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Research Paper

EFFECT OF NAOH MOLAR CONCENTRATION TO SOFT CLAY SOIL STABILIZED BY FLY ASH BASED GEOPOLYMER MECHANICAL STRENGTH SUBJECTED TO INITIAL HEATING

Abdalla M Shihab[1]*, Jasim M Abbas[2] and Amer M Ibrahim[3]

*Corresponding Author: Abdalla M Shihab ✉ engabdalla88net@gmail.com

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The main aim of this study is to investigate the effect of NaOH molar concentration to the mechanical strength of soft clay soil stabilized by fly ash based geopolymer sujected to initial heating at 2.714, 3.167, 3.8 and 4.75 liquid over fly ash ratios. The mechanical strength was characterized by the unconfined compression strength, the microstructural nature was also observed by scanning electron microscope for the treated and untreated soil. The formation of geopolymer gels was confirmed by the means of x-ray diffraction tests analyzed by using Match program. The results showed that optimum molar concentration is 12 Molar to all liquid over fly ash ratios used, the peack un confined strength at 2.714 and 3.167 is more than 3.8 and 4.75 liquid over fly ash ratio at the same molar concentration due to the high presence of source material. X-ray diffraction analyses showed that Potassium aluminium silicate hydrate and Sodium tecto-alumosilicate hydrate form about 20% of the resulted compounds for 10 Molar, 3.8 liquid over fly ash ratio subjected to to 6 houres heating at 70 °C.

Keywords: Geopolymers, Soil stabilization, Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD), NaOH molar concentration

INTRODUCTION

In general sense, geotechnical engineers classify soils into cohesive and cohesion less, moreover, cohesive soil matrix have low size particles resulting a general trend to exhibit soil water attraction. However, due to many resons like drying wetting cycles, phisycal disturbenses to such soils represent a considerable problem because of the consequent low shear strength, high plastisicy and compressibility (Coduto, 1999). In accordance, many proposals through the literature recognized these soils by its low

[1] MsC. Student, College of Engineering, Universityof Diyala, Baqubah, Daiyla, Iraq.
[2] Assist Prof Dr, College of Engineering, Universityof Diyala, Baqubah, Daiyla, Iraq.
[3] Prof Dr, College of Engineering, Universityof Diyala, Baqubah, Daiyla, Iraq.

undrained shear strength (less than 40 kPa) and high compressibility (C_c betweeen 0.19 to 0.44) at known water content levels (45 to 65%) (Brand and Brenner, 1981; and Broms,1987).

Many techniques like pre loading, stone column, electro osmoses, were highly practiced in the literature to treat such soils to avoid its hazardous effects, the term "soil stabilization" refers usually to a soil improvement technique that involves blending soils with some additives or simply "stabilizers" to render soil properties less sensitive to hesitations (Nicholson, 2015).

Many materials are used to play this improvement role such as Ordinary portland cement, lime, fly ash and bitumeen. Using Ordinary portland cement is fairly un sustainable because of the CO_2 high emission (Khedari *et al.*, 2005). Lime, high calicium fly ash and calicum based additives have a considerable shortcoming which is the loss of its long term strength due to the possibility of ettringite and thaumasite formation dictated by sulfates attacks.

Geopolymers are usually defined as the binding gels that can be resulted from the alkali activation of a suitable alumino silicate source material, these materials comprise fly ash, meta kaoline, rice husk ash, red mud, etc. These binding gels can play the same role of the common hydrolic primary binders such as ordinary portland cement. The process of hydration led to synthesize common binding gels compounds which are calcium silicate hydrate (C-S-H) and/ or aluminum silicate hydrate (A-S-H) or even both, while in geopolymers the alternatives are sodium alominosilicate hydrate (N-A-S-H) (Fernandez and Palomo) and/or potassium alominosilicate hydrate (K-A-S-H) (Davidovits, 1988). Using this inovative materials has a good succefull applications in civil engineering due to it sustainable nature and good mechanical properties especially in concrete and mortar (Morsy *et al.*, 2014), although using geopolymers to treat soils is a current issue (Singhi *et al.*, 2016) several stydies started to discover this area such as using meta kaoline based geopolymer to stabilize clay (Zhang *et al.*, 2012) and using fly ash based geopolymer to treat granular soil (Cristelo *et al.*, 2012). However, many of geopolymers production key elements are recognized to be un understood regarding its effect to soil goeoplymers mixes. The present study tries to investigate the effect of NaOH molar concentration to the strengh development in term of uncnfined compresive strength of soft clay stabilized by flay ash based geopolymer subjected to intial duration time of heat at different liquid over fly ash ratio.

EXPERIMENTAL WORK

Materials Used

Soft Clay Soil

Soft clay soil used during the present study is recovered at Albawya suburb near Baqubah, Iraq. Some of the geotechnical properties of that soil is listed in Tables 1 while 2 shows the element composition by energy dispersive spectrotropy "EDS". Figure 1 illustrates the X-Ray diffraction of that soil.

Fly Ash

Deyana construction projects company class F fly ash used throgh this study, this material represents the aluminosilicate sourced used. Table 3 lists the elements composition.

Sodium Silicate

Sodium silicate used in the present study is manufactured at United Arab Emirates, some

Table 1: Some Geotechnical Properties of Soil Used

Item	Property	Value	Specification
1	Specific gravity	2.71	ASTM D 854-2
2	Liquid limit	33.6	ASTM D 4318-00
3	Plastic limit	21.6	ASTM D 4318-00
4	Placticity Index	12	/
5	Passing No. 200	100%	/
6	Percent of sand	0%	ASTM D-422, D-1140
7	Percent of clay	59%	ASTM D-422
8	Percent of silt	41%	ASTM D-422
9	USCS classification	CL	ASTM D-2487
10	pH	8.7	ASTM D-2472

important properties of this material is listed in Table 4.

Sodium Hydroxide

Flakes form is used in this study to prepare sodium hydroxide soultion, these flakes are commercially manufactured in Kuwait. The flakes should be dissolved at specific weights to reflect the desirred molar concentrations. Table 5 lists the important properties of the sodium hyroxide used in the present study.

Soil-Geopolymer Recipe

It is common in the geopolymer field that some kinds of materials usually known as "activators" are used to activate the source materials, in general sense, alkali hydroxides or silicates can be used, furthermore, alkali hydroxides are the preferred for the purpose of its simplicity (Morsy *et al.*, 2014). Otherwise, alkali hydroxides and silicates can be used togather as in this study, in addition, many recent contributions studied the effect of silicate to hydroxide ratio in the geopolymer concrete and mortar and the rusults

Table 2: EDS Analyses of Soil Used

Element	Weight %	Atomic %
O	55.44	72.36
Mg	2.65	2.27
Al	4.41	3.41
Si	15.36	11.42
K	1.46	0.78
Ca	14.12	7.36
Cr	0.11	0.05
Fe	5.91	2.21
Ni	0.35	0.12
Cu	0.01	0
Zn	0.02	0.01
Pb	0.16	0.02

Figure 1: XRD Analyses for Soil

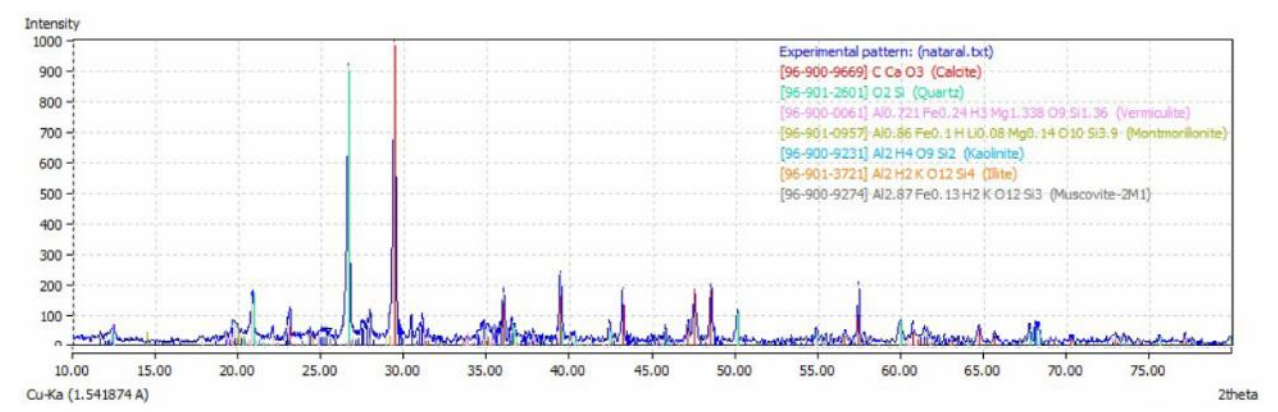


Table 3: EDS Analyses of Fly Ash

Element	Weight %	Atomic %
O	51.41	67.46
Na	0.49	0.45
Mg	0.91	0.79
Al	12.71	9.89
Si	20.89	15.61
K	1.15	0.62
Ca	3	1.57
Ti	1.41	0.62
Fe	7.55	2.84
Co	0.15	0.05
Ni	0.12	0.04
Zn	0.14	0.05
Pb	0.05	0.01

Table 4: Properties of Sodium Silicate

Item	Description	Value
1	Ratio of SiO_2 to Na_2O	2.4 ± 0.05
2	Na_2O percent by weight	13.10 – 13.70
3	SiO_2 percent by weight	32.00 – 33.00
4	Density - 20° Baumé	51 ± 0.5
5	Specific Gravity	1.534 – 1.551
6	Viscosity (CPS) 20 °C	600 – 1200
7	Appearance	Hazy

Noe: *According to the manufacturer.

confirmed this ratio perferrable to be 2 to exhibit best strength gain.

The author obsereved after many trials that silicate to hydroxide ratio dictated to be 0.5 due to sodium silicate viscosity, furthermore, another series of trials showed that total activator liquid to total soilds (fly ash + dried soil) ratio is ranged between 0.35 to 0.4, however, a resonable value of 0.38 is established at this study.

Table 5: Sodium Hydroxide Properties

Property	Unit Measuring	Specification ASTM E291-09	Results
Sodium hydroxide (NaOH), min.	Percent	97.5?	98.14
Sodium carbonate (Na_2CO_3), max.	Percent	0.4	0.36
Sodium chloride (NaCl), max.	Percent	0.15	0.07
Iron oxides (Fe_2O_3), max.	Percent	0.01	0.005
Sulphate as Na_2SO_4	Ppm	200?	70
Copper as Cu^{+2}	Ppm	4.0?	0.1
Nickel as Ni^{+2}	Ppm	5.0?	2.42
Manganese as Mn	Ppm	4.0?	0.02
Silicate as SiO_2	Ppm	20?	14
Water Insoluble	Ppm	200?	60

Note: *According to the manufacturer.

According to (Hardjito and Rangan, 2005) sodium hydroxide can be prepared at the desired molar concentration based on the flakes weight per liter of 1 kg of NaOH solution. The mass of NaOH solids is measured as 262 grams per kg of NaOH solution with a concentration of 8 Molar. Similarly, the mass of NaOH solids per kg of the solution for other concentrations was measured as 10 Molar: 314 grams, 12 Molar: 361 grams, 14 Molar: 404 grams, and 16 Molar: 444 grams

However, during the present study, 8, 10, 12, 14 Molar concentration was used to prepare the NaOH solution which then added to sodium silicate using the specified percent to form the finall activator liquid.

There are no an agrrement observed in the literature about the percent of the source materials used in soil-geopolymer mixes, actually, the author beleives that soil-cement experience is very usfull in this issue, cement percents that usually used to treat clayey soil ranged between 10 to 15% (Nicholson, 2015). The fly ash percents in this study were 8, 10, 12 and 14% respectively which corresponds liquid over fly ash ratio equals to 4.74, 3.8,3.167 and 2.714 respectively.

Characterization Tests for Soil Stabilization

Un Confined Compressive Strength (UCS)

The nominal dimensions used to perform the un confined compression test are 44 mm diameter and 100 mm in height. In accordance of the geopolymer recipe, the activator liquid was preparred, the natural soil was dried and pulverized, dried soil and fly ash mixed togather before the activator to be added, the author suggests three minautes to get reasonable homogeneity before the poured mixture to be remolded. The latter mixture then compated at five layrs using adequate tamper at resonable compaction efforts. Then, the resulted specimens extruded using sample ejector and submitted to initial 6 houres of 70 °C of heating, finally, specimens were stored at curring chamber at 23 ± 3 °C till 7 days. The loading rate of unconfined testing is 2% per minaute.

Microstructural Characterization

Scanning Electron Microscope “SEM” is usually used to observe the micro structure of the stabilized soils, the test was conducted at University of Technology/Nanotechnology and advanced Material Research Centre (NTRC) using Tescan VEGA 3 SB apparatus for un treated and for 10 Molar, 3.8 liquid over fly ash cured at 70 °C subjected to 6 houres initial heating.

Mineralogical Analyses

X-Ray Powder Diffraction (XRD) was done to characterize the mineralogical changes and to confirm the resulting gels. this tests was conducted at University of Baghdad/Central laboratory of Ibn Alhaytham College for un treated and for 10 Molar, 3.8 liquid over fly ash cured at 70 °C subjected to 6 houres initial heating. Match software was used to perform Minerals matching.

RESULTS AND DISCUSSION

Unconfined Compression Strength

Figures 2, 3, 4 and 5 shows the un confined peack strength versus NaOH molar concentrations for 4.75, 3.8, 3.167 and 2.714 liquid over fly ash ratio resperctivelly. It can be seen from these figures that optimum molar concentration is evident at 12 M. That reflect the fact that the excessive amount of hydroxel ions which are usually initiates the geopolymerization process may reduces the consequent strength gain. The peack UCS strength in 4.75 and 3.8 is lower than these of 3.167 and 2.714 due to the low presence of source material.

Figure 2: Variation of UCS vs NaOH Molar Concentrations for 4.75 Liquid Over Fly Ash Ratio

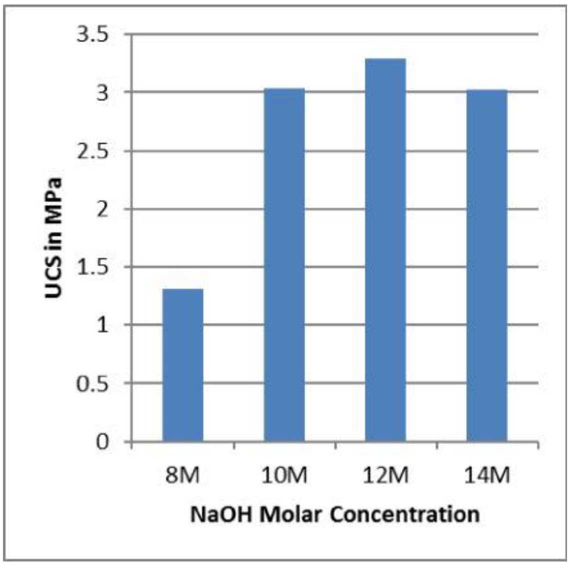


Figure 3: Variation of UCS vs NaOH Molar Concentrations for 3.8 Liquid Over Fly Ash Ratio

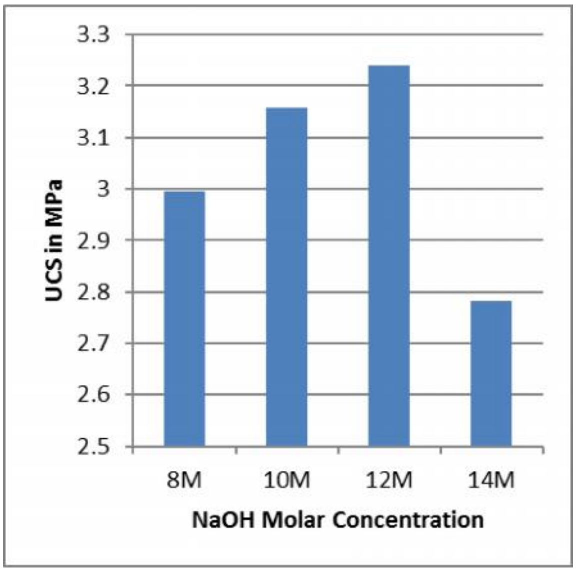


Figure 4: Variation of UCS vs NaOH Molar Concentrations for 3.167 Liquid Over Fly Ash Ratio

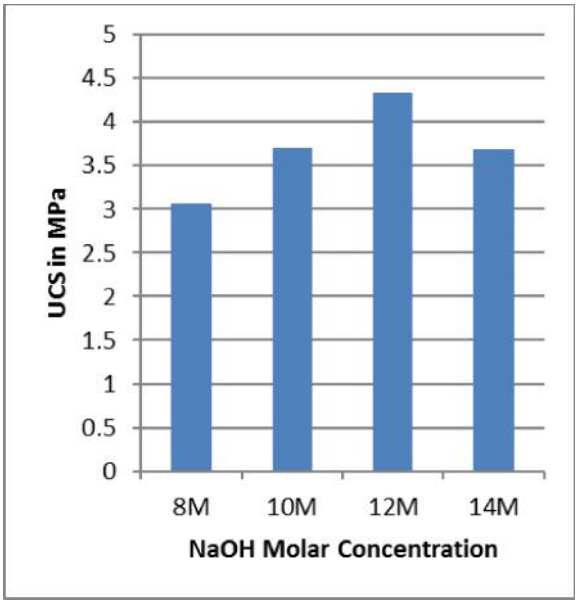


Figure 5: Variation of UCS vs NaOH Molar Concentrations for 2.714 Liquid Over Fly Ash Ratio

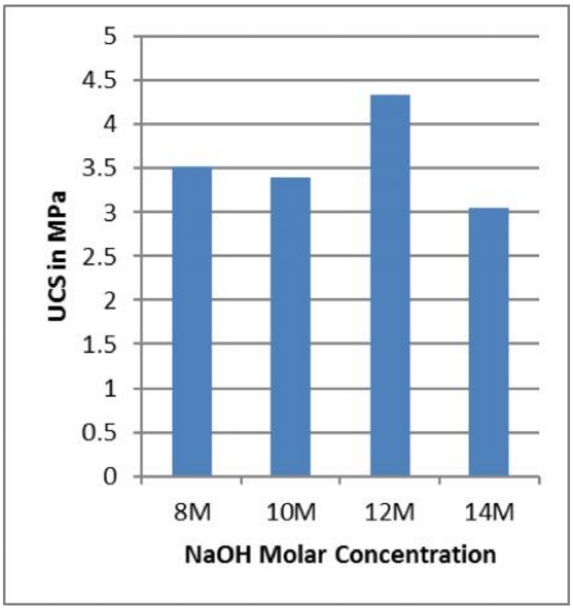
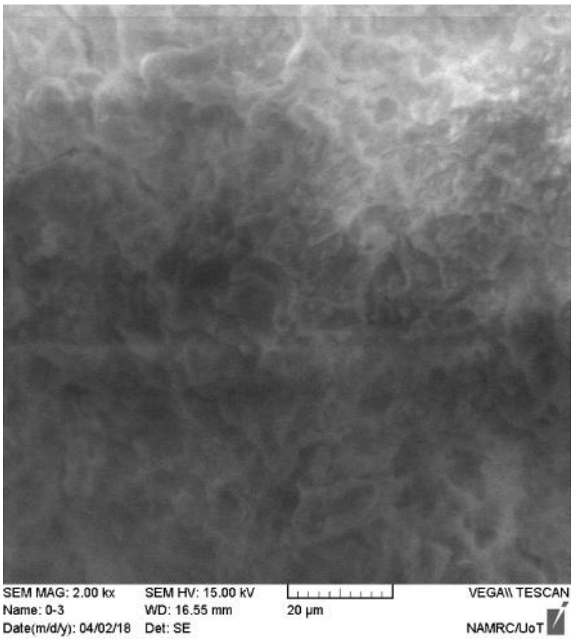


Figure 6: SEM Image for Untrated Soil 20 µm



SEM Characterization of Stabilized Soil

Figures 6 and 7 show SEM images for untreated soil while Figures 8 and 9 show the images for 10 M, 3.8 liquid over fly ash curred at 70 °C subjected to 6 houres initial heating. Foil-like structure is clearly evident in Figures 8 and 9.

Figure 7: SEM Image for Untrated Soil 5 µm

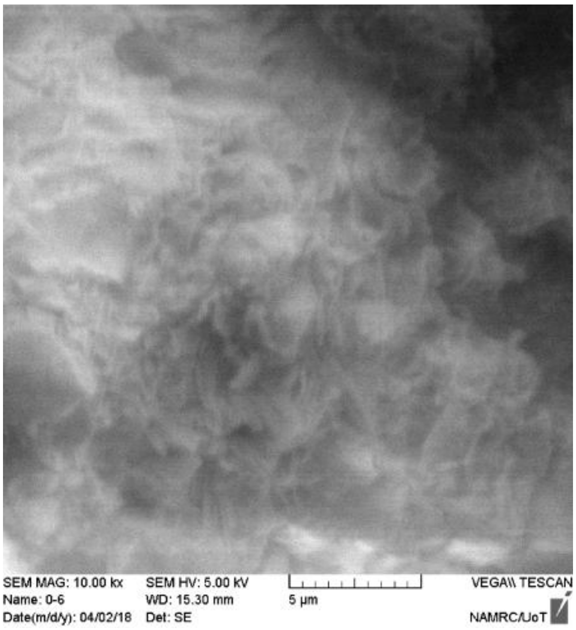
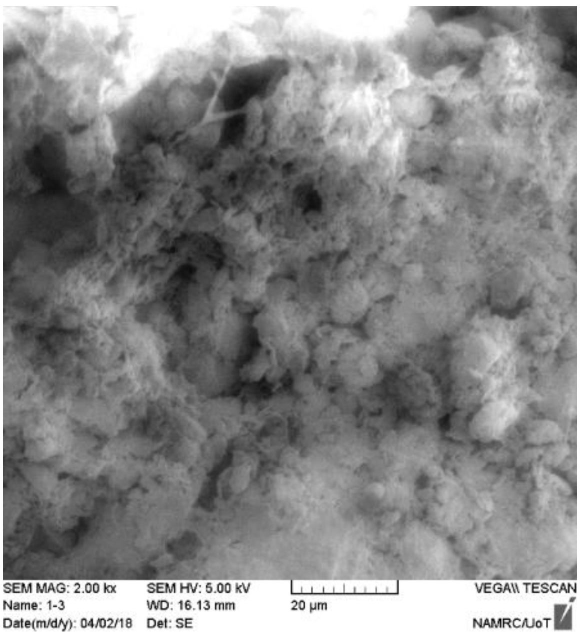


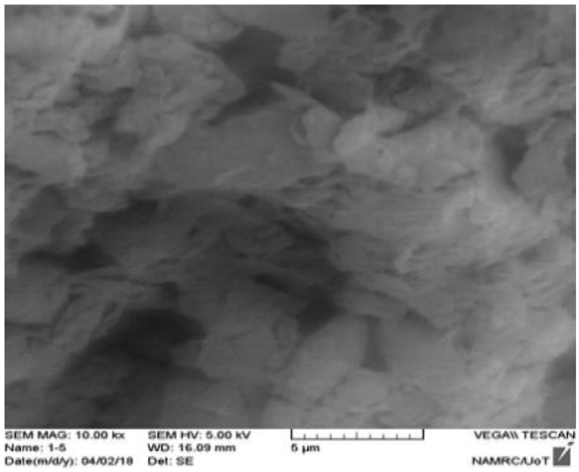
Figure 8: SEM Image for 10 M, 3.8 Liquid Over Fly Ash Curred at 70 Co Subjected to 6 Houres Initial Heating 20 µm



XRD Characterization of Geopolymer Gels

X-Ray powder diffraction was done to confirm

Figure 9: SEM Image for 10 M, 3.8 Liquid Over Fly Ash Curred at 70 Co Subjected to 6 Houres Initial Heating 5 µm



the formation of the resulted gels potassium alominosilicate hydrate (K-A-S-H) (18.46%) and sodium alominosilicate hydrate (N-A-S-H) (1%). Figure 10 shows the XRD pattern of 10 M, 3.8 liquid over fly ash curred at 70 °C subjected to 6 houres initial heating, no new peacks was gained through this analyses which means that no reaction was happened between soil and other materials. Tables 6 and 7 showed the minerological composion percents to natural and stabilized soil by using match program.

Table 6: Minerological Percents for Unstabilized Soil

Mineral Name	%
Calcite	33.29
Quartz	23
Vermiculite	18.57
Montmorillonite	6.27
Kaolinite	4.71
Illite	5.47
Muscovite	8.68

Figure 10: XRD Analyses for 10 M, 3.8 Liquid Over Fly Ash Curred at 70 Co Subjected to 6 Houres Initial Heating

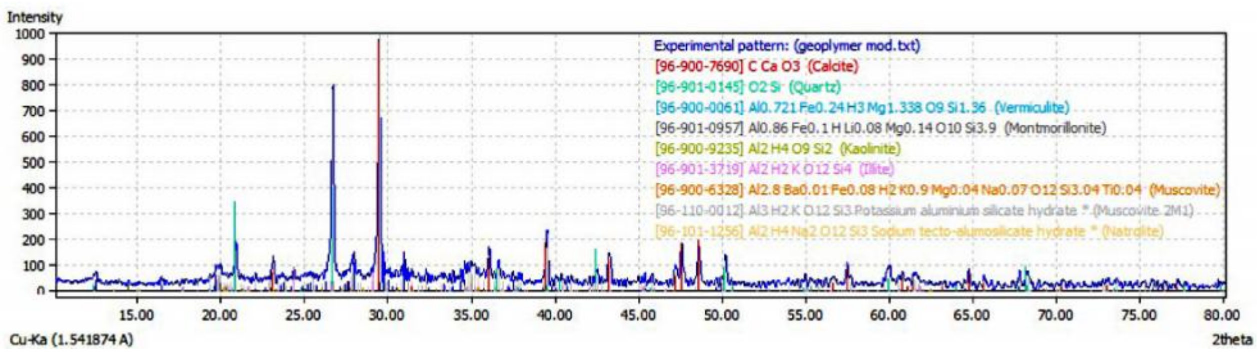


Table 7: Minerological Percents for Unstabilized Soil

Mineral Name	%
Calcite	32.48
Quartz	15.86
Vermiculite	6.9
Montmorillonite	4.36
Kaolinite	2.54
Illite	11.88
Muscovite	5.78
Potassium aluminium silicate hydrate	18.46
Sodium tecto-alumosilicate hydrate	1.74

CONCLISION

Based on the results and discussion presented in this paper the following conclusions may be drawn:

- NaOH molar concentration is very important factor and highly affects the the consequent mechanical strength.
- NaOH molar concentration affects the time between mixing and compaction which may decresed with high molar concentrtions.
- Changing NaOH molar cencentration illustrates an optimum value.

REFERENCES

1. Brand E W and Brenner R P (1981), "Soft Clay Engineering", Elsevier, Amesterdam, Netherlands.
2. Broms B B (1987), "Stabilization of Soft Clay in Southeast Asia", Proceedings of 5th International Geotechnical Seminar, December 2-4, Kazakhstan.
3. Coduto D P (1999), *Geotechnical Engineering*, 2nd Edition, Prentice Hall, Upper Saddle River, New Jersey, USA.
4. Davidovits J (1988), "Geopolymer Properties and Chemistry", Proceedings of 1st European Conference on Soft Mineralurgy, pp. 25-48, Compiegne, France.
5. Fernandez J A and Palomo A (2005), "Composition and Microstructure of Alkali Activated Fly Ash Binder: Effect of the Activator", *Cement and Concrete Research*, Vol. 35, pp. 1984-1992, Elsevier.
6. Hardjito D and Rangan B V (2005), "Development and Properties of Low-Calcium Fly Ash-Based Geopolymer Concrete", Research Report GC1, Faculty of Engineering, Curtin University of Technology, Perth.

7. Khedari J, Watsanasthaporn P and Hirunlabh J (2005), "Development of Fiber-Based Soil-Cement Block with Low Thermal Conductivity", *Cement and Concrete Composite*, Vol. 27, pp. 111-116, Elsevier.

8. Morsy M S, Alsayed S H, Salloum Y A and Almusallam T (2014), "Effect of Sodium Silicate to Sodium Hydroxide Ratios on Strength and Microstructure of Fly Ash Geopolymer Binder", *Arabian Journal for Science and Engineering*, Springer, Vol. 39, pp. 4333-4339.

9. Nicholson P G (2015), "Soil Improvement and Ground Modification Methods", Elsevier.

10. Singhi B, Laskar A I and Ahmed A M (2016), "Investigation on Soil-Geopolymer with Slag, Fly Ash", *Arab J Sci Eng*, Vol. 41, pp. 393-400.

11. Zhang M, Gue H, El-Korchi T, Zhang G and Tao M (2013), "Experimental Feasibility Study of Geopolymer as the Next-Generation Soil Stabilizer", *Construction and Building Materials*, Vol. 47, pp. 1468-1478, Elsevier.

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