GEOPOLYMER STABILIZED EARTH BRICK

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Abstract: The use of natural earth material in Modern construction sector has been reduced over many years. It is because of the lack of strength and durability of these earth materials. This project deals with stabilization of locally available soil and makes it usable in the construction sector. In order to stabilize the soil, geopolymer was used here. Geopolymer consists of fly ash, ground granulated blast furnace slag, sodium hydroxide and sodium silicates. The main objective of this study is to make soil stabilized with geopolymer earth brick. In order to achieve this objective, proportions of source materials and molarity of sodium hydroxide are found out. For fixing the proportion, three different proportion of source materials (15% fly ash + 5% GGBS, 10% flyash + 10% GGBS, 5% flyash + 15% GGBS) and different concentration of sodium hydroxide (6, 10, 15&18M) are taken. Then the tests for compressive strength, water absorption, efflorescence and thermal conductivity were done. From the study, it was concluded that 20%locally available soil which was replaced by an equal proportions of fly ash and GGBS and the range of 10 to 15M of sodium hydroxide give better results.

Index Terms: Geopolymer, Compressive strength, curing

I. INTRODUCTION

The development of both rural villages and cities, which is the fastest growing economy in the world, the progressive increase in the demand of residential buildings requires a huge amount of building materials to be prepared and used which need huge amount of money. Nowadays, energy shortage and pollution have become the main problems in the society. The modern building materials which have high energy costs and CO_2emissions should be replaced by the sustainable and environmental building materials which are abundant and inexpensive. Construction using earth helps to reduce the global warming and helps to improve living comfort. Construction using earth helps to make building warm in winter and cool in summer. Earth construction helps to improve living comfort and reduce environmental impacts. Unfortunately, nowadays the use of earth material is reduced because of its durability and strength. Soil stabilization is a general method and it is done to change the soil properties and to meet soils for various engineering purposes. Soil stabilization is done to improve bearing capacity of soil, tensile strength, and overall performance. Two types of soil stabilizations are present such as mechanical stabilization and physical stabilization. In the case of mechanical stabilization, soil is compacted by using hammers or other mechanical means. In the case of physical stabilization, chemicals or other materials are used to change the texture of the soil. Different types of soil stabilizations methods are given below.

- Stabilization with Cement
- Soil Stabilization using Lime
- Soil Stabilization with Bitumen
- Chemical Stabilization of Soil
- Electrical Stabilization of Clayey Soils
- Soil Stabilization by Grouting
- Soil Stabilization by Geotextiles and Fabrics

Nowadays soil is also stabilized by using cement. During the manufacture of cement, huge amount of carbon dioxide is emitted. It causes global warming. The production of each ton of cement releases approximately an equal amount of carbon dioxide is emitted into the atmosphere. Cement industry is partially responsible for this problem. The increased use of cement can be reduced by employing alternative materials such as geopolymer. In 1994 Davidovits proposed that an alkaline activator could be used to react with silicon and aluminum in a source material of fly ash and GGBS to produce binders. Because where polymerization process takes place, he coined the term geopolymer to represent these binders which have sufficient compressive strength and durability. Thus the disposal problems of fly ash can also be reduced. Huge volumes of fly ash are generated around the world; most of the fly ash is not effectively used, and a large part of it is disposed in landfills. Soil is locally available, cost effective, energy efficient and environment friendly building material in Kerala.

Geopolymer is an environment friendly and low carbon emission binding material (Yan –Jun Du Et.al 2016). Light weight geopolymer stabilized soil has less water absorption, high permeability and greater material strength than light weight cement stabilized soil. In the case of geotechnical applications geopolymer was a better option for soil stabilization in geotechnical engineering. In 1994Akinmusuru Et.al studied the variation of thermal conductivity with fire resistance of earth block in addition of cement, lime and slag. Addition of such type of material influences the thermal conductivity. Thermal conductivity of plain brick is 0.64, thermal conductivity of cement stabilized brick is 0.5 and thermal conductivity of lime stabilized brick is 0.34. The thermal conductivity of GGBS stabilized brick is 0.63. 10% of ground granulated blast furnace slag is recommended at high sodium silicate to sodium hydroxide ratios (Runglawan Rachan,2017). In 2013, Suksun Horpibulsuk et.al conducted a study in which clayey soil is stabilized by flyash based geopolymer and the strength development are checked where silty clay is used as fine aggregates and fly ash is used as source material. The specimen is heated at 65°Celsius for 48 hours. The result shows that sodium silicate to sodium hydroxide ratio increases with increase in alkali activator to binder ratio up to an optimum value and then tends to decrease. In the case of clayey soil, liquid activator to binder ratio was 0.6. In 2011 Che Mohd Ruzaidi et.al included optimization of alkali liquid to binder ratio. For the purpose of optimization, tests on flyash based geopolymer were conducted. The result concluded that alkali liquid to fly ash ratio ranges from 0.3 to 0.4, and it is highly suitable for producing geopolymer with high compressive strength.

Alkali activated binder such as potassium hydroxide sodium hydroxide and sodium silicates have emerged as alternative to ordinary Portland cement binders. This seems to have good durability and environmental impact. Now new binders are needed to replace Portland cement for enhanced environmental and durability performance (Said Jalali et.al 2007).The commonly used activators for geo polymerization include alkaline metal and alkaline earth metal compound. In 2017Shading Miao Et.al, the stabilization of highly expansive black cotton soil by means of geopolymerization The oven curing of 60 degree Celsius was adopted for the geopolymer stabilized compressed earth brick. The results concluded that geopolymerization of compressed earth brick significantly improved their mechanical performance. A quantity of 10 or 15% of geopolymer made compressed earth block give the compressive strength of at least 14MPa.Thermal properties of geopolymer block were 0.7 W/Mk it's lower than of thermal properties than cement stabilized blocks. 2016 Ilker Tekin, where properties of sodium hydroxide activated geopolymer with marble, travertine and volcanic tuff wastes were used. In 2013 Shui-Long Shen Et.al, where clayey soil stabilized by geopolymer. Different ratios of sodium silicate to sodium hydroxide are selected for the study as 0.7, 1, 1.5, and 2.3. Check the compressive strength of specimen at 7, 14 and 28 day, after 65 degree Celsius for 48 hrs. Results from the study concluded that sodium silicates to sodium hydroxide ratio of 0.7 were suitable for clayey soil.

RESEARCH METHODOLOGY

3.1 Material Properties

Table 3. 1 Material properties

Materials	Specific gravity	Liquid limit	Optimum moisture content	Maximum dry density
Soil	2.018	38%	18%	1.55 g/cc
Fly ash	2.02			
GGBS	2.8			
Sodium hydroxide	1.37			
Sodium silicates	1.59			

The locally available soil is taken from Amal Jyothi College Of Engineering Kottayam. The properties of the soil are given in table 3.1. In this study two type of alkali activators such as sodium silicates and sodium hydroxide are used. In this study sodium hydroxide was chosen because sodium hydroxide was cheaper than potassium hydroxide. Sodium hydroxide was collected from Minar chemicals Ernakulum, properties are shown in table 3.1. In this study 6, 10, 15 and 18M was used. Class F Fly ash used in this study was obtained from Alan hydraulic bricks, Ankamaly. Fly ash is an inorganic non combustible finely divided residue collected from the chimneys of coal fired boiler plants. The chemical composition of ground granulated blast furnace same as that of ordinary Portland cement but difference is that its proportions. Where JSW GGBS was used for this project work and particle size less than 45 microns.

3.2 Optimum moisture contents for various trials

As per IS 2720 Part8, to determine the optimum moisture content the specimen subjected to standard compaction. For determine the optimum moisture content take 3 kg of soil .Sufficient water was added to the sample which is less than essential optimum moisture content and mixed thoroughly. In this case 20% of soil is replaced by 15% of flyash and 5% of GGBS. Three layers of soil was added to the mould and each layer give 25 blows by using rammer weighting 2.6 kg by dropping it from a height of 310mm

Table 3. 2 Optimum moisture contents

Proportions	Optimum moisture content (%)	Maximum dry density (g/cc)
15% Fly Ash +5%GGBS	26	1.53
10%Flyash +10%GGBS	43	1.35
5% Flyash +15 % GGBS	55	1.37

3.3 Mix Proportions

In the case of geopolymer trial and error method was used to fix the mix proportion of materials and there was no appropriate mix design. Were mix proportions are fixed as per literature surveys and basis of trial mix. The bricks mould of size of 190 x 90 x 90 mm was selected for this study. As per IS 1077:1992.Specific gravity and optimum moisture content of the soil was fixed from the material testing of soil. The specific gravity of soil was 2.018 and optimum moisture content of soil was 20%. Based on the literature surveys ratio of sodium silicate to sodium hydroxide and alkali liquid to binder ratio was fixed. Sodium silicate to sodium hydroxide ratio was 2 and alkali liquid to binder ratio was 0.35. Quantity calculations for making three bricks are shown in below.

3.4 Procedure

- Find optimum moisture content for various percentages of flyash and GGBS
- 20% of locally available soil was replaced by fly ash and GGBS. Where three proportions of fly ash and GGBS with varying molarity of sodium hydroxide is selected. The proportions are 15% of Fly ash and 5% of GGBS, 15%of Fly ash and 15% of GGBS and 5% of flyash and 15% of GGBS and also the molarities are 6,10,15 and 18M. Sodium silicate to sodium hydroxide ratio was fixed as 2 and alkali liquid to fluid ratio was 0.35. In this study specimens were subjected to oven curing at 60 degree Celsius for 24 hrs.
- Compressive strength of various proportions is determined. On the basis of higher compressive strength select better proportions of source materials.
- To fix the molarity of sodium hydroxide, using selected proportions of fly ash and GGBS. Then to find water absorption, thermal conductivity and efflorescence.
- Using the results from water absorption, thermal conductivity and efflorescence fix the better molarity of sodium hydroxide

IV. RESULTS AND DISCUSSION

4.1 Compressive strength

From this study 20 % of locally available soil was replaced with three proportions of fly ash and GGBS, the proportions are 15% fly ash and 5% of GGBS,10% of fly ash and 10 % of GGBS and 5% of flyash and 15% of GGBS. The each proportion was tested with varying molarity of sodium hydroxide. Specimens were cured at room temperature for 24 hrs. After 24 hrs the specimens were subjected to oven curing at 60^0C for 24hrs. From the above table 4.1, compressive strength increased with increase in morality of sodium hydroxide. Among compressive strength of various combinations such as 15% of flyash with 5% of GGBS, 10% of flyash with 10% of GGBS and 5% of flyash with 15% of GGBS, 10% of flyash and 10% of GGBS gave high strength compared to other two combinations. As per IS1077:1992, the compressive strength of any individual brick shall not fall below 3.5N/mm².

Compressive strength test results of 10% of GGBS, 10% of flyash and with varying molarity of sodium hydroxide (6M, 10M, 15M and 18M) are given table 4.1. The equal proportions of fly ash and GGBS gives high compressive strength at each molarity of sodium hydroxide compared to other two combinations. The compressive strength increases with increasing molarity of sodium hydroxide. The strength of bricks increases with increasing molarity of sodium hydroxide. Based on compressive strength of various proportions of brick, 10% of flyash and 10% GGBS was selected for further study.

Table 4.1 compressive strengths

Molarity	Combination of source material	Average compressive strength (N/mm²)
6M	15 %Fly ash +5%GGBS	2.4
	10 %Fly ash +10%GGBS	4.5
	5 %Fly ash +10%GGBS	3.1
10M	15 %Fly ash +5%GGBS	4.8
	10 %Fly ash +10%GGBS	5.7
	5 %Fly ash +10%GGBS	4.4
15M	15 %Fly ash +5%GGBS	7.7
	10 %Fly ash +10%GGBS	9.7
	5 %Fly ash +10%GGBS	8
18M	15 %Fly ash +5%GGBS	10.3
	10 %Fly ash +10%GGBS	14.6
	5 %Fly ash +10%GGBS	12.8

4.2 Water absorption

The strength of brick depends upon its water absorption capacity. It depends on the properties of materials used and voids present in the earth brick. Based on compressive strength of various proportions of brick, equal percentage of flyash and ground granulated blast furnace slag was selected for water absorption test. In this study, different molarities of sodium hydroxide were tried. Table 4.2 shows results from water absorption of brick with varying molarity of sodium hydroxide. These water absorption tests were done to determine the suitable molarity of sodium hydroxide and to check which molarity gives the lowest percentage of water absorption. The results of water absorption of various molarity of sodium hydroxide are shown in the table. As per IS 1077:1992 water absorption shall not be more than 20% by weight up to class 12.5 and15% by weight for higher class brick. Where 20% percentage of locally available soil was replaced by 10% of flyash and 10% of ground granulated blast furnace slag .The 6M of sodium hydroxide give high water absorption compared to 18M of sodium hydroxide. Figure 4.1 shows water absorption versus molarity of sodium hydroxide. As per IS 1077: 1992 water absorption shall not be more than 20% by weight up to class 12.5 and15% by weight for higher class brick. The results were conforming to IS specification. AS per IS specification geopolymer stabilized earth bricks are higher class bricks. In the case of 6M of sodium hydroxide, water absorption of 9.2% is achieved and 10 and 15 molarity gave 8.1% and 6.6% of water absorption respectively. The lowest percentage of water absorption was obtained at 18M of sodium hydroxide.

4.2 Water Absorptions

Molarity	Water Absorption (10% Flyash +10% of GGBS)
6M	9.2%
10M	8.1%
15M	6.6%
18M	4.9%

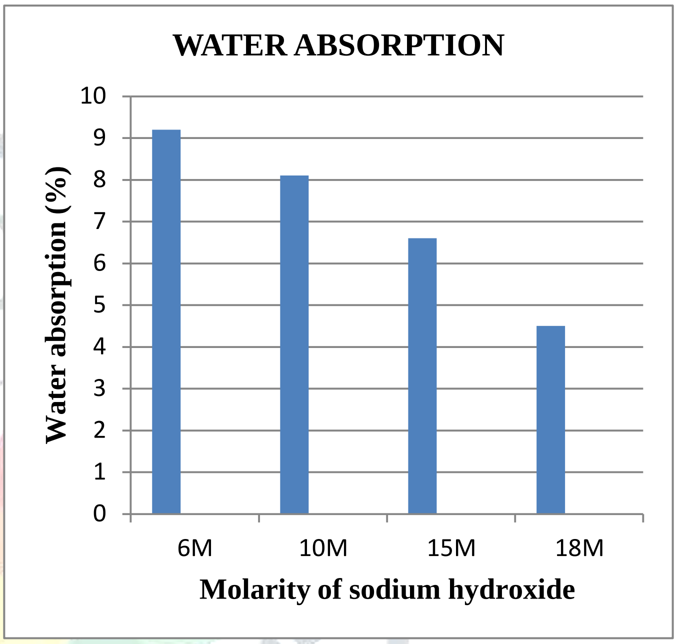

Fig 4.1 Water Absorption

4.3 Thermal conductivity

Thermal conductivity testing apparatus is used for measuring thermal conductivity based on the results from compressive strength of various proportions of source materials. Equal proportions of flyash and ground granulated blast furnace slag was used for fixing the molarity of sodium hydroxide by checking thermal conductivity of the specimen using 190 x 90 x 90 mm size specimen.

Table 4.3 Thermal conductivity

Molarity Of Sodium Hydroxide	Average thermal Conductivity(K/Mk)
6M	0.504
10M	0.403
+ 15M	0.288
18M	0.132

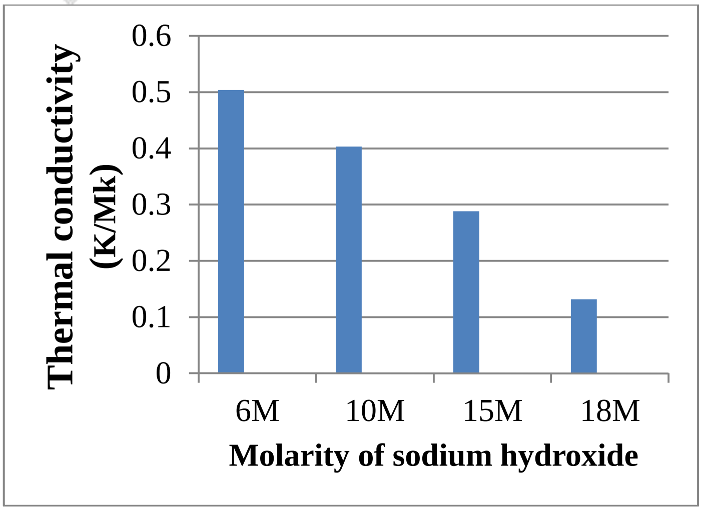

Fig 4.2 Thermal conductivity

Thermal conductivity test results of the study are given in table 4.3. The thermal conductivity decreases with an increase in the molarity of sodium hydroxide. Figure 4.2 shows thermal conductivity versus molarity change of sodium hydroxide where 6M of sodium hydroxide had higher thermal conductivity than 18M sodium hydroxide. In the case 18 M had thermal conductivity of 0.132. Thermal conductivity of 10 and 15 molarity of earth brick gives thermal conductivity of 0.403 and 0.288 respective

4.4 Efflorescence

Based on the results from compressive strength of various proportions of source materials, equal proportions of flyash and ground granulated blast furnace slag was used for fixing the molarity of sodium hydroxide. This test was done by taking a flat bottom panel filled with 2.5 cm of distilled water. The bricks are placed inside of flat bottom panel. The room shall be warm and well ventilated. The brick should not be removed until all water gets absorbed. When all water gets absorbed, brick appears to be dry and then add similar quantity of water to the panel. Then brick is examined after second evaporation. The result shows that there was no efflorescence in the specimen. As per IS 1077:1992, the rating of efflorescence shall not be more than moderate up to class 12.5 and slight for higher class brick.

5 CONCLUSIONS

In Kerala, locally available soil can be used to manufacture the building bricks with good properties such as compressive strength, water absorption, thermal conductivity and efflorescence. This locally available soil can't be directly used or making bricks. From this study, for making brick locally available soil was stabilized by geopolymer. For stabilizing the soil, 20% of its part was replaced by flyash and ground granulated blast furnace slag also by using alkali liquids. In this study, fix the proportions of source material and molarity of sodium hydroxide and also check difference between oven curing at 60degree Celsius for 24 hrs and air curing at room temperature for14 days. The results from the study concluded that follows.

- From the compressive strength test, 20% of locally available soil can be replace by an equal amount of fly ash and ground granulated blast furnace slag was preferred. The proportions of 10 % flyash and 10 % ground granulated blast furnace slag give good result compared to other two combinations.
- Based on the result from water absorption, compressive strength, thermal conductivity, and efflorescence, the range of 10 to 15M of sodium hydroxide give better results. Increases in the molarity of sodium hydroxide help to increase compressive strength, decrease in water absorption and thermal conductivity. Were 15 M was taken by considering economic factor.

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