IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

GEOPOLYMER STABILIZATION OF SOIL COLLECTED FROM HABITAT AREA OF NILGIRIS

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ABSTRACT - Geopolymer stabilization can transform a wide range of waste alumino silicate material into building and mining material with excellent chemical and physical properties. However, there is lack of research related to geopolymer stabilized soil compared to use of geopolymer in concrete. In this study, the utilization of geopolymer has been investigated to stabilize the soil including the factors affecting the geopolymer stabilization process. Geopolymer is based on alumino-silicate chain which is a combination of alumino silicate material and alkaline activator. In this study, fly ash was used as a alumino silicate material, combination of sodium silicate (Na2SiO3) and sodium hydroxide (NaOH) was used as an alkaline activator. Unconfined Compressive Strength (UCS) was an indicator to the strength development and hence evaluating the performance of geopolymer stabilized soil. This study focusses on the effect of fly ash and alkaline activator with different molarities of NaOH solution (6M, 8M and 10M) on geopolymerized soil which was prepared and cured for 3 days. Three different ratios (2.0, 2.5 and 3.0) of fly ash and alkaline activator with three different ratios (2.0, 2.5 and 3.0) of alkaline activator were used. UCS tests were carried on prepared specimens. The maximum UCS strength obtained was 166kN/m^2 for the geopolymer stabilized soil using ratio of fly ash and alkaline activator 2.0 with ratio of alkaline activator 2.0 and 8M NaOH solution.

Key Words: Geopolymer, fly ash, sodium silicate, sodium hydroxide, alkaline activator.

***Index Terms* - Component, formatting, style, styling, insert.**

1. INTRODUCTION

Since 1970's, one of the recent material technology is geopolymer. Geopolymer technology have been developed by Davidovits and gives a number of benefits to the construction material field especially for the building structures. Geopolymer are a family of cementitious materials synthesized by alkaline activationof aluminium and silica containing solid precursors. Precursors that can be used in geopolymer synthesis include clays (usually kaolin, either raw or made more reactive via thermal conversion to metakaolin), fly ash, slag, silica fume and many other industrial and urban wastes for reducing the carbon footprint. Commercially produced geopolymer may be used for fire and heat- resisting coating and adhesives, medical applications, high-temperature ceramics, new binders for fire-resistingfibre composites, toxic and radioactive waste encapsulation and new cements for concrete. Scientifically, geopolymer is the reaction of inorganic polymeric materials with a chemical composition similar to zeolite but containing an amorphous structure and possessing ceramic like structure and properties. The amorphous to semi- crystalline three dimensional structure of silicate network consists of silicate (SiO_4) and aluminate (AlO_4) tetrahedral, which is linked alternatively by sharing all the oxygen to create polymeric Si-O-Al bonds. The geopolymer contains negatively charged tetrahedral silica and aluminium sites in the network which are charge balanced by alkali metal cations such as sodiumor potassium.

The production processes of traditional stabilizers are energy intensive and emit a large quantity of carbon dioxide (CO_2), while using geopolymer stabilization withits rapid gain of strength, low heating temperature, low cost, low energy consumption, low permeability making it more durable and low CO_2 emission making it a green material during synthesis, offers a promising alternative to Ordinary Portland Cement (OPC). However, the geopolymer stabilization largely depends on different factors such as types of soils, types of raw materials,solid to liquid ratio, sodium silicate to sodium hydroxide ratio, temperature and curing time which all can affect the cost and product characteristics. The effectiveness of geopolymer is studied in terms of UnconfinedCompressive Strength (UCS), Differential Free Swelling (DFS), Swelling Pressure (SP), durability and dispersion tests.

1.1. OBJECTIVE

The following are the objectives of the current investigation

- To determine the effect of different molarities of geopolymer materials in the improvement of strength of unstable soil.
- To study the effect of curing period on the strength improvement of geopolymer stabilized soil.

2. MATERIALS AND METHODS

2.1 Materials

The soil sample used for this study work was collected from Gandhinagar site. The latitude andlongitude extends from 11°12' N to 11°37' N and 76°30' E to 76°55' E, respectively. Fly ash (residue from coal combustion) is an industrial by product where is used finely divided residue resulting from combustion of coal and has been used as cement replacement for the recent years. However, it can only partially replace Portland cement since SiO_2 and Al_2O_3 in fly ash still need $Ca(OH)_2$ from Portland cement hydration for its pozzolanic reaction to produce calcium silicate hydrate and calcium aluminate hydrate. One of the geopolymer isusually made of fly ash activated with alkaline solution at low temperature and it is sometimes called alkali-activated fly ash. Fly ash contains high percentage of amorphous silica and alumina, hence is suitable as asource of alumino silicate material for making geopolymer. Fly ash is mainly glassy with somecrystalline inclusion of mullite, hematite and quartz. The alkaline activator with the combination between sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) was prepared just before mixing with fly ash. A various concentration of alkaline activator also used for in this study. In the preparation of sodium hydroxide (NaOH) solution, Sodium hydroxide pellets (97% - 99% purity) were dissolved in distilled water in a volumetric flask at various molarities concentration. 40 grams of sodiumhydroxide dissolved in 1000 ml of distilled water which means 1Molarity. Sodium silicate (Na_2SiO_3) which consists of Na_2O is 7.9%, SiO_2 is 26% and H_2O is 66.1% with weight ratio SiO_2 / Na_2O : 3.2 and specific gravity 1.35 were used in this study. The addition of sodium silicate was to enhance the process of geopolymerization.The type and concentration of alkali solution affect the dissolution of fly ash. Leaching of Al^{3+} and Si^{4+} ions are generally high with sodium hydroxide solution comparedto potassium hydroxide solution. Therefore, alkali concentration is a significant factor in controlling the leaching of alumina and silica from fly ash particles.

Table 1. Physical Properties of soil

SI.NO	Properties	Value
1	Natural moisture content (%)	26.76
2	Specific gravity	2.68
3	Sand (%)	34.3
4	Silt and clay (%)	65.70
5	Liquid limit (%)	48
6	Plastic limit (%)	33
7	Shrinkage limit (%)	21
8	Optimum moisture content (%)	20
9	Maximum dry density (g/cc)	1.861
10	Coefficient of permeability (cm/sec)	2.57×10^{-5}
11	Unconfined compressive strength (kPa)	83

2. TESTING PROCEDURE

3.1 Preparation of geopolymer for unstabilized soil sample

Geopolymerization can transform a wide range of waste aluminisilicate materials into building and mining materials with excellent chemical and physical properties. Generally, to make geopolymer paste, separate mixing and normal mixing were used. For separate mixing, Sodium hydroxide solution was mixed with fly ash for the 10 minutes subsequently sodium silicate solution solution was added into the mixture. Fornormal mixing, fly ash, sodium hydroxide and sodium silicate solution were incorporated and mixed at the same time. For mixing producure, separate mixing gave slightly better strength than normal mixing. Longer period time (more than 30 minutes) was not performed since the mixture would become very sticky with formation of $Si(OH)_4$ and $Al(OH)_4$ gel. Soil sample and fly ash were dry mixed together to allow the fly ash distributed uniformly. In this study separate mixing was used meanwhile sodium silicate (Na_2SiO_3) were mix together with sodium hydroxide (NaOH) at design various ratio to form Alkaline Activator (AA) and restfor 30 minutes for complete reaction. After that, the AA was poured into fly ash mixed together until the homogeneous paste was obtained. The available paste is called as Geopolymer.

3.2 Various mix proportion of geopolymer soil sample

The mixing process of soil sample and geopolymer can be handles within 5 minutes for eachmixture with different concentration of sodiumhydroxide solution (6M, 8M and 10M), different ratiosof sodium silicate to sodium hydroxide (Na_2SiO_3/NaOH), also different ratios of fly ash toalkaline activator. However, the ratios can be variousdepend on its applications. Different curing time alsogive an impact to the strength of geopolymer. But thisstudy focusses on constant curing period at 3 days each sample.

Table 2. Mix proportion of geopolymer

S.No	Sample Identification Number	Fly ash / Alkaline activator	Na_2SiO_3/NaOH
1	1-1	2	2
2	1-2	2	2.5
3	1-3	2	3
4	2-1	2.5	2
5	2-2	2.5	2.5
6	2-3	2.5	3
7	3-1	3	2
8	3-2	3	2.5
9	3-3	3	3

3.3 UNCONFINED STRENGTH OF GEOPOLYMERIZED SOIL

Unconfined compression test was used to determine the unconfined compressive strength of unstabilized and geopolymerized soil. There was significant increase of shear strength of soil sample at various solid to liquid ratio and activator ratio for different molarities concentration of sodium hydroxide solution.

Figure 1 Before failure of UCS soil

Figure 2 After failure of UCS soil

4 .RESULTS AND DISCUSSION

4.1 Strength of 6 Molarity NaOH of geopolymerizedsoil

While using 6M NaOH solution, the optimum concentration obtained at ratio of sodium silicate to sodium hydroxide was 2.0 and the ratio of fly ash to alkaline activator was 2.5. The highest strength of geopolymerized soil sample obtained by this type of concentration was 124kPa and also lower strength 85kPais about 45.88% increment.

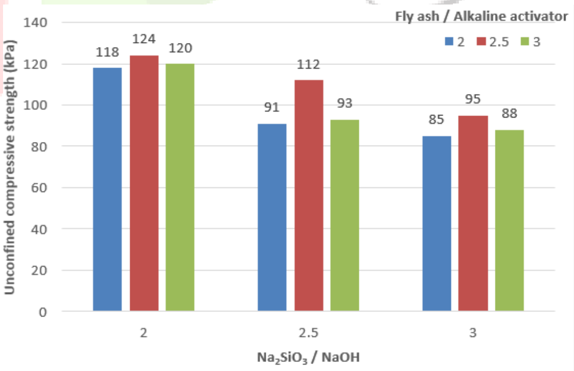

Figure 3. Comparison bar chart for overallstrength of 6M NaOH

4.2 Strength of 8Molarity NaOH ofgeopolymerized soil

While using 8M NaOH solution, the optimum concentration obtained at ratio of sodium silicate to sodium hydroxide was 2.0 and the ratio of fly ash to alkaline activator was 2.0. The highest strength of geopolymerized soil sample obtained by this type of concentration was 166kPa and also lower strength 92kPais about 80.43% increment.

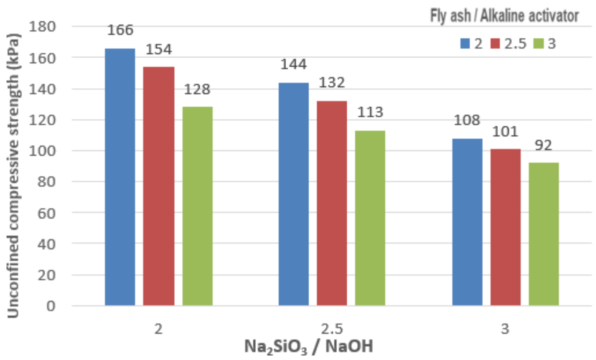

Figure 4. Comparison bar chart for overall strengthof 8M NaOH

4.3 Strength of 10 Molarity NaOH of geopolymerized soil

While using 10M NaOH solution, the optimum concentration obtained at ratio of sodium silicate to sodium hydroxide was 2.5 and the ratio of fly ash to alkaline activator was 2.5. The highest strength of geopolymerized soil sample obtained by this type of concentration was 148kPa and also lower strength 87kPais about 70.11% increment.

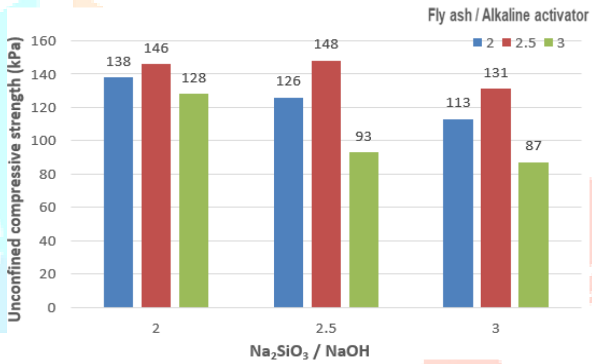

Figure 5. Comparison bar chart for overall strengthof 10M NaOH

5.CONCLUSION

The aim of this study was to present the effect of different molarities of sodium hydroxide, different ratio of sodium silicate to sodium hydroxide and differentratio of fly ash to alkaline activator for the geopolymer stabilized soil curing was done for a period of 3 days. From the experimental results, the following conclusionshave been made:

1. The strength improvement of the sample was 124kPa when 6M NaOH solution was used. It wasincreased to 33.87% with 8M NaOH and thendecreased.
2. At 6M NaOH, the dissolution was low due less concentration. For 8M NaOH, the base concentration was higher and dissolution was increased. For the 10M NaOH, dissolution was reduced be primarily to an increase in coagulationof silica.
3. The unconfined compressive strength was foundto be 166kPa for 8M NaOH solution and ratio of fly ash to alkaline activator was 2.0 and ratio of sodium silicate to sodium hydroxide was 2.0. Thiswas the highest strength obtained compared toother combination.

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