International Journal of GEOMATE, Sept., 2020, Vol.19, Issue 73, pp. 20 – 25
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2020.73.9294
Geotechnique, Construction Materials and Environment

EFFECT OF CHLORIDE AND SULPHATE ON COMPRESSIVE STRENGTH OF BANGKOK CLAY ADMIXED CEMENT

Worawit Phojan[1], *Haruetai Maskong[2] and Anuchat Leeanansaksiri[3]

[1,3]Department of Civil Engineering, Faculty of Engineering, North Eastern University, Thailand
[2]Faculty of Engineering and Architecture, Rajamangala University of Technology Isan, Thailand

*Corresponding Author, Received: 18 June 2019, Revised: 19 Jan. 2020, Accepted: 20 March 2020

ABSTRACT : The paper presents the results of an experimental investigation on the influence of salt content on the unconfined compressive strength of Bangkok clay admixed with cement. The soil sample was added with sodium chloride (NaCl) and sodium sulphate ($NaSO_4$) at varying salt content of 3%, 5%, 10% and 15% by weight of soil. Based on the results of the study, it was found out that as the salinity increases, the diffusion double layer decreases. Hence, resulting to a decrease on the liquid limit (LL), plastic limit (PL), and plasticity index (PI). Moreover, at a certain moisture content, cement content, and curing time, the unconfined compressive strength of saline (sodium chloride and sodium sulphate) Bangkok clay admixed cement decreases with the increase of salt content. It was observed that the compressive strength of Bangkok clay admixed cement mixed with sodium sulphate ($NaSO_4$) exhibited higher compressive strength than the one mixed with sodium chloride (NaCl) for all curing times and mixing ratios. Moreover, it was noted that it has compressive strength than the natural clay admixed with cement.

Keywords: Sodium chloride, Sodium sulphate, Bangkok clay, Diffusion double layer

1. INTRODUCTION

Bangkok and its metropolitan areas are well known as soft clay. Bangkok clay occurred from the accumulation of subsoil layer by layer at the points of low lands or estuary caused by water flow. It is found that Bangkok and its metropolitan consist of soft clay with high moisture content and large settlement. This soft clay becomes harder in accordance with the depth consisted of sand and gravel layers alternatively deep into the ground until the rock layer. Bangkok clay is classified as non- to low swelling [1] as per free swelling test [2].

Nowadays, before the construction of buildings, roads, or embankments in the area of soft clay, chemical soil improvement is the popular solution to be used. This method uses soft clay mix with cement to improve the engineering properties of soil admixed cement. However, in the nature, there always be many kinds of mixed substances embedded in the soil which provide some effects to the engineering properties of the soil such as chemical substances, organics, salts (sulphate and chloride), acidity, basicity, etc. These chemical substances help enhance the properties of soft clay.

The effect caused by chloride and sulphate are one of the factors that causes some problems in soil admixed cement improvement such as reduction in soil bearing capacity and compressive strength. Hence, the investigation or prevention from the damages which could happen from sulphate and chloride are very important factors and should not be missed in the improvement of soil admixed cement properties. Davidson [3] reported that the chemical composition of soils causes soil particle to have reactions with cement in different forms subjected to anion (negative ion) in the soil particles, especially for organic soils, the reaction will be changed such as slow stabilization. Whereas, the soil consisted of sulphate will be swelled causing its compressive strength to be reduced. Sherwood [4] studied about the influence of organic matters by finding the relationship between the compressive strength and the pH value of soil admixed cement obtained by the combination of soil and cement in the ratio of 1:10. The results showed that if pH is less than 12.1, it means that the soil consists of organic substances consequently slow down the solidification of soil admixed cement and significantly reduce the compressive strength even if the same cement content is maintained.

This paper aims to study about the influences of salts (chloride and sulphate) on unconfined compressive strength of soft clay admixed cement considering the cement ratio, type of salt, and curing time.

2. MATERIAL AND METHODOLOGY

2.1 Soil Samples Preparation

The unconfined compressive strength of saline soft clay is discussed (chloride and sulphate). The soil samples used in this study were collected from Soi Sukhumvit 103, Bang Na District, Bangkok, Thailand at 3-5 meters depth. Soil samples were brought and placed under the sun until it become dry. A rubber hammer was used to break the soil samples into pieces and sift through the sieve No.20 to remove the shells, roots, and other waste materials in the soil samples. Subsequently, the soil samples were mixed with water until its liquidity index is equal to 1.5 times the moisture content. Then, the sample is mixed with Portland cement type I subject to some variables (cement content, chloride and sulphate content, and curing time). Salt components consisted of sodium chloride and sodium sulphate.

Table 1: Test and soil samples used in the test

Soil cement sample		
Variable	No.	Note
Soil sample	1	Clayey soil at Soi Sukhumvit 103, Bang Na District, Bangkok, Thailand
Chloride and sulphate	2	Sodium chloride and sodium sulphate
Moisture content	1	Moisture content with the Liquidity Index = 1.5%
Cement content	3	10%, 20%, and 30% by weight of soil
Chloride and sulphate content	5	0%, 3%, 5%, 10%, and 15% by weight of soil
Curing time	4	7, 14, 28, and 60 days
Number of sample	3	Three samples per test

2.2 Soil admixed cement, chloride, and sulphate sample preparations

Table 1 shows the detail of the soil sample used in this test. The soil sample passed through the sieve No.20 in order to adjust the level of water content until its liquidity index (LI) equals to 1.5%. Then the cement content was varied at 10%, 20%, and 30% by weight of soil. The chloride and sulphate content were also varied from 0%, 3%, 5%, 10%, and 15% by weight of soil. Altogether, mix the component samples for about 10 minutes until it becomes homogenous. Subsequently, put the soil sample in a cylinder with a 45 mm diameter and 90 mm height. Then the sample in 3 layers, and one layer needs to be compacted for 30 time to remove air from the soil. Prepare at least 3 soil samples for each test. Remove the cylinders after 24 hours and then the samples were wrapped using a food preservation film. Then cure the sample in the water for about 7, 14, 28, and 60 days. After curing, take the soil samples to the laboratory and test its unconfined compressive strength.

2.3 Unconfined compressive strength

Prior to the compressive strength test, the diameter, height, and weight of the samples were recorded. The measurement should be detailed until 0.1 mm by using a Vernier Caliper. The pressing speed of the unconfined compression testing machine was set at 1.4 (please indicate the unit). During the test, record the new height of the sample in order to determine the maximum value of unconfined compressive strength. Then the average of the test results obtained in the 3 samples with the same curing time were determined.

3. RESULTS AND DISCUSSION

3.1 Fundamental properties of soil

The soil sample used in this study has liquid limit and plastic limit of 64.5% and 30%, respectively. Its specific gravity is 2.68, and is classified as clay high plasticity (CH). Based on the Unified Soil Classification System (USCS), this type of soil has electrical conductivity (EC) of 1.8 dS/m, and according to the US Soil Salinity Laboratory Staff 1954, it can be counted as a saline soil [5].

Table 2: Salinity of soil and its influence on plants [5]

EC (dS/m)	Salt content (%)	Salinity	Influence on plants
<2	< 0.1	Not salty	No influence on plants
2–4	0.1– 0.2	Slightly salty	Grow slowly
4–8	0.2– 0.4	Moderate salty	Limit the growth of many kinds of plants
8–16	0.4– 0.8	Very salty Absolutely salty	Only salt-tolerant plants can grow
>16	>0.8	Very salty Absolutely salty	Only some salt-resistant plants cannot grow

3.2 Influence of salt content to physical properties of soil

Figure 1 shows that as the salt content increases, the liquid limit (LL) and plastic limit (PL) decreases, and the resulting plasticity index (PI) also decreases since the liquid limit (LL) of soil is occupied by shearing resistance and diffuse double layer thickness [6]. The salinity components mixed in the sample consisted of cation (positive ion) in the form of sodium (Na+).

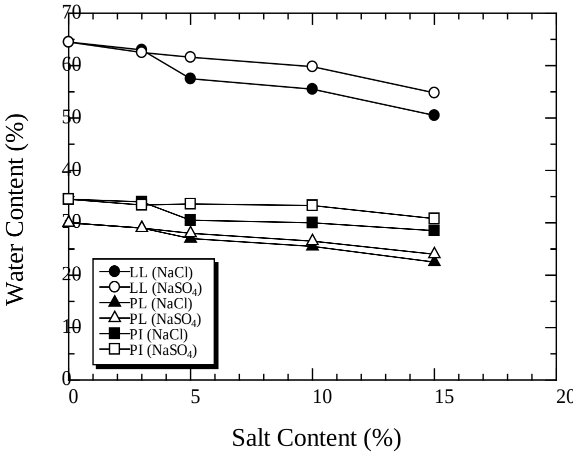

Fig. 1 Influence of salt content on Atterberg's limit.

When the cation gets melt in the water, it goes and sticks into the space between soil particles so that the soil particles moved closely to each other; and the diffuse double layer thickness decreases, resulting to a decreases in the liquid limit (LL).

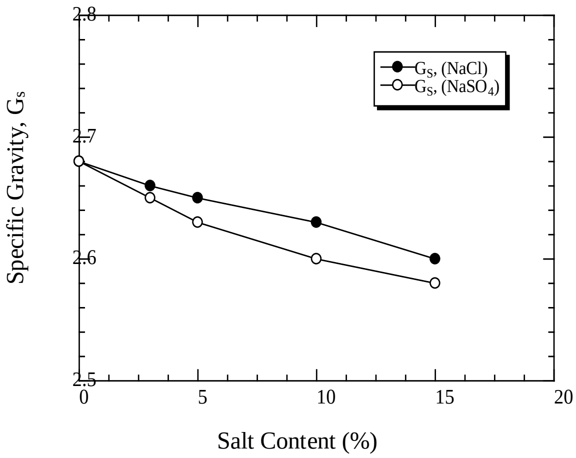

Fig. 2 Influence of salinity on specific gravity

Figure 2 shows about the influence of salinity on specific gravity. When salt content increases, it causes the specific gravity to decreases since salts (sodium chloride and sodium sulphate) are chemical substances consisted of specific gravity less than soil. The addition of salts into the soil causes organic substances to occur, hence, causes a decrease specific gravity.

Figure 3 illustrates the relationship between electrical conductivity (EC) and salt content added into the soil sample. The results show that when NaCl in added, the electrical conductivity is higher than adding $NaSO_4$ since $NaSO_4$ causes the soil to become more acidity than NaCl. Moreover, NaCl is the salt which can melt easily in water, resulting to a higher electrical conductivity in the soil than using $NaSO_4$.

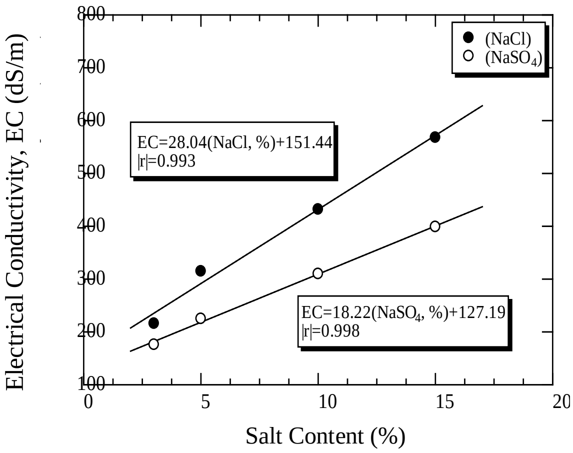

Fig.3 Relationship between salt content and electrical conductivity

3.3 Influence of salt content to the unconfined compressive strength of soil cement

Figure 4 proves about the test results when using 10%, 20%, and 30% of cement content and 81.75% of moisture content (LI=1.5) at various curing times. It shows that when mixing soil admixed cement with NaCl more than 3% by weight of soil, its unconfined compressive strength is lower than the unconfined compressive strength of the natural soil admixed cement at all curing times since the positive ion (cation) in NaCl causes soil particles get swelled. At the same moisture content and curing time of soil mixed with NaCl, its unconfined compressive strength decreases in accordance with the increase of salt content because at the same moisture content the low salinity soil will provide low value of e/e_L (matric suction). The bonding strength between soil particles happened from the hydration reaction, are similar to each other since the hydration reaction varies as a function of moisture content.[7]

In the soil sample contained $NaSO_4$, its unconfined compressive strength decreases as the amount of salt content increases. All mixing ratios have unconfined compressive strength higher than the natural clayey soil admixed cement at all curing periods. When using 10% of cement content, soil admixed cement mixed with $NaSO_4$ exhibited higher unconfined compressive strength than natural soil at all curing periods and the differentiation of unconfined compressive strength decreases in

accordance with the increase of 20% and 30% of cement content. The increase of $NaSO_4$ content causes the unconfined compressive strength to decreased because sulphate reacts with calcium hydroxide ($Ca(OH)_2$ and the calcium aluminate hydrate which occurred from the reaction between water and cement (hydration reaction) causes the strength of cement to decreases and the compressive strength of soil admixed cement also decreases.

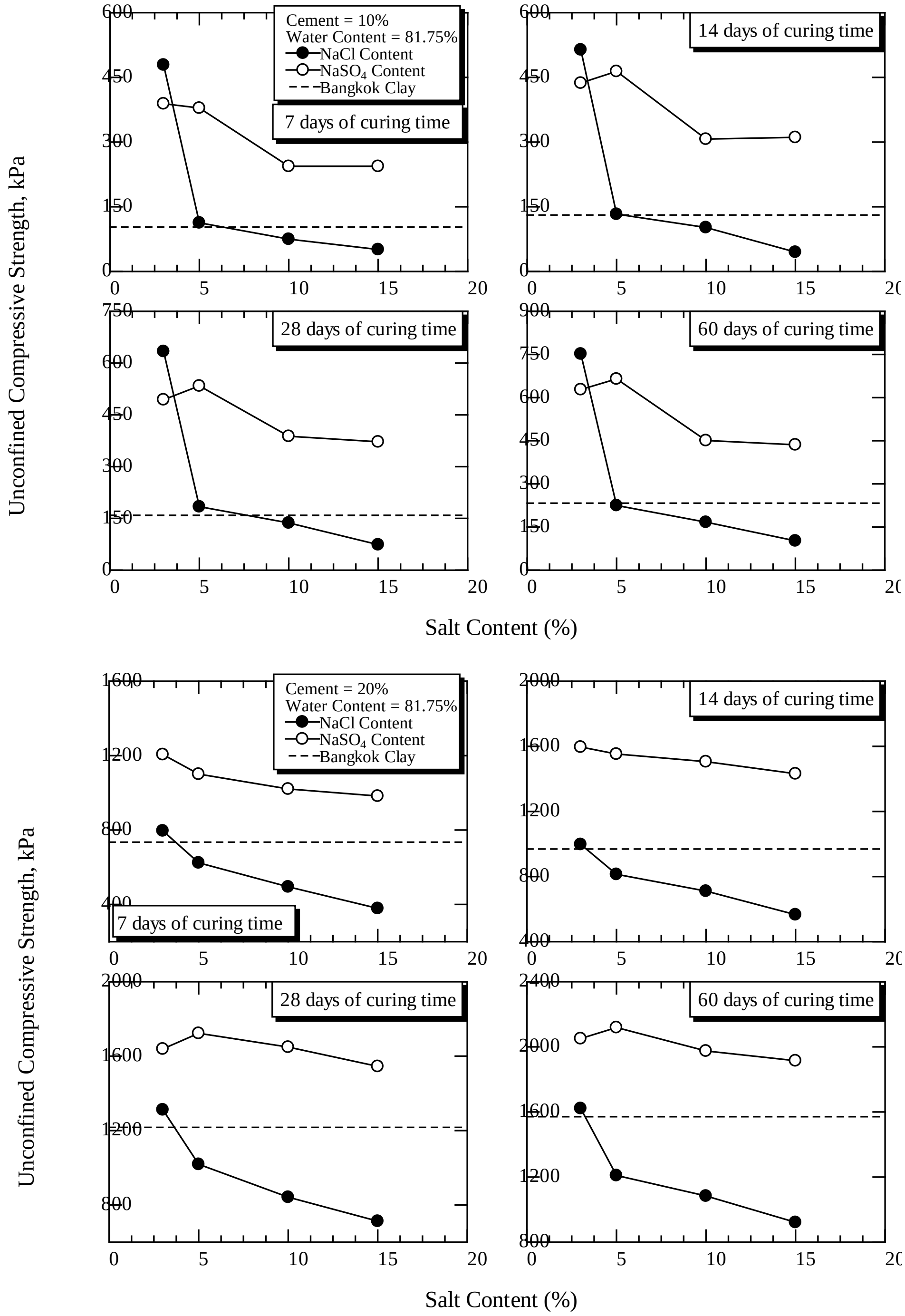

Fig.4 Influence of salt content on compressive strength of Bangkok clay

3.4 Compressive strength development on soft clay admixed cement

Figure 5 shows the types of salt influence on unconfined compressive strength of soft clay admixed cement at varying salt contents and varying curing times using cement content at 10%, 20%, and 30% by weight of soil. From the test results, it was found that the unconfined compressive strength increases accordingly with the increase of curing time for all mixing ratios; however, the compressive strength of soil cement mixed $NaSO_4$ resulted to a higher compressive strength than mixing with NaCl at all curing times and varying salt contents.

4. CONCLUSION

The increase of salinity in soil sample causes diffusion double layer to decrease leading the liquid limit (LL), plastic limit (PL), and plasticity index (PI) decrease. At a particular moisture content, cement content, and curing time, the unconfined compressive strength of saline (sodium chloride and sodium sulphate) soft clay admixed cement decreases in accordance with the increase of salt content because sodium chloride (NaCl) influences the soil particles disperse (specific surface becomes larger), whereas sodium sulphate ($NaSO_4$) causes to have a kind of crystal called Ettringite. This kind of crystal causes soil to disperse larger when hydration reaction happens. However, at the same level of salinity, the soil admixed cement mixed with sodium sulphate ($NaSO_4$) provides the unconfined compressive strength higher than soil admixed cement mixed with sodium chloride (NaCl) for all mixing ratios and curing times, and also higher than the unconfined compressive strength of natural clay admixed cement.

5. ACKNOWLEDGMENTS

The Authors would like to express their sincere thanks and gratitude to the Department of civil engineering, Faculty of engineering, North Eastern University, Khonkaen, Thailand.

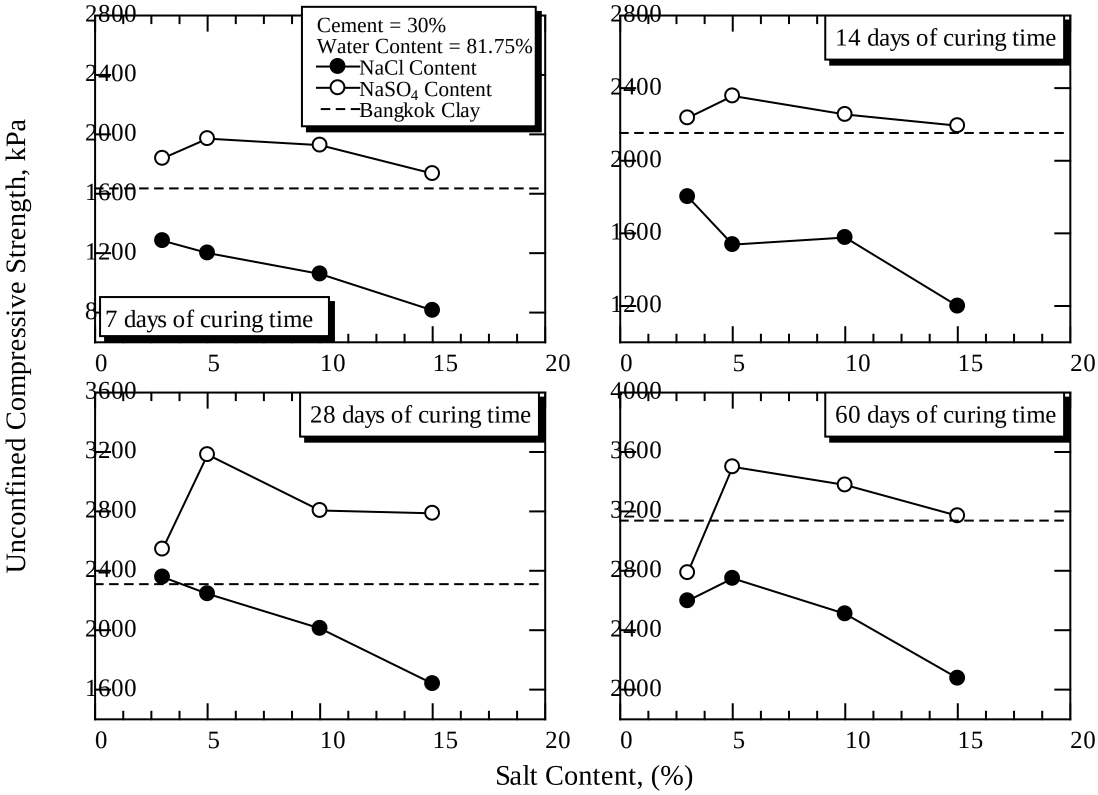

Fig.4 Influence of salt content on compressive strength of Bangkok clay (Cont.)

6. REFERENCES

[1] Horpibulsuk S., Rachan R., and Suddeepong A. "Assessment of strength development in blended cement admixed Bangkok clay", Construction and Building Materials, 25(4), 2011, pp. 1521-1531.

[2] Prakan K. and Sridharan A. "Free swell ration and clay mineralogy of fine-grained soils", Geotechnical Testing Journal, ASTM, 27(2), 2004, pp. 220-225.

[3] Davidson D.T. "Soil stabilization with Portland cement", Highway Research Board, 1961, 200 p.

[4] Sherwood, P.T. "The effect of Sulphates on Cement Stabilization Clay", Highway Research Board, Bulletin. 198, 1958, pp. 45 – 54.

[5] United States Salinity Laboratory Staff. "Diagnosis and improvement of saline and alkali soils" US Department of Agriculture, Agricultural Handbook No. 60, 1954, Washington: US Government Printer.

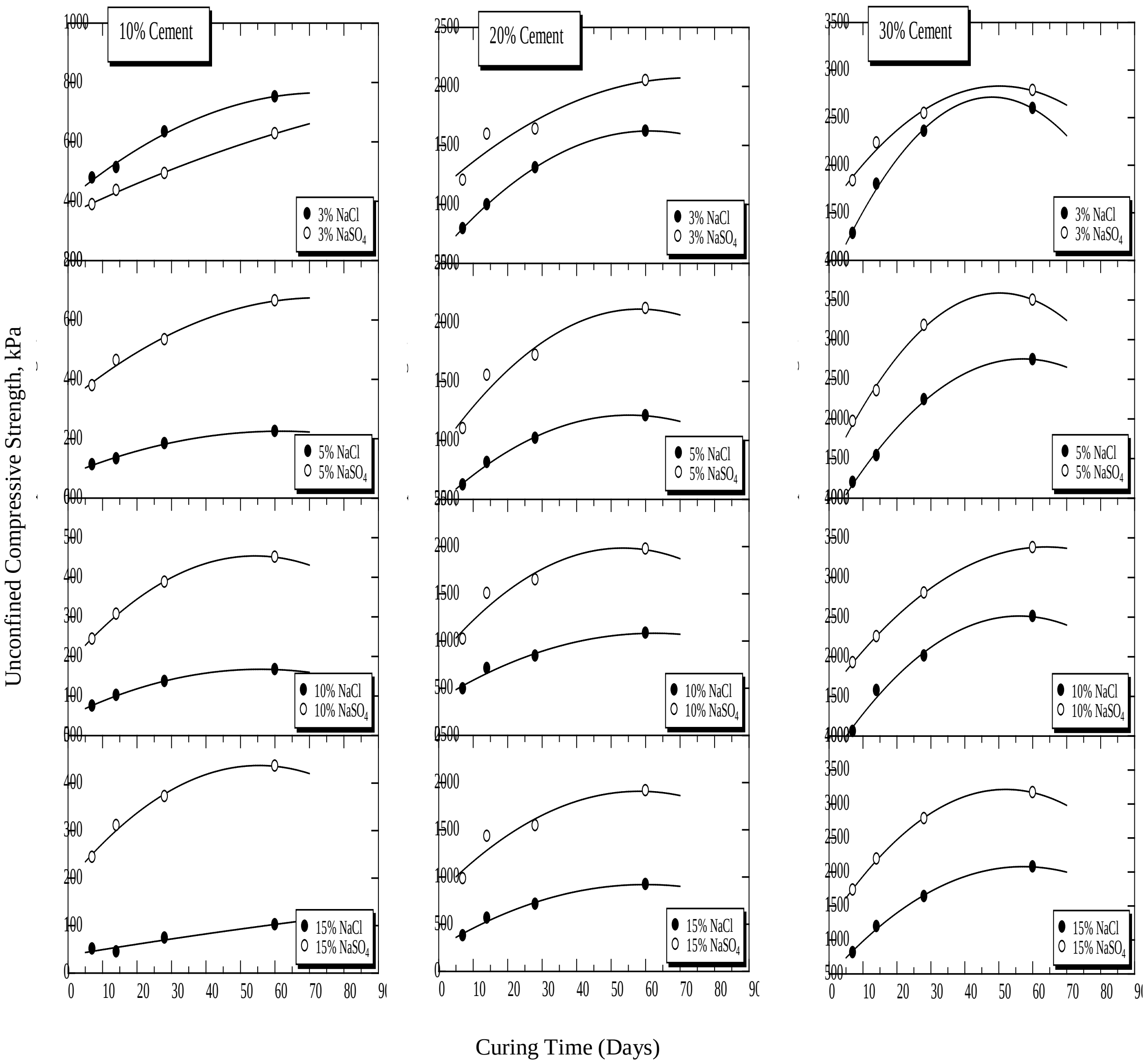

Fig.5 Compressive strength development on Bangkok clay admixed cement at various curing time

[6] Sridharan A. and Rao G. “Mechanisms controlling the liquid limit of clay”. Proc. Conf. an Soil Mechanics and Foundation Engineering, Istanbul, Vol.1,1975,pp.65-75.

[7] Horpibusuk S., Phojan W., Suddeepong A., Chinkulkijniwat A., and Liu M.D. “Strength development in blended cament admixed saline clay”. Applied Clay Science. 55, 2012, pp. 44-52.