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Research on correlation between compression index (Cc) and other properties of soil for geotechnical design in coastal regions of Vietnam and cambodia

Abstract

Compression index (C_c) takes an important role in settlement prediction for engineering foundation. Value of C_c depends heavily on methods of taking sample, sample transportation, quality of laboratory testing equipment, laboratory staff experience. These works are not well controlled in developing countries such as Vietnam and Cambodia. Our research is to find out the most suitable correlation between Cc and other properties of weak soil layer in coastal regions of Vietnam and Cambodia. From that, authors propose a new formula showing the correlation between C_c and liquid limit (LL) of the soil layer for geotechnical design in Vietnam and Cambodia.

Keywords: compression index (cc), correlation, settlement

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Introduction

International and Vietnamese scientists have proposed many correlations between physical and mechanical properties of soil for geotechnical design. But, only some of them are suitable for construction areas in Vietnam and Cambodia. This research will find out and propose some suitable correlations between some physical and mechanical properties of very soft to soft dark grey lean Clay in these areas. This weak soil layer has wide distribution and great thickness and greatly affects stability and settlement of construction works, but methods of taking sample, sample transportation, quality of laboratory testing equipment, laboratory staff experience and in-situ tests performed in the layer do not often meet the technical requirements for geotechnical design in Vietnam and Cambodia.

Data used in this paper are received from geotechnical investigation results in Quang Ninh, Nghe An, Soc Trang, Quang Ngai provinces, Ho Chi Minh city of Vietnam and Sihanoukville province of Cambodia. Research areas are shown in Figure 1 below.

Figure 1 Location map of research areas.

Overview of the study subject

The meaning of compression index (C_c) in geotechnical design

Compression index (C_c) is mentioned in a lot of construction standards in Vietnam and other countries in the world. It takes an important role in settlement prediction for engineering foundation.

Settlement prediction of each soil layer is calculated by the following formula:

$$\Delta S_c = \frac{C_c}{1+e_0} H_i \log\left(\frac{\sigma'_o + \Delta\sigma'}{\sigma'_o}\right)$$

Where:

ΔS_c: Consolidation settlement of the soil layer;

C_c: Compression index;

H_i: The thickness of the soil layer.

e_o: Initial void ratio.

σ'_o: Initial stress at the middle of the soil layer.

$\Delta\sigma'$: Effective stress increase at the middle of the soil layer.

Therefore, the evaluation and determination of correlation between Cc and other properties of soil have extremely important meaning in geotechnical design.

Research areas in vietnam and cambodia

Vietnam's coastline stretches the entire length of the country, about 3260kilometers and just about 443kilometers for Cambodia. Vietnam and Cambodia have a tropical monsoon climate, large rainfall amount.

The geological structure of the research areas contains a thick, soft to very soft marine dark grey lean clay layer with the thickness of

5 to 50m (Figure 2) which creates dangerous engineering-geological processes, including land subsidence and deformation of buildings and other structures.

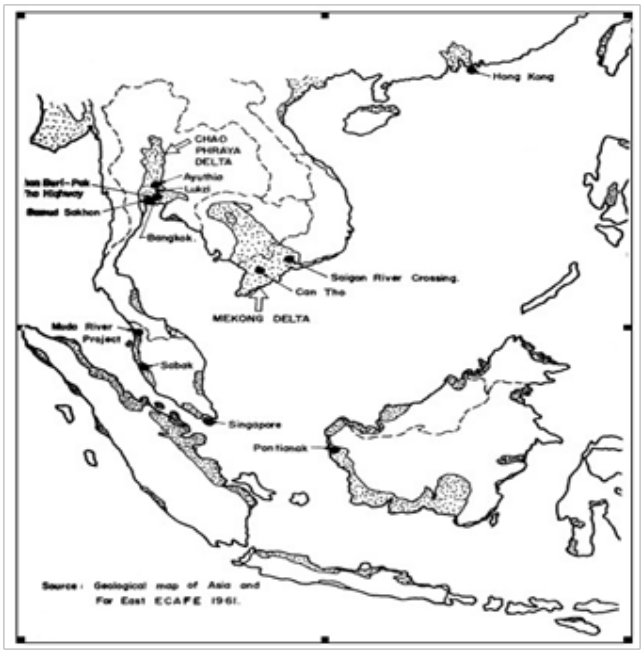

Figure 2 Distribution of marine clay in South East Asia (Cox, 1968).

Average value of some physical and mechanical properties of the layer is as follows:

I. Natural moisture content (W): 55.8-53.3%;

II. Natural unit weight (ρ): 1.62-1.58g/cm^3;

III. Natural void ratio (e_o): 1.470-1.400;

IV. Liquid limit (LL): 45-60%;

V. Plasticity index (PI): 16.9-15.9%;

VI. Cohesion (c): 7.0-8.9kPa;

VII. Internal friction angle (φ): $5^0$33' - $5^0$49';

VIII. Compression index (Cc): 0.40-0.58.

Table 2 Determination of Cc at Cai Lan Port - Quang Ninh province

No.	Soil name	PI (%)	e_0	LL (%)	ρ (g/cm^3)	Sridha- ran and nagaraj	Hough	Tsuchi-da	Skemp-ton	Terza-ghi and peck	Proposed by authors	Lab
1	Lean clay with sand	8.20	0.82	26.31	1.92	0.17	0.16	0.16	0.14	0.15	0.22	0.25
2	Fat clay with sand	32.51	1.51	50.69	1.63	0.51	0.36	0.38	0.31	0.37	0.44	0.40
3	Fat clay	51.88	3.30	88.67	1.37	0.78	0.88	0.73	0.57	0.71	0.78	0.70
4	Lean clay with sand	25.02	1.12	43.98	1.79	0.40	0.25	0.32	0.26	0.31	0.38	0.38
5	Fat clay with sand	33.09	1.26	53.68	1.76	0.51	0.29	0.41	0.33	0.39	0.47	0.45
6	Fat clay	37.31	2.06	63.77	1.51	0.57	0.52	0.50	0.40	0.48	0.56	0.58
7	Fat clay	36.96	2.01	59.18	1.52	0.57	0.50	0.46	0.37	0.44	0.51	0.45
AVERAGE		32.14	1.72	55.18	1.64	0.50	0.59	0.59	0.47	0.57	0.48	0.46

Some correlations between Cc and other properties of soil

There are a lot of formulas showing the correlation between C_c and other properties of soils proposed by famous scientists in the world. Below some formulas showing correlation between C_c and other properties such as void ratio (e_0), moisture content (W), liquid limit (LL), plasticity index (PI) are listed in Table 1.

Table 1 Some correlation between Cc and other properties of soil

Formula	Proposed by
C_c=0.007(LL - 7.0%)	Skempton (1944)
C_c=1.15(e_0 - 0.35)	Nishida (1956)
C_c=0.29(e_0 - 0.27)	Hough (1957)
C_c=0.256 + 0.43(e_0 - 0.84)	Cozzolino (1961)
C_c=0.0046(LL-9.0%)	Cozzolino (1961)
C_c=0.009(LL -10.0%)	Terzaghi & Peck (1967)
C_c=0.75(W-0.5)	Sowers (1970)
C_c=0.006(LL-9.0%)	Azzouz et al. (1976)
C_c=0.037(e_0 - 0.003LL - 0.34)	Azzouz et al. (1976)
C_c= 0.01(W-7.549%)	Herrero (1983)
C_c=0.54(e_0 -0.23)	Moh a kol. (1989)
C_c=0.007(LL - 7.0%)	Moh a kol. (1989)
C_c=0.009(LL - 8.0%)	Tsuchida (1991)
C_c=0.014(PI + 3.6%)	Sridharan & Nagaraj (2000)

The suitable correlation between Cc and other properties of soil in coastal regions of vietnam and cambodia

Based on data received from the geotechnical investigation results in Quang Ninh, Nghe An, Soc Trang, Quang Ngai provinces, Ho Chi Minh city of Vietnam and Sihanoukville province of Cambodia carried out from 2010 to 2016, correlation between C_c and other properties of weak soil layer in coastal areas of Viet Nam and Cambodia is analysed Table 2-8.

Citation: Thinh PH, Tuan HA, Bien DC, et al. Research on correlation between compression index (Cc) and other properties of soil for geotechnical design in coastal regions of Vietnam and cambodia. *MOJ Civil Eng.* 2017;2(3):97–101. DOI: 10.15406/mojce.2017.02.00034

Table 3 Determination of Cc at Ha Long city - Quang Ninh province

No.	Soil name	PI (%)	e_0	LL (%)	ρ (g/cm^3)	Sridha- ran and Nagaraj	Hough	Tsuchi-da	Skemp-ton	Terza-ghi and peck	Propo-sed by authors	Lab
1	Lean clay	22.82	1.43	45.82	1.68	0.37	0.34	0.34	0.27	0.32	0.39	0.38
2	Lean clay	21.53	1.15	41.58	1.79	0.35	0.26	0.3	0.24	0.28	0.36	0.37
3	Organic clay	24.32	1.48	48.21	1.68	0.39	0.35	0.36	0.29	0.34	0.42	0.45
4	Silty clay	25.81	1.55	51.07	1.64	0.41	0.37	0.39	0.31	0.37	0.44	0.44
5	Lean clay	20.23	1.21	38.84	1.77	0.33	0.27	0.28	0.22	0.26	0.33	0.37
6	Lean clay	10.71	0.83	25.53	1.91	0.20	0.16	0.16	0.13	0.14	0.21	0.2
7	Organic silt	22.4	1.52	42.89	1.66	0.36	0.36	0.31	0.25	0.30	0.37	0.38
8	Organic silt	26.25	1.66	50.48	1.63	0.42	0.40	0.38	0.30	0.36	0.44	0.5
AVERAGE		7.57	0.47	14.97	0.60	0.36	0.32	0.32	0.26	0.30	0.38	0.38

Table 4 Determination of Cc at Cua Lo Town - Nghe an province

No.	Soil name	PI (%)	e_0	LL (%)	ρ (g/cm^3)	Sridha- ran and Nagaraj	Hough	Tsuchi-da	Skemp-ton	Terza-ghi and Peck	Proposed by Authors	Lab
1	Lean clay	16.60	1.48	36.2	1.68	0.28	0.35	0.25	0.20	0.24	0.31	0.28
2	Lean clay	16.40	1.53	35.7	1.68	0.28	0.37	0.25	0.20	0.23	0.30	0.30
3	Lean clay	22.40	1.55	44.00	1.67	0.36	0.37	0.32	0.26	0.31	0.38	0.40
4	Fat clay	30.80	2.07	60.30	1.54	0.48	0.52	0.47	0.37	0.45	0.52	0.50
5	Lean clay	24.00	1.5	48.20	1.68	0.39	0.36	0.36	0.29	0.34	0.42	0.40
6	Lean clay	23.70	1.64	47.50	1.65	0.38	0.40	0.36	0.28	0.34	0.41	0.41
7	Fat clay	25.5	1.84	52.40	1.57	0.41	0.46	0.40	0.32	0.38	0.45	0.43
8	Fat clay	25.90	1.80	50.00	1.58	0.41	0.44	0.36	0.29	0.35	0.43	0.42
AVERAGE		18.53	1.34	37.43	1.31	0.30	0.33	0.28	0.22	0.26	0.43	0.45

Table 5 Determination of Cc at Quang Ngai province

No.	Soil name	PI (%)	e_0	LL (%)	ρ (g/cm^3)	Sridha- ran and Nagaraj	Hough	Tsuchi-da	Skemp-ton	Terza-ghi and Peck	Propo-sed by Authors	Lab
1	Fat Clay	31.50	1.11	57.60	1.80	0.49	0.24	0.45	0.35	0.43	0.50	0.48
2	Fat Clay	33.70	1.38	67.30	1.70	0.52	0.32	0.53	0.42	0.52	0.59	0.54
3	Fat Clay	38.20	1.40	65.70	1.68	0.59	0.33	0.52	0.41	0.50	0.57	0.55
4	Fat Clay	50.50	1.70	81.00	1.62	0.76	0.41	0.66	0.52	0.64	0.71	0.70
5	Fat Clay	41.90	1.46	79.00	1.65	0.64	0.35	0.64	0.50	0.62	0.69	0.66
6	Fat Clay	44.80	1.60	78.90	1.63	0.68	0.38	0.64	0.50	0.62	0.69	0.65
7	Fat Clay	24.20	1.28	51.30	1.71	0.39	0.29	0.39	0.31	0.37	0.44	0.40
AVERAGE		22.07	0.83	40.07	0.98	0.54	0.33	0.53	0.42	0.51	0.58	0.55

Table 6 Determination of Cc at Ho Chi Minh city

No	Soil name	PI (%)	e_0	LL (%)	ρ (g/cm^3)	Sridha-ran and Nagaraj	Hough	Tsuchi-da	Skemp-ton	Terza-ghi and peck	Propo-sed by authors	Lab
1	Fat clay	48.70	2.01	83.40	1.56	0.73	0.50	0.68	0.53	0.66	0.73	0.7
2	Fat clay	26.30	1.45	53.10	1.69	0.42	0.34	0.41	0.32	0.39	0.46	0.46
3	Fat clay with sand	24.80	1.46	51.60	1.68	0.40	0.35	0.39	0.31	0.37	0.45	0.45
4	Fat clay with sand	23.10	1.38	44.50	1.66	0.37	0.32	0.33	0.26	0.31	0.38	0.40
5	Fat clay	40.10	1.87	73.40	1.58	0.61	0.46	0.59	0.46	0.57	0.64	0.63
6	Fat clay	42.90	1.75	72.20	1.60	0.65	0.43	0.58	0.46	0.56	0.63	0.63
AVERAGE		34.32	1.65	63.03	1.63	0.53	0.40	0.50	0.39	0.48	0.55	0.6

Citation: Thinh PH, Tuan HA, Bien DC, et al. Research on correlation between compression index (Cc) and other properties of soil for geotechnical design in coastal regions of Vietnam and cambodia. *MOJ Civil Eng.* 2017;2(3):97–101. DOI: 10.15406/mojce.2017.02.00034

Table 7 Determination of Cc at Soc Trang province

No.	Soil name	PI (%)	e_0	LL (%)	ρ (g/cm³)	Sridha- ran and Nagaraj	Hough	Tsuchi-da	Skemp-ton	Terza-ghi and Peck	Propo-sed by Authors	Lab
1	Lean clay	26.00	1.48	49.10	1.65	0.41	0.35	0.37	0.29	0.35	0.42	0.43
2	Fat clay	31.30	1.56	56.60	1.65	0.49	0.37	0.44	0.35	0.42	0.49	0.49
3	Fat clay	33.40	1.60	59.40	1.64	0.52	0.39	0.46	0.37	0.44	0.52	0.54
4	Fat clay	25.40	1.58	52.00	1.65	0.41	0.38	0.40	0.32	0.38	0.45	0.47
5	Fat clay	33.70	1.52	56.30	1.64	0.52	0.36	0.43	0.35	0.42	0.49	0.52
6	Fat clay	35.30	1.57	63.1	1.63	0.54	0.38	0.50	0.39	0.48	0.55	0.54
7	Fat clay	26	1.54	50.9	1.62	0.41	0.37	0.39	0.31	0.37	0.44	0.53
9	Fat clay	35.7	1.52	63.4	1.67	0.55	0.36	0.50	0.39	0.48	0.55	0.53
AVERAGE		22.44	1.12	40.98	1.20	0.46	0.37	0.42	0.33	0.40	0.47	0.47

Table 8 Determination of Cc at Sihanoukville province, Cambodia

No.	Soil name	PI (%)	e_0	LL (%)	ρ (g/cm³)	Sridha-ran and Nagaraj	Hough	Tsuchi-da	Skemp-ton	Terzaghi and peck	Proposed by authors	Lab
1	Fat clay with sand	24.30	2.03	51.10	1.55	0.39	0.51	0.39	0.31	0.37	0.44	0.42
2	Sandy fat clay	22.80	2.55	51.30	1.44	0.37	0.66	0.39	0.31	0.37	0.44	0.45
3	Sandy lean clay	14.80	1.58	35.90	1.57	0.26	0.38	0.25	0.20	0.23	0.31	0.32
4	Sandy lean clay	22.30	2.08	50.20	1.51	0.36	0.53	0.38	0.30	0.36	0.43	0.40
5	Sandy lean clay	20.30	1.62	45.00	1.63	0.33	0.39	0.33	0.27	0.32	0.39	0.39
6	Sandy fat clay	26.70	1.75	53.60	1.60	0.42	0.43	0.41	0.33	0.39	0.46	0.45
AVERAGE		21.87	1.94	47.85	1.55	0.36	0.48	0.36	0.29	0.34	0.41	0.41

Some formulas in Table 1 and a formula proposed by authors [C_c=0.009(LL-2.0%)] are used for analysis. The values of C_c determined by these formulas are compared with C_c received from laboratory testing results. The C_c received from laboratory testing results is considered as standard values for analysis. Analysis results are shown in tables and figures below (Figure 3-9). Correlation between C_c & other properties of soil at Sihanoukville province. The research results show that the value of C_c received from Terzaghi & Peck's formula is close to C_c received from laboratory testing results; and Cc received from formula proposed by the authors is not deferent from C_c received from laboratory testing results.[1–8]

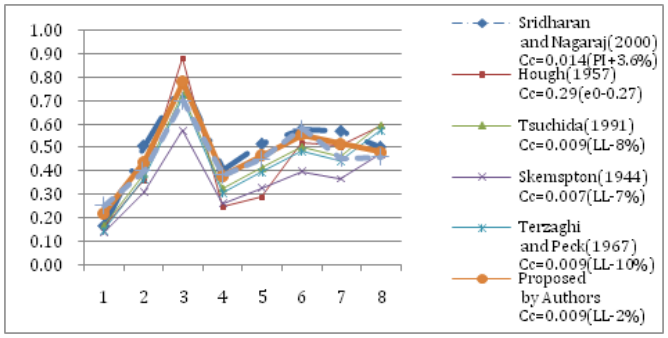

Figure 3 Correlation between Cc & other properties of soil at Cai Lan Port

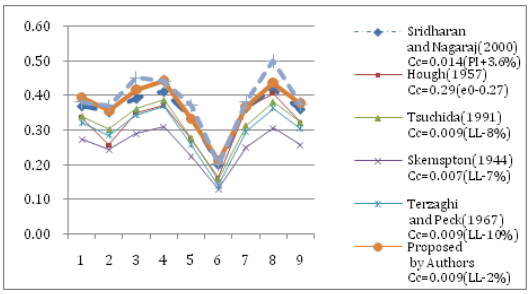

Figure 4 Correlation between Cc & other properties of soil at Ha Long city

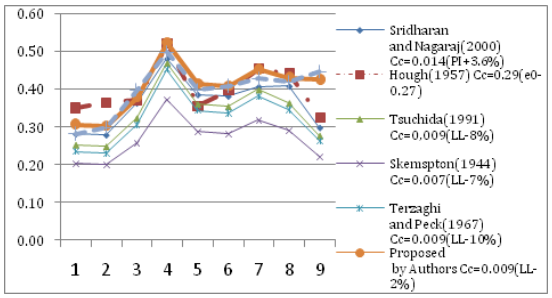

Figure 5 Correlation between Cc & other properties of soil at Nghe an province.

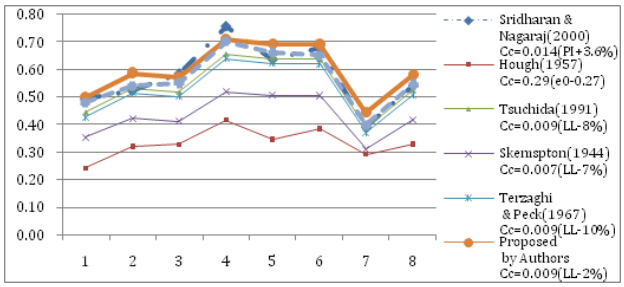

Figure 6 Correlation between Cc & other properties of soil at Quang Ngai province.

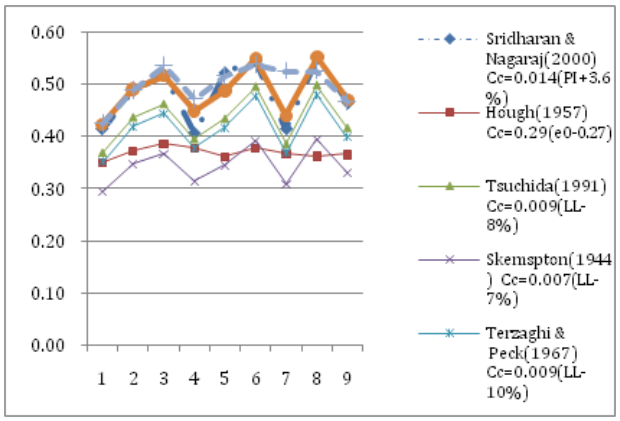

Figure 7 Correlation between Cc & other properties of soil at Quang Ngai province.

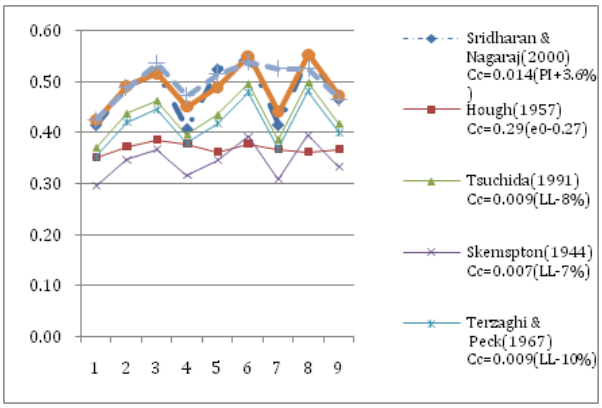

Figure 8 Correlation between Cc & other properties of soil at Soc Trang province.

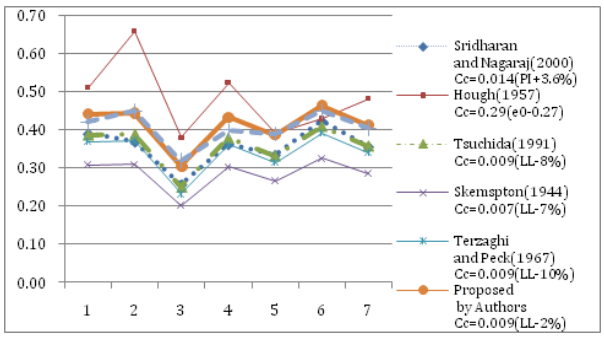

Figure 9 Correlation between Cc & other properties of soil at Sihanoukville province.

Conclusion and recommendation

In coastal regions of Vietnam and Cambodia, there is a thick, soft to very soft marine dark grey lean clay layer which creates dangerous engineering-geological processes, including land subsidence and deformation of buildings and other structures.

Compression index (Cc) takes an important role in settlement prediction for engineering foundation. Value of C_c depends heavily on methods of taking sample, sample transportation, quality of laboratory testing equipment, laboratory staff experience. These works are not well controlled in developing countries such as Vietnam and Cambodia. The research focuses on the correlation between C_c and other properties of the layer. Research results show that the correlation between C_c and Liquid limit is the tightest. The formula proposed by Terzaghi & Peck is suitable correlation between C_c and LL. The authors revised Terzaghi & Peck's formula and proposed a new formula [C_c=0.009(LL-2.0%)]. The research results show that this formula is the most suitable one for the correlation between C_c and LL of the layer in research areas.

We recommend to use the correlation C_c=0.009(LL-2.0%) for the clay layer in coastal regions of Vietnam and Cambodia.

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Conflict of interest

The author declares no conflict of interest.

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