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Effect of Compression Index and Consolidation Coefficient on Settlement of Rectangular Foundation Resting on Clayey Soil

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***Abstract* –** Significant settlements may occur in the soils because of structural loads. These settlement values are affected by multiple factors. Consolidation coefficient and compression index are among the factors that change settlement calculations the most. In this study, the model was created in the Settle 3D program to analyze a 30m deep soil profile consisting of 10m clay, 10m sand, and 10m gravel, with the water level at the ground surface. A 10m x 20m rectangular foundation loaded with 10 kPa was considered. The construction period was 365 days, and settlement calculations were performed for 12 different periods ranging from 15 days to 50 years. The 50 years with the highest settlement values were taken into account in the evaluations. A total of 2025 analyses were made by changing the consolidation coefficient, compression index, and unit volume weights. Results showed that after the consolidation coefficient of clay reaches 0.002 m^2/year for all unit volume weights and compression indices, settlement reaches its maximum value for the relevant situation, and increasing the consolidation coefficient does not change the result. The lowest and highest settlement values detected in all analyses were 2.96 cm and 134 cm, respectively. At the same time, the minimum settlement value found when the compression index value is 0.7 and above is 25.3 cm. This situation causes serious problems for structures due to the settlement of high plasticity clay soils with high compression index and coefficient of consolidation.

Keywords – Clay, Compression Index, Coefficient Of Consolidation, Settlement, Settle 3D

I. INTRODUCTION

Settlement of structures can be affected by various factors. Material properties may also change due to dynamic forces, frost action, drying weathering, etc. Selection of those properties properly is a compulsion in today's world. The effect of change in parameters should be evaluated. Base pressure effect on settlement was also studied and base pressure less than 200 kPa gave settlement value that can be acceptable [1]

The compression index is one of the most significant parameters in settlement calculations. There are so many studies on this issue [2-6]. Prediction of compression index from Atterberg limit values for 46 samples was performed. Shrinkage limits were chosen as the best compared to liquid limit and plastic limit [2].

Correlations for compression index from past to present were discussed and the result indicated that liquid limit is the best when used 1 variable and those correlations for city of Baghdad is very consistent [3].

The consolidation coefficient provides the opportunity to make a preliminary estimate regarding the time and consolidation speed in which the settlement of the soil will be completed. Therefore, the result of the consolidation coefficient of a soil is important in field works when the 90% consolidation amount will be met. Because, if settlement will continue at a high rate after the construction process is completed, this will be an undesirable situation for engineers and designers. Therefore, it would be beneficial to determine the level of this coefficient and to estimate the maximum possible value and take precautions accordingly. This issue attracts attention, especially among researchers studying settlement. There are multiple studies in the literature examining the consolidation coefficient [7-11].

In this study, research was carried out on a 10 x 5 meter rectangular foundation. Within the scope of the research, 3 different soil layers, each 5 meters thick, were created. The ground water level (Y.A.S.S.) is defined at the beginning of the clay layer on the ground surface. Then, by changing the unit volume weight, consolidation coefficient and compaction index of the clay material, the amount of settlement that will occur at the end of 50 years is estimated (found by the software). At the same time, the effect of consolidation coefficient and compression index on settlement was evaluated.

II. MATERIALS AND METHOD

In this study, the soil profile with a total depth of 15 m includes clay, sand and gravel soils, at depths of 5 meters each, respectively. SETTLE 3D program was preferred for those analysis. Interface of program was shown in Figure 1.

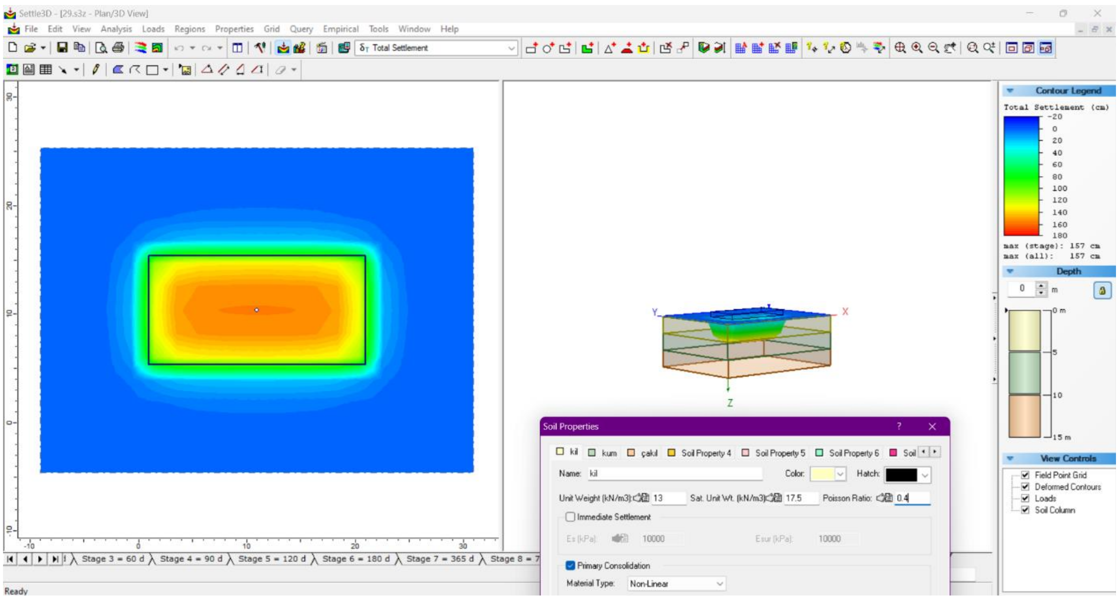


Fig. 1 Interface of SETTLE 3D program and model [12]

The material properties in this section are given for clay material. The unit volume weight of clay was changed between 10 – 18 kN/m^3, with a range of 1 kN/m^3. In this way, there was a chance to use data from the weakest and strongest possible clay soils. Poisson's ratio (ν) and initial void ratio (e_o) values were selected in accordance with the unit weights, taking into account the changes for clay in the Settle 3D program. Table 1, and Table 2 provide detailed information about the analyses performed in this study. In Table 1, when the consolidation coefficient was constant, the compression index was changed and a total of 81 analyzes (9x9) were made. In Table 2, when the compression index was constant, the consolidation coefficient was changed and a total of 1944 analyzes (18x9x12) were made. Total number of analyses performed in this study are 2025.

Table 1. First group analysis (varying C_v value for each γ while C_c is constant)

γ (kN/m³)	**γ_{doy} (kN/m³)**	**ν**	**e_o**	**C_v (m²/yıl)**	**C_c**
10	16	0.495	2.7	0.00003	
11	16.5	0.475	2.5	0.00006	
12	17	0.45	2.2	0.00009	
13	17.5	0.4	1.9	0.002	0.2, 0.7, 1.2, 1.7,
14	18	0.35	1.6	0.004	2.2, 2.7, 3.2,
15	18.5	0.3	1.3	0.006	3.65, 3.95
16	19	0.25	1	0.008	
17	19.5	0.2	0.7	0.01	
18	20	0.15	0.4	0.03	

Table 2. Second group analysis (varying C_v value while other parameters are constant)

Number	**γ (kN/m³)**	**γ_{doy} (kN/m³)**	**ν**	**e_o**
1	10	16	0.495	2.7
2	11	16.5	0.475	2.5
3	12	17	0.45	2.2
4	13	17.5	0.4	1.9
5	14	18	0.35	1.6
6	15	18.5	0.3	1.3
7	16	19	0.25	1
8	17	19.5	0.2	0.7
9	18	20	0.15	0.4
Material Properties	C_c		C_v	
	0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.6, 0.65, 0.7		0.00001, 0.00002, 0.00003, 0.00004, 0.00005, 0.00006, 0.00007, 0.00008, 0.00009, 0.0001, 0.00015, 0.002, 0.04, 0.06, 0.08, 0.01, 0.02, 0.03	

III. RESULTS

This section summarizes the coefficient of consolidation and compression index effect for varying soil properties. B10, B11, B12, B13, B14, B15, B16, B17, and B18 shown in Fig 2 and 3 represent the unit weight of samples. B10 means unit weight of that analysis is 10 kN/m3. In the light of the data obtained in Figure 2, the effect of changing the Cc value between 0.2 and 3.95 on settlement was observed. It has been observed that the B10 group material has the smallest settlement amount with a settlement value of 7.14 cm, and the maximum settlement amount of the same material group is 134 cm. Again, the biggest jump in seating amounts, with an increase of approximately 18.5 times, occurred in this group. In addition, it was observed that the smallest settlement amount of the B18 group material was 15.9 cm and the largest settlement amount was 246 cm, the maximum settlement value among all experimental groups.

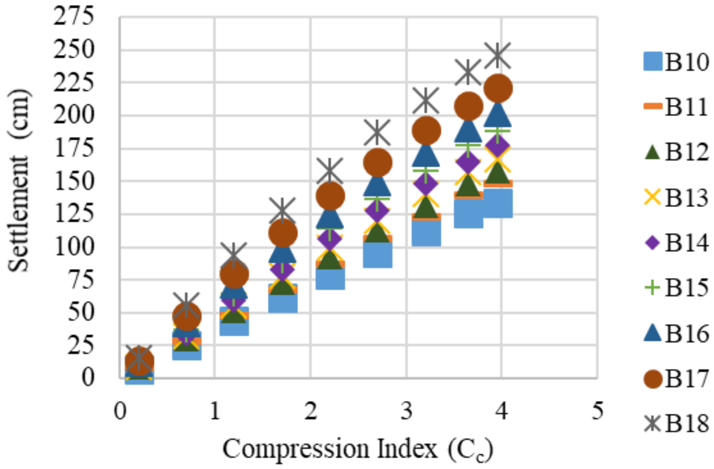
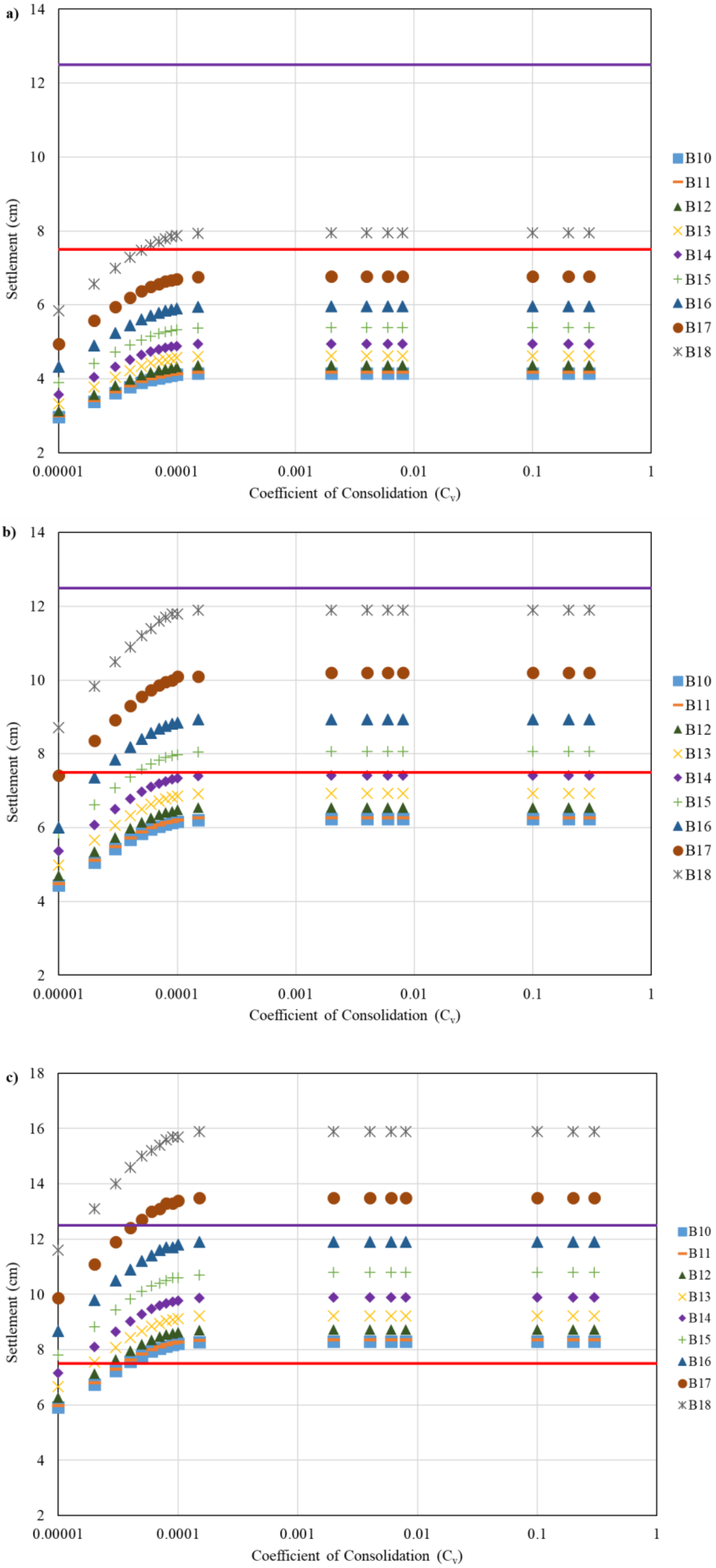
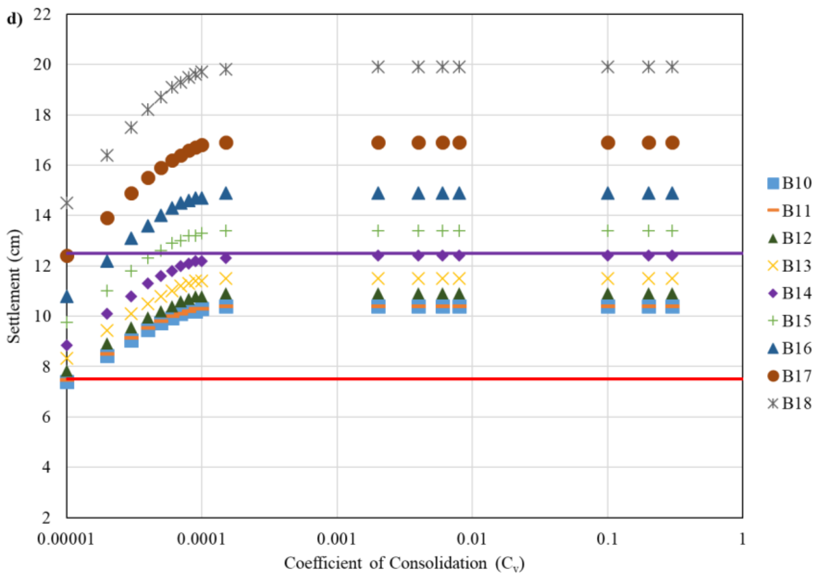
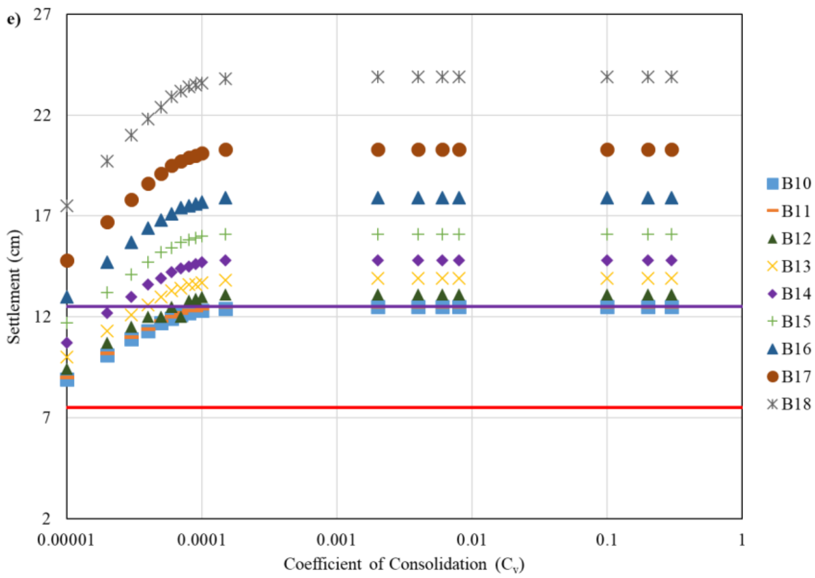


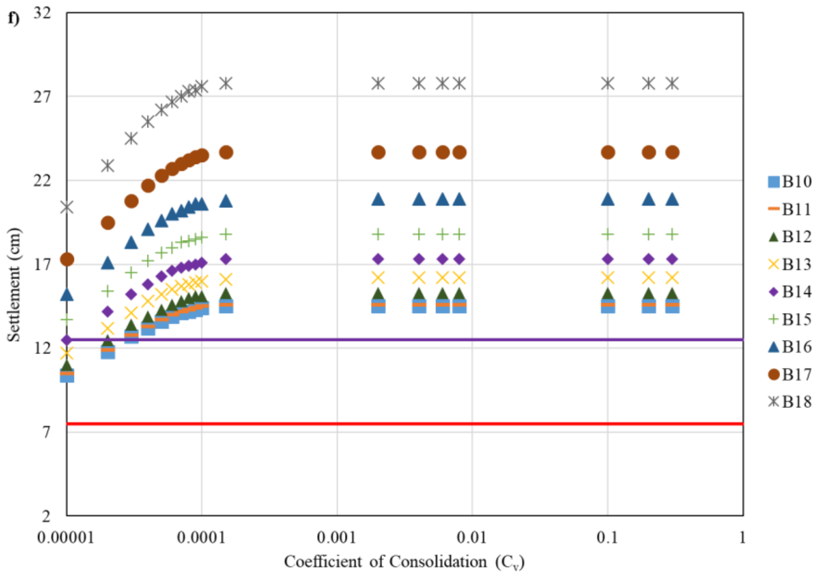
Fig. 2 Effect of compression index on settlement

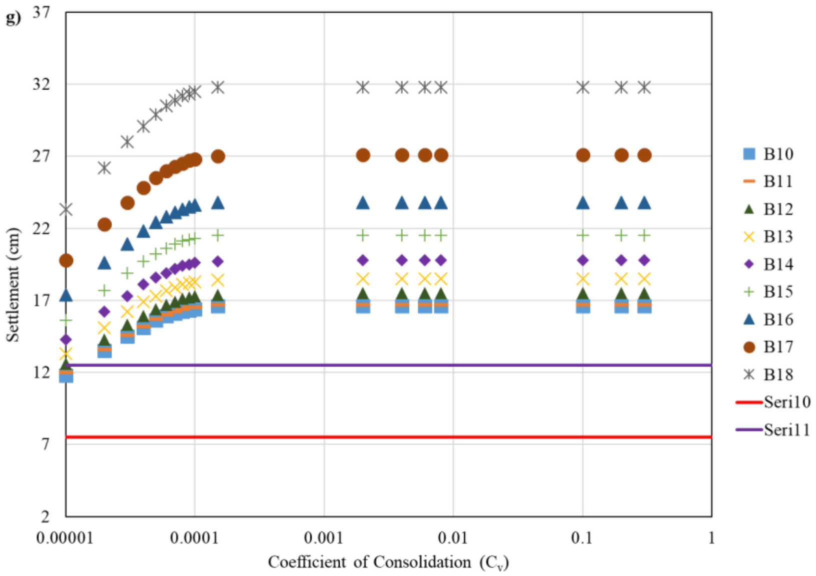
In Fig. 3a, settlement calculations were performed at different C_v values while the C_c value was fixed at 0.1. Accordingly, except for the soil group with a unit volume weight of 18 kN/m^3, the settlement values obtained in all other unit weights are below 7.5 cm. In addition, when the consolidation coefficient was 0.00001 m^2/year, the settlement value of the B10 group material was 2.96 cm. When the coefficient increased to 0.00015 m^2/year, settlement reached 4.14 cm and became approximately 1.40 times compared to the lowest value. Similarly, when the consolidation coefficient was 0.00001 m^2/year, the settlement value of the B18 group material was 5.84 cm. When the coefficient reached 0.00015 m^2/year, settlement increased to 7.94 cm. This value is 1.36 times higher than the lowest value. Settlement values when C_c = 0.15 began to increase compared to C_c = 0.1. Unit weight higher than 14 kN/m^3 gave settlement more than 7.5 cm as shown in Fig. 3b. A similar situation was observed in other unit weights, the highest and lowest values belong to the B18 and B10 groups, respectively. The maximum settlement value was obtained after the consolidation coefficient (c_v) reached 0.002 m^2/year, and settlement remained constant at higher values of c_v. The red and purple lines drawn in the graphs in Fig3a, 3b, 3c, 3d, 3e, 3f, 3g, 3h, 3i, 3j, 3k, 3l, and 3m represent 7.5 cm and 12.5 cm of settlement, respectively. The settlement acceleration continued to decrease and increase until the C_v value was 0.0001 m^2/year, which was valid in all analyses. As seen in Figure 3a, when the C_c value was 0.1, the settlement value was below 7.5 cm in the majority of the analyses. When C_c reached a value of 0.3 or greater, all settlements exceeded 7.5 cm as seen in Fig 3d, 3e, 3f, 3g, 3h, 3i, 3j, 3k, 3l and 3m. When C_c was 0.45, settlement value exceeded 12.5 cm.

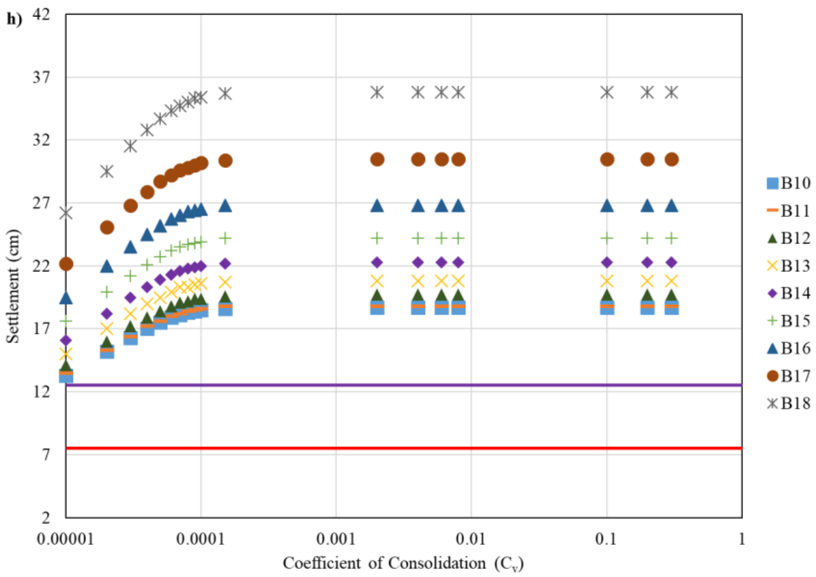

a)
Settlement (cm)
2
4
6
8
10
12
14
0.00001
0.0001
0.001
0.01
0.1
1
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18
b)
Settlement (cm)
2
4
6
8
10
12
14
0.00001
0.0001
0.001
0.01
0.1
1
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18
c)
Settlement (cm)
2
4
6
8
10
12
14
16
18
0.00001
0.0001
0.001
0.01
0.1
1
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18

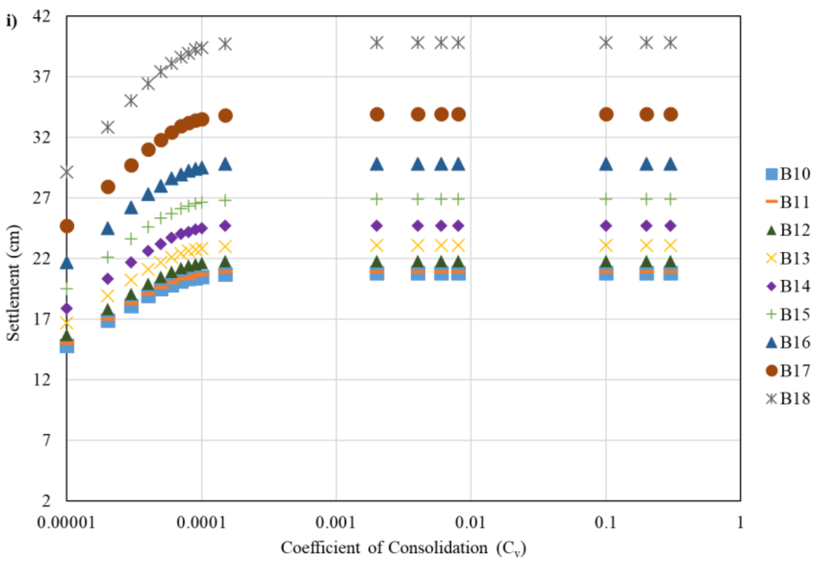

d)
22
20
18
16
14
12
10
8
6
4
2
Settlement (cm)
0.00001
0.0001
0.001
0.01
0.1
1
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18

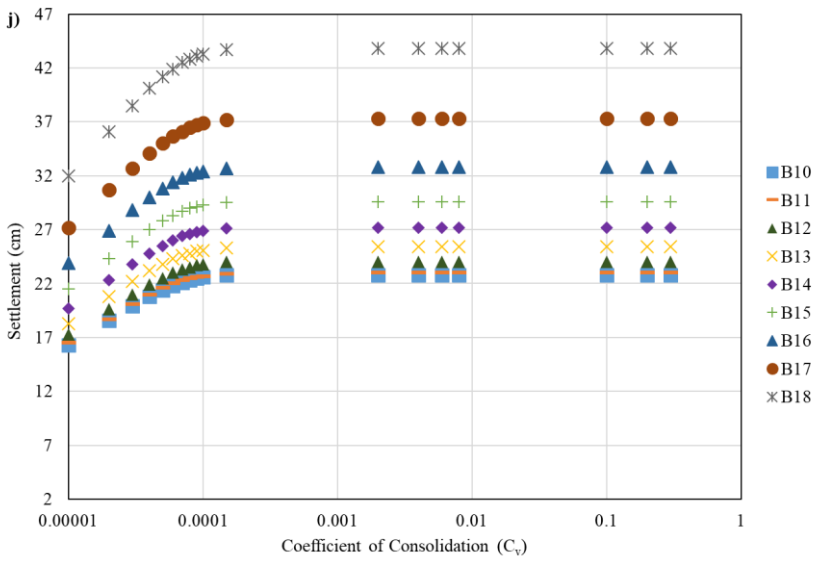

e)
27
22
17
12
7
2
Settlement (cm)
0.00001
0.0001
0.001
0.01
0.1
1
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18

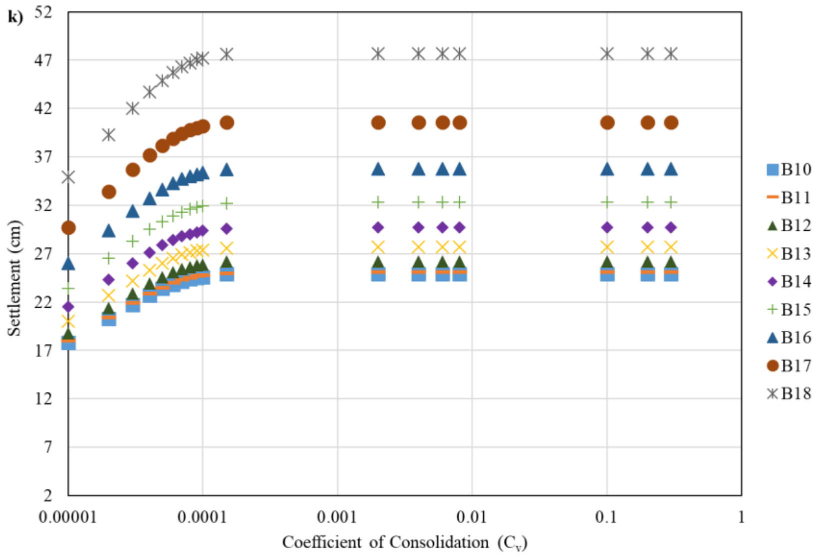

f)
32
27
22
17
12
7
2
Settlement (cm)
0.00001
0.0001
0.001
0.01
0.1
1
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18

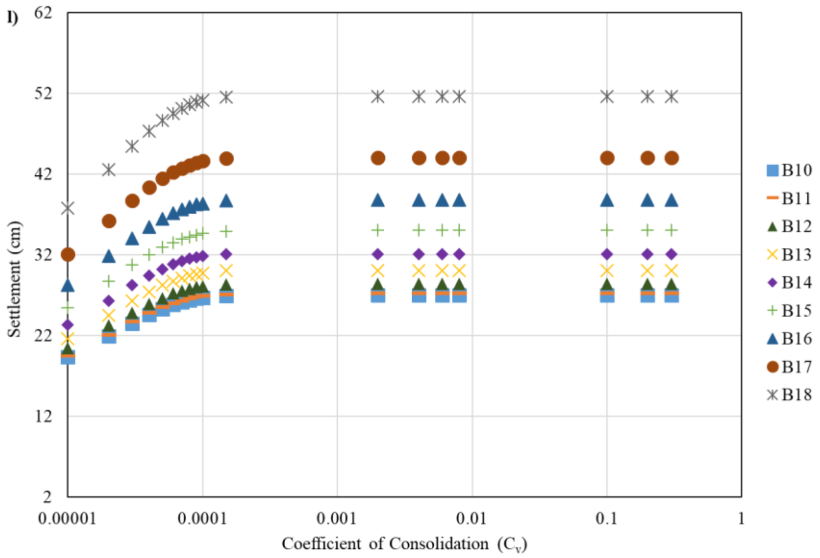

g)
Settlement (cm)
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18
Seri10
Seri11


h)
Settlement (cm)
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18


i)
Settlement (cm)
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18


j)
Settlement (cm)
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18


k)
Settlement (cm)
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18


l)
Settlement (cm)
Coefficient of Consolidation (C_v)
B10
B11
B12
B13
B14
B15
B16
B17
B18

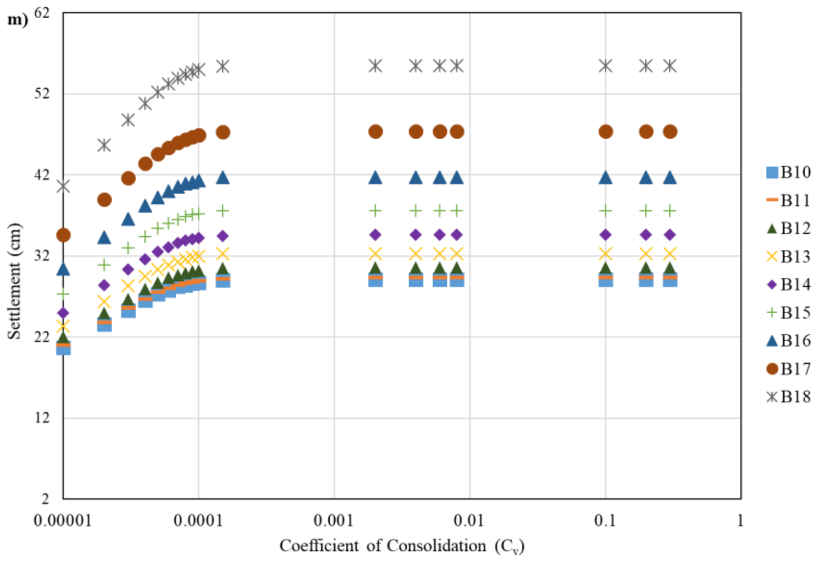


Fig. 3 Effect of consolidation coefficient on settlement a) C_c = 0.1 b) C_c = 0.15 c) C_c = 0.20 d) C_c = 0.25 e) C_c = 0.30 f) C_c = 0.35 g) C_c = 0.40 h) C_c = 0.45 i) C_c = 0.50 j) C_c = 0.55 k) C_c = 0.60 l) C_c = 0.65 m) C_c = 0.70

IV. DISCUSSION

All results obtained verified that the effect of the consolidation coefficient is limited for the analysis. After a certain value, change in this parameter have no effect on settlement. Settlement analysis mainly depends on the compression index. Fig 2 proves that issue since this value directly increases the settlement. Increasing the density and consolidation characteristics (consolidation coefficient and compaction index) of the material causes an increase in the settlement amount of the soil.

V. CONCLUSION

In this study, it was tried to examine to what extent the settlement changes as a result of the change in the compression index and consolidation coefficient, which are among the consolidation characteristics, and the material properties at different values. At this point, the results stated below have been reached.

• At the lowest value of the compaction index (Cc = 0.1), changing the density and/or consolidation coefficient of the material could not increase the resulting settlement above 7.5 cm. However, after the Cc value increased to 0.25, settlement values began to exceed 7.5 cm even at the lowest consolidation coefficient.

• In case the consolidation coefficient remains constant, the compaction index and settlement vary in direct proportion. In this analysis, when the Cc value is greater than 0.2, the settlement values are above 12.5 cm. When Cc = 0.2, the settlement exceeds 7.5 cm at unit volume weights higher than 10 kN/m3. Similarly, when Cc = 0.2, the settlement exceeds 12.5 cm at unit volume weights higher than 16 kN/m3.

• It has been observed that maximum settlement is achieved after the Cv value reaches 0.002 m2/year (0.002 m2/year in some analyses), and additional increases have no effect on ground settlement. According to this result, it was determined that the Cv change interval was kept short and at what settlement amount it reached its maximum value.

REFERENCES

[1] E. Dağlı, "Varying base pressure and groundwater level effect on settlement of clayey soil under circular loading", *International Journal of Advanced Natural Sciences and Engineering Researches*, vol. 8, no. 3, pp. 52–57, 2024.

[2] C. I. Giasi, C. Cherubini, and F. Paccapelo, "Evaluation of compression index of remolded clays by means of Atterberg limits", *Bull Eng Geol Environ*, vol. 62, no. 4, pp. 333–340, 2003.

[3] H. Güllü, H. Canakci, and A. Alhashemy, "Development of correlations for compression index". *Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi*, vol. 16, no. 2, pp. 344-355, 2016.

[4] T. F., Kurnaz, U. Dağdeviren, M. Yıldız, and O. Ozkan, "Prediction of compressibility parameters of the soils using artificial neural network", *Springer Plus*, vol. 5, Article Number 1801, pp. 1-12, 2016.
[5] J. J. Muhammed, and P.W. Jayawickrama, "Settlement of a railway embankment on PVD-improved Karakore soft alluvial soil" *15th Int. Conf. Geotech. Eng*., Lahore, Pakistan, In Press, 2020.
[6] Onyejekwe, S., Xin Kang, X. and Ge, L. Assessment of empirical equations for the compression index of fine-grained soils in Missouri. *Bull Eng Geol Environ*, vol. 74, pp. 705–716, 2015.
[7] R. G. Robinson, and M. M. Allam, "Effect of clay mineralogy on coefficient of consolidation ". *Geotechnique*, vol. 46, no. 5, pp. 596-600, 1998.
[8] H. Liu, and G. Quan, "Research of the anisotropy's effect on the deformation and consolidation coefficient of the soft soil*" Applied Mechanics and Materials*, vol, 353-356, pp. 374-378, 2013.
[9] Q. Yu, L. Cai, and X. Shi, "Reliability design of soft soil foundation preloading method for airport runway". *Advances in Civil Engineering*, vol. 2019, pp. 1-8, 2019.
[10] R. M. Alzubaidi, Effect rate of strain on ın situ horizontal coefficient of consolidation from pressuremeter. *Geotechnical and Geological Engineering*, vol. 38, no. 9, pp. 1669-1674, 2020.
[11] A. Sridharan, and H. B. Nagaraj, " Coefficient of consolidation and its correlation with index properties of remolded soils. *Geotechnical Testing Journal*, vol. 27, no. 5, pp. 1-6, 2004.
[12] *Rocscience, Settle 3D Software*.