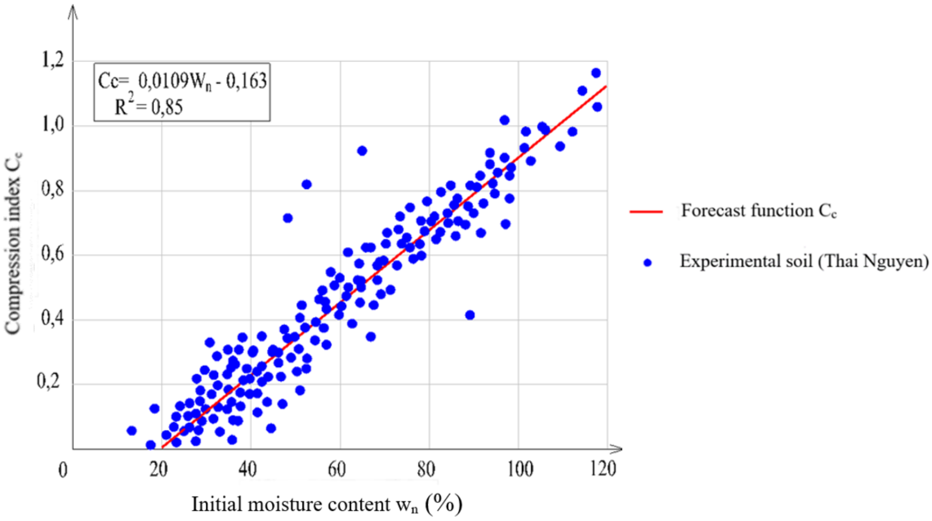

Figure 5. Relationship between compression index (C_c) and initial moisture content (w_n) for 200 soil samples

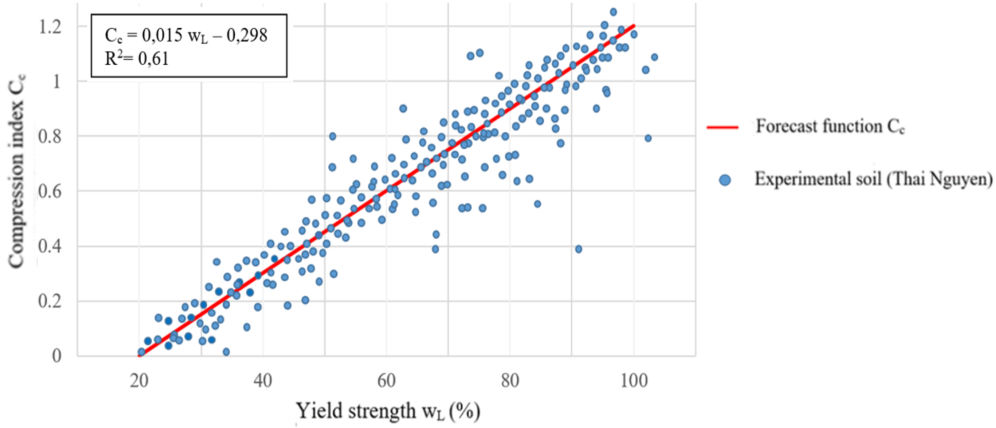

Figure 6. Relationship between compressive index (C_c) and yield strength (w_L) for 200 soil samples

IV. CONCLUSION

Through analysis and comparison between the predicted data of Cc compression index from the collected models and experimental data, the results are as follows:

- Most of the models that predict the compression index C_c over the yield limit w_L found by the author are not suitable with the dataset obtained from the Thai Nguyen area.

- In the models that predict C_c from initial void ratio (e_0) and initial moisture (w_n), there are two models: Azzouz et al. (1976) and Yoon et al (2004) with similar coefficients. The correlation (R^2) between forecast and experimental data is quite good, greater than 0.6.

- The authors used the univariate regression method to build three predictive functions of the compression index C_c with the correlation R^2 between experimental data and forecasted data being above 0.6.

From the basic physical criteria of the soil, the author's team evaluated and built models used to predict the settlement index for calculating the foundation of the building. The authors used the univariate regression method to build three predictive functions of the compression index C_c with the correlation R^2 between experimental data and forecast data all above 0.6.

Forecast equation	Correlation coefficients R^2
$C_c = 0{,}015\ w_L - 0{,}298$	0,61
$Cc = 0{,}462\ e_0 - 0{,}2$	0,87
$Cc = 0{,}0109\ w_n - 0{,}163$	0,85

Conflict of interest

There is no conflict to disclose.

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