SOFT SOIL CONSOLIDATION WITH THE ELECTROOSMOSIS EFFECT

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ABSTRACT

Areas with geomorphology in plains or lowlands, such as Pontianak City, have soft soil and peat covering most of their area. Lands in areas with low soil bearing capacity, high water content, high compressibility properties, and high groundwater levels or even practically the same as the land surface. Theoretically, soil improvement is preferred over several other options such as relocation, redesign, and replacement of unsuitable soils. Electroosmosis is one of the effective methods to reduce the moisture content in soft clay to reduce the amount of settlement that occurs when loading is carried out. The use of electroosmosis by placing a conductor in the ground with a certain distance, then between the conductors, an electric current is given. By reducing the water content in the soil, the decrease in soil subsidence will decrease and increase the strength of the soil. This electroosmosis test was carried out in a laboratory with a test model using a PVC pipe tube with a length of 19 cm and a diameter of 15 cm using five conductor rods. The soil specimens are subjected to two cases: direct loading and preloading during the electroosmosis test. Tests were conducted to study the effect of the current magnitude applied with a particular voltage on the physical and mechanical properties of the soil. The tests showed a significant of settlement with 0.0679 cm and 0.0663 cm for direct loading and preloading with the current effect. The mechanical properties showed an improvement in the soil samples, which was indicated by a low compressibility index and an increase in the shear strength of the soil.

Keywords: Current; Electroosmosis; Settlement; Soft Soil

INTRODUCTION

Soft soils generally have the following characteristics: shallow bearing capacity, easy to compress, significant shrinkage, unstable volume, considerable consolidation but require a long time because of small permeability soil (Ou et al., 2009). Electroosmosis (EO) in soils is a complex process (Liu et al., 2018). Therefore, to overcome these geotechnical problems, an effort is needed to increase the carrying capacity and reduce compressibility. Electro-osmosis (EO) method is a ideal method to reinforce the soft soil foundation, which can quickly improve the bearing capacity of the foundation and will not cause instability (Li et al., 2021).

Land has an important role in building a building construction, before the building is erected it is necessary soil improvement is carried out first to increase the strength of the soil so as to prevent large land subsidence (Prastiwi et al., 2016).

This paper regarding Consolidation of Pontianak Soft Soil Under Electroosmotic Effect is due to the geotechnical nature of the soil in Pontianak, which has soft soil that spreads and covers most of its area. The area of the city of Pontianak is the some of the land is soft soil. Soil conditions in the city of Pontianak are not everything has texture and type the same one. There are different types This land is possible because of the process the formation of each type of soil does not the same, depending on environmental conditions geography and location of the land (Sepriawan, 2012).

The soil structure in such areas is known as difficult soils, which is generally indicated by

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the low bearing capacity of the soil, high water content, high compression, and high groundwater level, or even practically the same as the ground level. Soil consolidation simply refers to water discharge through the pores, due to applied force (load), subse-quently leading to land subsidence (Rusdiansyah et al., 2021). This problem is a factor causing building failure (construction), mainly due to settlement. Thus, an appropriate stabilization method is needed to overcome geotechnical problems. In this research, we conduct an electroosmosis technique to investigate the electric current effect for the settlement of consolidated soil.

The coefficients of electro-osmotic permeability are relatively independent of the electrode materials and are controlled by the effective electric field intensity in the soil (Mohamedelhassan & Shang, 2001). The fact that with colloidal materials agreement between theoretical equilibrium heads and test results exist only for the short interval of time immediately after applying an electric potential was attributed to the development of cracks within the mass of material. The possibility of diverting the flow of pore-water away from cuttings is discussed and illustrated by practical examples. Some indications are given of the magnitude of the required consumption of energy for a few arrangements of electrodes. An explanation is also offered for the favourable effect of electro-osmosis on the consolidation of soft soil deposits (Casagrande, 2015).

METHODS

Six specimens of undisturbed soft soil are investigated. Soft soils are known for their high compressibility and low shear strength. In engineering practice, there are three main aspects of behavior of these soils that may be improved. They are strength, volume changes and permeability (Testad et al., 2013). The equipment used in testing the compression of soft soil is an oedometer cell (Krage et al., 2015). The main difference is in the loading system, measurement, and variation of the flow system (Gabryś & Szymański, 2011). This study used six samples, 15 cm in diameter and 19 cm in height. The experiment model of the consolidation test process uses the ASTM D 2435-80 standard. Model of electroosmosis experiment shown in figure 1.

The physical properties tested were moisture content, volume weight, dry volume weight, specific gravity, grain analysis (hydrometer), organic content, and weight distribution (Fathurrozi & Rezqi, 2016). The specimen is given a direct load, the load increases and the load increases with an initial loading (preloading) of 0.00625 kg/cm^2 of: 0.00625 kg/cm^2; 0.0125 kg/cm^2; 0.025 kg/cm^2; 0.05 kg/cm^2; 0.1 kg/cm^2 for 15 cm of diameter.

RESULTS AND DISCUSSION

Testing the Physical Properties

The test of physical properties of Pontianak soil specimen is described as follows Table 1.

Based on the results of the test, the soil can be classified: (1) Based on the texture by the United States Department of Agriculture (USDA), it is classified as a combination of clay and silty loam, (2) Based on AASHTO system included in A-7-6 can be used for subgrade (Chang & Sheen, 2016).

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Soft Soil Compression Behavior Due to Changes in Electric Current

Relation of Compression and Time Log (Figure 2 & 3)

The graph shows the boundaries of primary consolidation and secondary consolidation; this graph also determines the value of the consolidation coefficient (Cv).

Relation of Void Ratio and Time Log (Figure 4 & 5)

The graph above determines the value of the secondary compression index (cα). Subsidence due to secondary consolidation is essential for all types of highly compressible organic and inorganic soils (Peng et al., 2021).

Relation of Void Ratio and Compression Log (Figure 6 & 7)

Relation of void ratio and compression log provides the value of compression index (Cc), which is used to calculate the total of the settlement that occurs in the field due to consolidation.

Consolidation Parameters

Based on analysis, the relation between electroosmosis and Cα can be seen in the Fig.8.

Based on Fig.8, it is show that the higher current and voltage produce higher secondary compression index.

Table 2.

Table 3.

Table 4.

Table 5.

Table 6.

Table 7.

Based on the above analysis, it can be concluded that the total settlement (Sc) with and without preloading conditions are increasing significantly for the initial current up to 20 mA. The increase of total settlement for direct loading with current is 0.0679 cm. Meanwhile, preloading with current is 0.0663 cm. The detail can be seen in figure 9. Both cases show that the electroosmosis test is an effective method to accelerate soft soil settlement (Edwin & Suhendra, 2019).

CONCLUSION

The electroosmosis test with different current magnitudes effectively accelerates the settlement (Sc) of soft soils. The increase of total settlement for direct loading with current is 0.0679 cm, and preloading with current is 0.0663 cm. This study has successfully verified the effectiveness of the electroosmosis method for accelerating the settlement of soft soil. Therefore, this method is potential to be implemented in practical cases.

REFERENCES

Chang, C. C., & Sheen, M. S. (2016). Deduction of three-dimensional electro-osmotic theory. *Environmental Geotechnics*, *3*(1), 47–60. https://doi.org/10.1680/envgeo.13.00070

Casagrande. (2015). Electro-Osmosis in Soils. 1(3), 8505.

Edwin, H., & Suhendra, A. (2019). Analisis Metode Vacuum Preloading Untuk Mempercepat Konsolidasi Pada Tanah Lempung Lunak Jenuh Air. *JMTS: Jurnal Mitra Teknik Sipil*, *2*(4), 87. https://doi.org/10.24912/jmts.v2i4.6166

Fathurrozi, & Rezqi, F. (2016). Sifat-Sifat Fisis Dan Mekanis Tanah Timbunan Badan Jalan Kuala Kapuas. *Jurnal POROS TEKNIK*, *8*(1), 1–59.

Gabryś, K., & Szymański, A. (2011). The analysis of consolidation in organic

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soils. *Annals of Warsaw University of Life Sciences - SGGW. Land Reclamation*, *42*(2), 261–270. https://doi.org/10.2478/v10060-008-0084-4

Krage, C. P., Dejong, J. T., Degroot, D. J., Dyer, A. M., & Lukas, W. G. (2015). Applicability of clay-based sample disturbance criteria to intermediate soils. *6th International Conference on Earthquake Geotechnical Engineering*, *November*.

Li, G., Liu, J., Luo, T., Xie, M., & Li, H. (2021). Model Test of Soft Soil Consolidation Based on Surcharge Preloading Combined with Electro-Osmosis Methods. *International Journal of Electrochemical Science*, *16*(2), 1–11. https://doi.org/10.20964/2021.02.52

Liu, Y., Xie, X., Zheng, L., & Li, J. (2018). Electroosmotic stabilization on soft soil: Experimental studies and analytical models (A historical review). *International Journal of Electrochemical Science*, *13*(9), 9051–9068. https://doi.org/10.20964/2018.09.40

Mohamedelhassan, E., & Shang, J. Q. (2001). Effects of electrode materials and current intermittence in electro-osmosis. *Ground Improvement*, *5*(1), 3–11. https://doi.org/10.1680/grim.5.1.3.39435

Ou, C. Y., Chien, S. C., & Wang, Y. G. (2009). On the enhancement of electroosmotic soil improvement by the injection of saline solutions. *Applied Clay Science*, *44*(1–2), 130–136. https://doi.org/10.1016/j.clay.2008.12.014

Peng, B., Feng, R., Wu, L., & Shen, Y. (2021). Controlling conditions of the one-dimensional consolidation test on peat soil. *Applied Sciences (Switzerland)*, *11*(23). https://doi.org/10.3390/app112311125

Prastiwi, H. A., Surjandari, N. S., & P, Y. M. (2016). *Parameter Konsolidasi Tanah*. *September*, 884–891.

Rusdiansyah, Markawiec, & Rusdiansyah. (2021). The effect of temperature on some engineering and consolidation properties of soft soil. *Journal of Applied Engineering Science*, *19*(3), 750–756. https://doi.org/10.5937/jaes0-29477

Sepriawan, M. (2012). *Studi Pemampatan Tanah Lunak Pontianak Dengan*. *VOLUME 12*. https://jurnal.untan.ac.id/index.php/jtsuntan/article/view/1530

Testad, I., Corbett, A., & Aarsland, D. et al. (2013). ORE Open Research Exeter. *Journal of Cleaner Production*, 0–48.

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Appendix

Table 1. Test Result of Soil Physical Properties

Soil Parameter	Result of Test
Average of Soil Specific Gravity (G_s)	2.472
Average of water content (w)	114.46%
Density (γ)	1.40 gr/cm^3
Liquid Limit (LL)	55.05%
Plastic Limit (PL)	30.24%
Void ratio (e)	3.3097

Table 2. Result of Total Settlement (Sc) Without Current and Compression 0.05 kg/cm^2

z	H	γ	Cc	e0	R	z/R	I	q	Po	ΔP'	Po+ΔP'	Sc	Sc
(cm)	(cm)	(gr/cm^2)			cm			(gr/cm^2)	(gr/cm)	(gr/cm)	(gr/cm)	(cm)	(cm)
0.5	1	0.4	0.0833	3.3097	7.5	0.0667	0.990	50	0.2	49.50	49.70	0.0463	0.0463
1.5	1	0.4	0.0833	3.3097	7.5	0.2000	0.980	50	0.6	49.00	49.60	0.0371	0.0834
2.5	1	0.4	0.0833	3.3097	7.5	0.3333	0.970	50	1.0	48.50	49.50	0.0326	0.1160
3.5	1	0.4	0.0833	3.3097	7.5	0.4667	0.960	50	1.4	48.00	49.40	0.0299	0.1459
4.5	1	0.4	0.0833	3.3097	7.5	0.6000	0.955	50	1.8	47.75	49.55	0.0278	0.1737
5.5	1	0.4	0.0833	3.3097	7.5	0.7333	0.950	50	2.2	47.50	49.70	0.0261	0.1998
6.5	1	0.4	0.0833	3.3097	7.5	0.8667	0.945	50	2.6	47.25	49.85	0.0247	0.2245
7.5	1	0.4	0.0833	3.3097	7.5	1.0000	0.930	50	3.0	46.50	49.50	0.0235	0.2480
8.5	1	0.4	0.0833	3.3097	7.5	1.1333	0.910	50	3.4	45.50	48.90	0.0224	0.2704
9.5	1	0.4	0.0833	3.3097	7.5	1.2667	0.900	50	3.8	45.00	48.80	0.0214	0.2918
10.5	1	0.4	0.0833	3.3097	7.5	1.4000	0.875	50	4.2	43.75	47.95	0.0205	0.3123
Total of Settlement													**0.3123**

Table 3. Result of Total Settlement (Sc) Preloading Without Current and Compression 0.05 kg/cm^2

z	H	γ	Cc	e0	R	z/R	l	q	Po	ΔP'	Po+ΔP'	Sc	Sc
(cm)	(cm)	(gr/cm^2)			cm			(gr/cm^2)	(gr/cm)	(gr/cm)	(gr/cm)	(cm)	(cm)
0.5	1	0.4	0.0528	3.3097	7.5	0.0667	0.990	50	0.2	49.50	49.70	0.0295	0.0295
1.5	1	0.4	0.0528	3.3097	7.5	0.2000	0.980	50	0.6	49.00	49.60	0.0236	0.0531
2.5	1	0.4	0.0528	3.3097	7.5	0.3333	0.970	50	1.0	48.50	49.50	0.0208	0.0739
3.5	1	0.4	0.0528	3.3097	7.5	0.4667	0.960	50	1.4	48.00	49.40	0.0190	0.0929
4.5	1	0.4	0.0528	3.3097	7.5	0.6000	0.955	50	1.8	47.75	49.55	0.0177	0.1106
5.5	1	0.4	0.0528	3.3097	7.5	0.7333	0.950	50	2.2	47.50	49.70	0.0167	0.1273
6.5	1	0.4	0.0528	3.3097	7.5	0.8667	0.945	50	2.6	47.25	49.85	0.0158	0.1431
7.5	1	0.4	0.0528	3.3097	7.5	1.0000	0.930	50	3.0	46.50	49.50	0.0150	0.1581
8.5	1	0.4	0.0528	3.3097	7.5	1.1333	0.910	50	3.4	45.50	48.90	0.0142	0.1723
9.5	1	0.4	0.0528	3.3097	7.5	1.2667	0.900	50	3.8	45.00	48.80	0.0136	0.1859
10.5	1	0.4	0.0528	3.3097	7.5	1.4000	0.875	50	4.2	43.75	47.95	0.0130	0.1989
Total of Settlement													**0.1989**

Table 4. Result of Total Settlement (Sc) Current 10 mA and Compression 0.05 kg/cm^2

z	H	γ	Cc	e0	R	z/R	I	q	Po	ΔP'	Po+ΔP'	Sc	Sc
(cm)	(cm)	(gr/cm^2)			cm			(gr/cm^2)	(gr/cm)	(gr/cm)	(gr/cm)	(cm)	(cm)
0.5	1	0.4	0.0980	3.3097	7.5	0.0667	0.990	50	0.2	49.50	49.70	0.0545	0.0545
1.5	1	0.4	0.0980	3.3097	7.5	0.2000	0.980	50	0.6	49.00	49.60	0.0436	0.0981
2.5	1	0.4	0.0980	3.3097	7.5	0.3333	0.970	50	1.0	48.50	49.50	0.0384	0.1365
3.5	1	0.4	0.0980	3.3097	7.5	0.4667	0.960	50	1.4	48.00	49.40	0.0352	0.1717
4.5	1	0.4	0.0980	3.3097	7.5	0.6000	0.955	50	1.8	47.75	49.55	0.0327	0.2044
5.5	1	0.4	0.0980	3.3097	7.5	0.7333	0.950	50	2.2	47.50	49.70	0.0306	0.2350
6.5	1	0.4	0.0980	3.3097	7.5	0.8667	0.945	50	2.6	47.25	49.85	0.0291	0.2641
7.5	1	0.4	0.0980	3.3097	7.5	1.0000	0.930	50	3.0	46.50	49.50	0.0277	0.2918
8.5	1	0.4	0.0980	3.3097	7.5	1.1333	0.910	50	3.4	45.50	48.90	0.0263	0.3181
9.5	1	0.4	0.0980	3.3097	7.5	1.2667	0.900	50	3.8	45.00	48.80	0.0252	0.3433
10.5	1	0.4	0.0980	3.3097	7.5	1.4000	0.875	50	4.2	43.75	47.95	0.0241	0.3674
Total of Settlement													**0.3674**

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Table 5. Result of Total Settlement (Sc) Preloading Current 10 mA and Compression 0.05 kg/cm^2

z	**H**	**γ**	**Cc**	**e0**	**R**	**z/R**	**l**	**q**	**Po**	**ΔP'**	**Po+ΔP'**	**Sc**	**Sc**
(cm)	(cm)	(gr/cm^2)			cm			(gr/cm^2)	(gr/cm)	(gr/cm)	(gr/cm)	(cm)	(cm)
0.5	1	0.4	0.0601	3.3097	7.5	0.0667	0.990	50	0.2	49.50	49.70	0.0333	0.0333
1.5	1	0.4	0.0601	3.3097	7.5	0.2000	0.980	50	0.6	49.00	49.60	0.0267	0.0600
2.5	1	0.4	0.0601	3.3097	7.5	0.3333	0.970	50	1.0	48.50	49.50	0.0236	0.0836
3.5	1	0.4	0.0601	3.3097	7.5	0.4667	0.960	50	1.4	48.00	49.40	0.0215	0.1051
4.5	1	0.4	0.0601	3.3097	7.5	0.6000	0.955	50	1.8	47.75	49.55	0.0200	0.1251
5.5	1	0.4	0.0601	3.3097	7.5	0.7333	0.950	50	2.2	47.50	49.70	0.0188	0.1439
6.5	1	0.4	0.0601	3.3097	7.5	0.8667	0.945	50	2.6	47.25	49.85	0.0178	0.1617
7.5	1	0.4	0.0601	3.3097	7.5	1.0000	0.930	50	3.0	46.50	49.50	0.0169	0.1786
8.5	1	0.4	0.0601	3.3097	7.5	1.1333	0.910	50	3.4	45.50	48.90	0.0161	0.1947
9.5	1	0.4	0.0601	3.3097	7.5	1.2667	0.900	50	3.8	45.00	48.80	0.0154	0.2101
10.5	1	0.4	0.0601	3.3097	7.5	1.4000	0.875	50	4.2	43.75	47.95	0.0147	0.2248
						Total of Settlement							**0.2248**

Table 6. Result of Total Settlement (Sc) Current 20 mA and Compression 0.05 kg/cm^2

z	**H**	**γ**	**Cc**	**e0**	**R**	**z/R**	**I**	**Q**	**Po**	**ΔP'**	**Po+ΔP'**	**Sc**	**Sc**
(cm)	(cm)	(gr/cm^2)			cm			(gr/cm^2)	(gr/cm)	(gr/cm)	(gr/cm)	(cm)	(cm)
0.5	1	0.4	0.1013	3.3097	7.5	0.0667	0.990	50	0.2	49.50	49.70	0.0564	0.0564
1.5	1	0.4	0.1013	3.3097	7.5	0.2000	0.980	50	0.6	49.00	49.60	0.0451	0.1015
2.5	1	0.4	0.1013	3.3097	7.5	0.3333	0.970	50	1.0	48.50	49.50	0.0397	0.1412
3.5	1	0.4	0.1013	3.3097	7.5	0.4667	0.960	50	1.4	48.00	49.40	0.0364	0.1776
4.5	1	0.4	0.1013	3.3097	7.5	0.6000	0.955	50	1.8	47.75	49.55	0.0338	0.2114
5.5	1	0.4	0.1013	3.3097	7.5	0.7333	0.950	50	2.2	47.50	49.70	0.0317	0.2431
6.5	1	0.4	0.1013	3.3097	7.5	0.8667	0.945	50	2.6	47.25	49.85	0.0301	0.2732
7.5	1	0.4	0.1013	3.3097	7.5	1.0000	0.930	50	3.0	46.50	49.50	0.0287	0.3019
8.5	1	0.4	0.1013	3.3097	7.5	1.1333	0.910	50	3.4	45.50	48.90	0.0273	0.3292
9.5	1	0.4	0.1013	3.3097	7.5	1.2667	0.900	50	3.8	45.00	48.80	0.0261	0.3553
10.5	1	0.4	0.1013	3.3097	7.5	1.4000	0.875	50	4.2	43.75	47.95	0.0249	0.3802
						Total of Settlement							**0.3802**

Tabel 7. Result of Total Settlement (Sc) Preloading Current 20 mA and Compression 0.05 kg/cm^2

z	**H**	**γ**	**Cc**	**e0**	**R**	**z/R**	**l**	**q**	**Po**	**ΔP'**	**Po+ΔP'**	**Sc**	**Sc**
(cm)	(cm)	(gr/cm^2)			cm			(gr/cm^2)	(gr/cm)	(gr/cm)	(gr/cm)	(cm)	(cm)
0.5	1	0.4	0.0701	3.3097	7.5	0.0667	0.990	50	0.2	49.50	49.70	0.0390	0.0390
1.5	1	0.4	0.0701	3.3097	7.5	0.2000	0.980	50	0.6	49.00	49.60	0.0313	0.0703
2.5	1	0.4	0.0701	3.3097	7.5	0.3333	0.970	50	1.0	48.50	49.50	0.0276	0.0979
3.5	1	0.4	0.0701	3.3097	7.5	0.4667	0.960	50	1.4	48.00	49.40	0.0252	0.1231
4.5	1	0.4	0.0701	3.3097	7.5	0.6000	0.955	50	1.8	47.75	49.55	0.0252	0.1483
5.5	1	0.4	0.0701	3.3097	7.5	0.7333	0.950	50	2.2	47.50	49.70	0.0221	0.1704
6.5	1	0.4	0.0701	3.3097	7.5	0.8667	0.945	50	2.6	47.25	49.85	0.0208	0.1912
7.5	1	0.4	0.0701	3.3097	7.5	1.0000	0.930	50	3.0	46.50	49.50	0.0198	0.2110
8.5	1	0.4	0.0701	3.3097	7.5	1.1333	0.910	50	3.4	45.50	48.90	0.0189	0.2299
9.5	1	0.4	0.0701	3.3097	7.5	1.2667	0.900	50	3.8	45.00	48.80	0.0181	0.2480
10.5	1	0.4	0.0701	3.3097	7.5	1.4000	0.875	50	4.2	43.75	47.95	0.0172	0.2652
						Total of Settlement							**0.2652**

Accepted : 26 February 2022

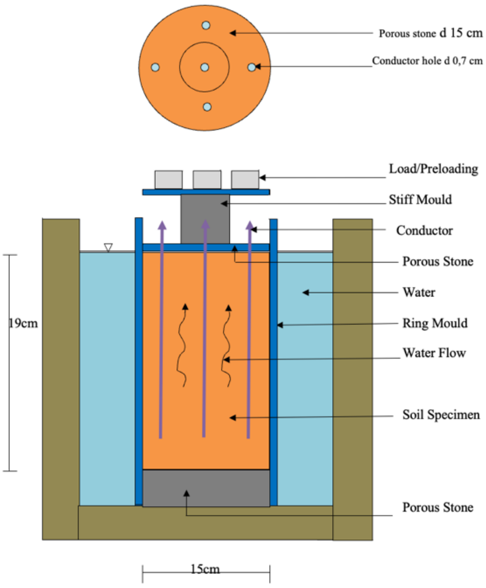

Figure 1. Model of Electroosmosis Experiment

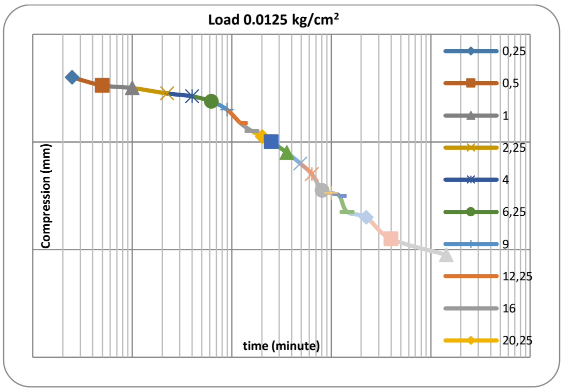

Figure 2. Relation of Compression and Time Log

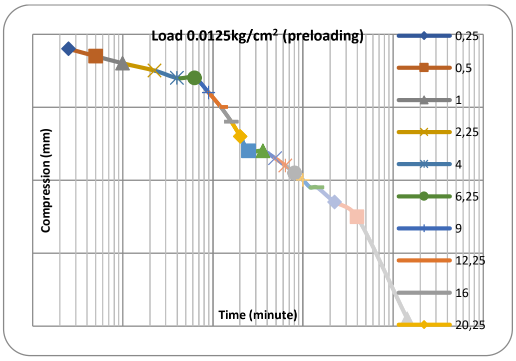

Figure 3. Relation of Compression and Time Log (Preloading)

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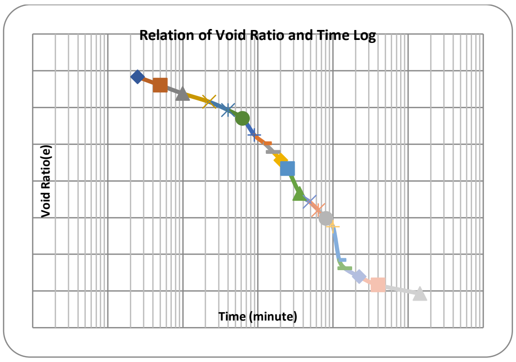

Figure 4. Relation Void Ratio and Time Log

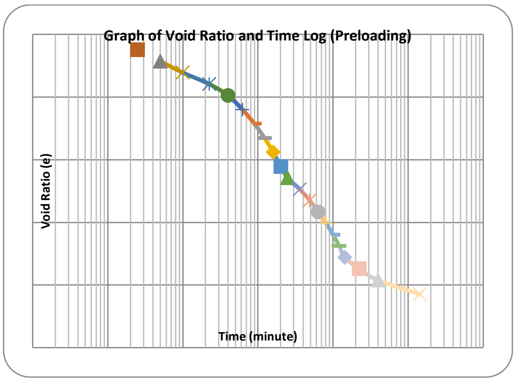

Figure 5. Relation of Void Ratio and Time Log

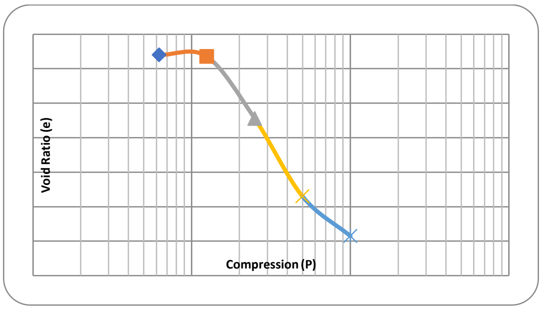

Figure 6. Relation of Void Ratio and Compression Log

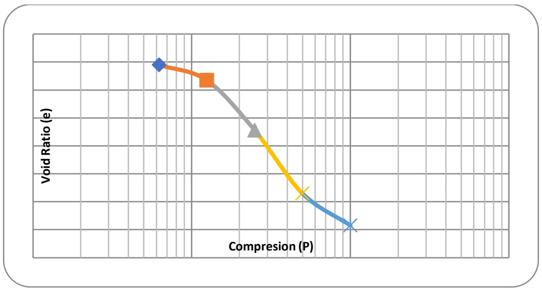

Figure 7. Relation of Void Ratio and Compression Log (Preloading)

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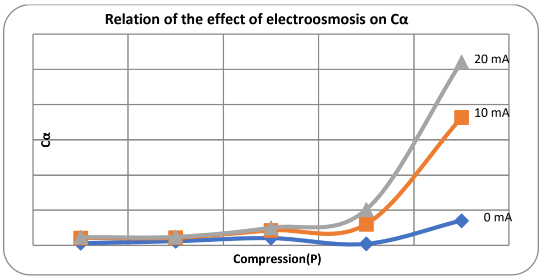

Figure. 8. Relation of Electroosmosis and Cα

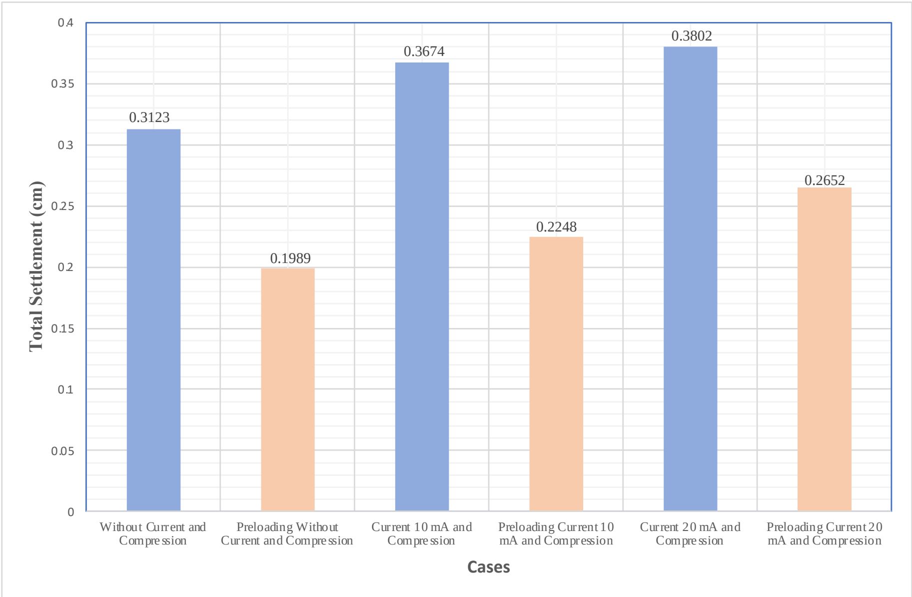

Figure. 9. Comparison of Total Settlement

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