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Research Article

Experimental Study on the Use of Fly Ash as Partial Replacement of Cement for Stabilized Soil Block

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Abstract

Now a days it is not a hidden fact to observe conflict of survival between exponentially grown population, industrialization and nature. This event becomes the initial Case for the rebirth of disable planate which couldn't care about existence of its creatures. The practice laid gloomy shadow for nations especially, in developing countries who punished by double edge sword (inadequate house and environmental impact). Hence The reason to conduct this study was to give response for escalating demand of adequate house alternative and sustainable construction material. This research aims to determine the optimum percentage of cement replacement by fly ash in stabilized soil block. several laboratory Tests was conducted to know the detail soil profile and results revealed that the soil is ASSITO A-7-6 clay soil which needs 10-16% of cement by dry weigh. The complete silicate analysis test report on fly ash and soil showed the existence of high pozzolana. To find the optimum percentage of fly ash one control and ten experimental group of stabilized soil blocks were produced. ASTM standards were applied for conducting the 7th and 28th compressive strength tests, and the 28th day test results reveal that replacing 5% and 10% of the cement with fly ash improves the compressive strength of the control group from 5.69 N/mm^2 to 6.48 and 7.14 N/mm^2, respectively. Furthermore, replacing cement with fly ash beyond 10% decreases the compressive strength of the block smoothly and at 20% it is becoming equivalent to the control group. In similar way the water absorption test results of stabilized blocks were increased correspondingly with increasing of fly ash. Generally, from all tests conducted on stabilized soil block, replacement of 12% cement stabilizer (experimental control group) from 5 - 20% of fly ash has been found good compressive strength, dimensional stability and null efflorescence defect which satisfied classs2, class3, class20 and class30 Indian brick standards. In addition, promotes green and sustainable practice of construction material production.

Keywords: Compressive Strength; Fly Ash; Soil; Stabilized Blocks; Sustainability

Introduction

According to studies [1] the world's population is expected to grow dramatically. Up to T2020, it will have grown by 25% to 9.9 billion by 2050 [2]. According to a new United Nations data set released today, urbanization, or the gradual shift in human population residence from rural to urban areas, combined with overall population growth, could add an additional 2.5 billion people to cities by 2050, with Asia and Africa accounting for nearly 90% of this increase [3,4]. Ethiopia is one of the countries grappling with this fast urbanization, which is expected to reach 4.1% [5]. As of 2016, the world's population was at 7.8 billion people. In accordance with [6] fast population growth in emerging countries such as Ethiopia is one of the reasons of environmental difficulties such as land degradation and other environmental issues.

According to [7] the exponential growth of the population, urbanization, and housing problem turn to be burning issue of economic, social, and humanitarian activities. The right to appropriate housing is undoubtedly recognized in international human rights legislation, including the International Covenant on Economic, Social, and Cultural Rights [8]. However, the study of [9] exposed those developing countries are the most victim of the problem. Again, the study of [10] revealed that the biggest challenge for future generation is demand adequate housing and sustainable energy. The study of [11] concluded that Ethiopia is in a Serious problem of providing adequate housing supply to urban dwellers.

On the other side, the government's policy to encourage industrialization and fast economic growth in emerging economies is visible all over the world [12]. Other scholars such as [13] blame industrialization due its various impacts on the ecology. [14] also said, industries represent the other way by which services exert an impact on the environment. This idea is supported by [15,16] the expansion of industries leads to discharge toxic byproducts in the form of gas, liquid and solid which becomes the Couse for the natal of other constraints for the ecosystem. [17] considered industries release the most hazardous pollutants which affect the surrounding environment.

The combustion of fossil fuels such as coal is a primary source of energy in large thermal power plants as a result, a massive quantity of byproducts is released into the environment [18,19]. As [20] described, Fly ash (FA) is the dominant industrial waste byproduct of solid fuel combustion. It has its own effect on soil acidity if it is not disposed properly. Coal fly ash, removed in a form of solid waste is leading to serious long-lasting ecological problems and it is not possible to handle with conventional disposal systems [21,22] stated that by reusing this source, The adverse environmental impact of fly ash will be minimized. The advantages of recycling fly ash for construction purposes were also revealed. In addition [23] revealed the benefits of recycling or reuse of fly ash for construction purposes.

Most of construction material are produced from nonrenewable natural resources and the production process of those materials is contributing for greenhouse gases (GHG) emission and high demand of energy [24]. In southwest Ethiopia, fired clay bricks are extensively used for house construction. But The production process uses forest wood for burning and this process leads to deforestation [25]. In addition, as [26] conducted the locally fired clay bricks could not satisfy required brick standards.

Encouragement of the production and use of environmentally friendly building materials is suggested as a solution to these problems [27]. One quick fix for the shortage of construction materials and the effects of industrial waste is to reuse industrial leftovers. In order to cut down on the consumption of cement, fly ash, a byproduct of the coal burning industry, can be added to concrete, brick, and earth blocks in small quantities [28]. The cement manufacturing industry, however, frequently finds fly ash with a loss of ignition (LOI) more than 6% to be unacceptable [22]. Fly ash is regarded as an economical and eco-friendly building material, according to [29] findings, when used as an addition in building materials. Again, [30] backed up this statement by stating that using fly ash in combination with cement to make road pavement can produce good results.

In the particular scope of this study, south west part of Ethiopia, [31] using fired bricks made from clay soils is common for house construction. Considering this wide use of fired bricks, [32] say that, there must be an alternative to reduce the use of burnt brick to reduce environmental impact through its manufacturing process. By Supporting this idea, [33,34] said, in addition to deforestation, fired clay bricks are causing environmental pollution and not effective in terms of energy consumption.

As a result, it is critical to incorporate more materials that are similar to and less energy-intensive alternatives. Producing adobe brick with fly ash is a feasible technique to reduce environmental pollution, according to [35]. The cementing efficiency factor (CEF) for fly ash replacement mixes improved as the substitution ratio increased, according to the study [36]. The other study [37] found that employing fly ash as a cement substitute more frequently will result in sustainable development by reusing waste and environmental protection by decreasing cement consumption. [33] Fly ash, a byproduct of thermal power plants, can be used as a replacement to reduce the cement content in bricks.

The study's overall goal is to "determine the optimal percentage of cement replacement by fly ash in stabilized soil block" through an examination of the components' respective properties. This study looked at the cement and fly ash stabilized soil block in order to promote a low-cost, low-energy alternative construction material that meets technical criteria and socioeconomic circumstances.

Materials and Methodology

Study area

The study was conducted in Oromia National Regional State, Southwest Ethiopia (Jimma town) which is located 335 km away from capital city. Based on the data of [38] its geographical coordinates are between 7° 13' - 8° 56N latitude and 35°49' - 38°38'E longitude with an estimated population of 177,900 and area of 50.52 square kilometers. According to investigation [39] Jimma is predominantly covered with red, black and gray soils Where the red colored soils found on rolling topography as well the black and gray soils, exists on flat topography of the town.

Materials used

Soil: Soil, samples for both control and experimental stabilized blocks was collected from jimma district by considering the distance of production site and quarry site. And also, the cement used for this experiment was commercially available ordinary port land cement (OPC) grade 32.5, which was purchased from local construction material supply. In addition, cement replacing fly ash was obtained from Duckem town, Eastern Industry Zone (Dongfang Spinning Printing and Dyeing PLC).

Methods

In order to achieve the objective of the study detail investigation such as Field observation, material sample selection, preparation of materials, characterization of ingredients, determination of block size, mold preparation, proportioning of samples, mixing of constituents, casting and curing of blocks, was conducted as per mentioned standards. The sample size of blocks for each individual quality tastes was followed different standards of burned brick and total 220 blocks were manufactured for this study. Further mor block quality experiments such like compressive strength test, water absorption test, dimensional stability test, and efflorescence test was applied on the manufactured block.

Field observation

Assessing soil condition was carried to know the existence of the proper soil, fly ash and required type of cement for the proposed study. The observations for soil were done to identify, presence of cracks, swelling potential, color, dry and wet strength etc [40]. Fly ash was the second stabilizer which was expected to replace cement partially. accordingly, the production and deposition of this waste product was observed in deferent coal user industries and the fly ash from Dukem, Eastern Industry Zone was selected due to its huge embankment. In the same manner the step was applied in cement selection from the local construction material supply.

Preparation and characterization of materials

The soil chosen for this investigation was grey in color and was taken from a nearby brick-firing quarry site (Bechobore). By removing the top organic soil, the necessary amount of soil was sent to the soil laboratory. The Jimma Institute of Technology (JiT) soil laboratory conducted physical property tests, including those for grain size, liquid limit, plastic limit, plasticity index, linear shrinkage, specific gravity, maximum dry density, and optimal moisture content, in accordance with AASHTO and ASTM standards, as shown in table 4. In accordance with the findings shown in table 1 below, the geological survey laboratory of Ethiopia (GSE), Addis Abeba, carried out the chemical composition (characterization) of a soil sample.

Compounds soil	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI
% of Soil Chemical	69.6	13.24	4	< 0.01	< 0.01	0.32	< 0.01	< 0.01	0.48	0.58	4.23	6.61
% of fly ash chemical	44.2	28.06	1.2	5.44	0.68	<0.01	< 0.01	0.2	0.97	0.53	43	18.38

Table 1: Chemical composition of soil sample test in geological survey of Ethiopia laboratory.

Characterization of fly ash

Eastern Industry Zone fly ash was collected from abandoned waste fly ash and has a specific gravity of 2.75, spherical glassy particles, and is dark grey in color. To achieve the appropriate particle size of cement, the sample was collected, treated to bright sunlight, pulverized, and sieved. Additional, more detailed silicate analysis tests were performed in the geological survey's laboratory. The chemical composition of the fly ash employed in the pozzolanic reaction that occurs between the fly ash, clay soil, and OPC cement was determined by this assay. An attempt was made to classify the flay ash based on the chemical makeup of the test findings in accordance with the standards of the (ASTM C 618) specification. The sum of the major components SiO_2, Al_2O_3, and Fe_2O_3 has been determined to be 73.46%, which is greater than 70%. This allows the researcher to classify the fly ash from the Dongfeng textile industry as class F.

Characterization of cement

The cement used in this study was commercially available Derba Ordinary (OPC) grade 32.5. The compound composition of cement, the specific gravity, initial and final setting time of this cement was specified by the by company. The cement required for stabilization of both control and experimental group was measured by weight as per standard of [41].

Determination of block size, mold preparation

Even though there are different recommended sizes of soil-based blocks, the block dimension for this study was determined to be 19 cm × 9 cm × 9 cm Indian standard by considering the availability of laboratory equipment's. Based on the selected block size, steel moulds were fabricated from local metal welding micro enterprise which is called Burqa give.

Proportioning of the mix

The quantity cement used was determined depending on the examined index property of the soil. From the investigation it has been ensured that the sample soil was class A-7-6 which require 10 to 16% by weight cement as stabilizer [41]. Therefore, by considering the property of soil, the researcher determined the cement of control group to be 12% of the soil by weight. The proportion materials have been used throughout the production process. To ensure uniformity in the compressed stabilized earth blocks, the weight of each material used in the block making process were measured at the same physical state. After establishing the exact proportion required for one mix, it was measured by container and recorded. To determine the optimum percentage of fly ash ten experimental groups were prepared to replace cement from 5% - 50% by weigh. Dried materials have been mixed until they form uniform color, then water was added gradually and mixing continued until a homogeneous mix is obtained. Mixing was performed with hand, spades and shovel on a wide surface metal sheet. The optimum water content for this particular soil was determined experimentally with three trials and decided to be 30% of air-dried soil.

Figure 1: Grinding, mixing and proportioning procedures of ingredients.

Type of specimen	Percentage Of fly ash replacement to cement by weight	Percentage dry mix Ratio per Clay- cement- fly ash respectively
Control group	0	88-12-0
Experimental group	5	88-11.4-0.6
	10	88-10.8-1.2
	15	88-10.2-1.8
	20	88-9.6-2.4
	25	88-9-3
	30	88-8.4-3.6
	35	88-7.8-4.2
	40	88-7.2-4.8
	45	88-6.6-5.4
	50	88-6-6

Table 2: Mix proportion of stabilizers and clay soil.

Production and curing of blocks

The rectangular steel mold was polished with lubricant and burnt oil after stabilizer preparation and correct mixing in order to reduce resistance between the mold and slurry during production. The excess slurry that had spilled onto the top of the mould was scraped using the soil laboratory equipment known as a spatula, which also smoothed the surface. The moulded block was then taken out of the mold. The blocks were then encouraged to go through the curing phase, which is a need for all cementitious materials. In order to slow down the loss of moisture, the blocks were covered with plastic sheeting and ware spray on the second day of curing. This allowed the curing process to continue for an additional two weeks.

Experimental investigation on stabilized block

Compressive strength

Compressive strength test was investigated to determine the compressive strength of stabilized blocks as per standard of ASTMC67-17. Stabilized blocks cured for 7 and 28 days were crushed. Since the exterior of the blocks were very smooth, It would not mandatory to cape the surface with mortar. The blocks were crushed by automatic compression testing Machin by measuring dimension, weight, area, failure load and strength of the blocks respectively.

Water absorption test

This test was performed to examine the adverse effects of water on the strength of block as well as the durability of the structure after constructed. The test was conducted as per ASTMC67-17. After 28 days of curing, five random block samples were prepared for test and oven dried at a temperature of 105°C for 24 hours. The specimen was cooled at room temperature and represented by (W1). Then samples were submerged in water for 24hr and taken out from the water and wiped by damp cloth to be weighted as (w_2). Finally, the water absorption of the blocks was determined by the following formula

$$\text{water Absorption}(\%) = \frac{w2 - w1}{w1} \times 100 \ldots\ldots\ldots.\ldots\ldots\ldots.\text{equation 1.}$$

The average absorption result of 5 blocks from each type of blocks taken as the absorption of the block type.

Dimension tolerance

The dimensional stability test for this research was conducted as per standard of ASTM C 216. For this study all the bricks are considered as brick for general use in masonry. 10 bricks from each specimen were taken and the test was conducted by measuring the length width and height of each block and the dimension was measured. The efflorescence test of blocks was conducted as per ASTMC67-17. From each type of blocks ten blocks was taken to determine the presence of salt on the blocks. The test samples were immersed in water for seven days and the rating was done by observing the surface of the blocks by naked eye if there are white crystalline substances on the surface of the blocks.

Results and Discussion

Laboratory test results of soil

To understand the complex property of soil, sample several tests such as grain size distribution, liquid limit, plastic limit, plasticity index, linear shrinkage, specific gravity, maximum dry density, optimum moisture content and chemical compassion were in conducted. To isolate the distribution of soil particles wet sieving process was applied based on the procedure of [42]. It has been conducted by soaking the soil sample for 24 hours and followed by washing the soaked soil to allowing the clay part for passing through (0.075 mm) size sieve and followed by dry sieve analysis method. The test results confirmed 0.39% course soil, 8.02% sandy soil and 91.59% finer. In [43] soil classification system, it has been verified that, if soil passing through 0.075 mm sieve ≥ 35% then it is classified under silt-clay soil type Therefore, it has been ensured that the soil is silt and clay.

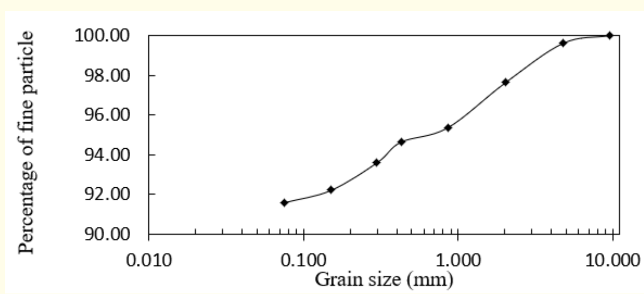

Figure 2: A graphical illustration of a sample soil's grain size distribution curve.

Atterberg limits

The Atterberg test is a crucial component of many engineering categorization systems, as described in [44]. The soil plasticity index, plastic limit, and liquid limit are all determined using these experiments.

Liquid limit

The liquid limit (LL) is the water content at which clayey soil changes from plastic to liquid behavior [45]. These tests were carried out using a variety of soil laboratory equipment, including, in line with industry standards, the Casagrande cup, grooving tools, evaporating dish, spatula, balance, thermostatically controlled oven, water container, sample containers, and 4.25-micron sieve. Following the execution of three trial experimental tests, the liquid limit of the soil sample was found to be 43.32% (See figure 3 below).

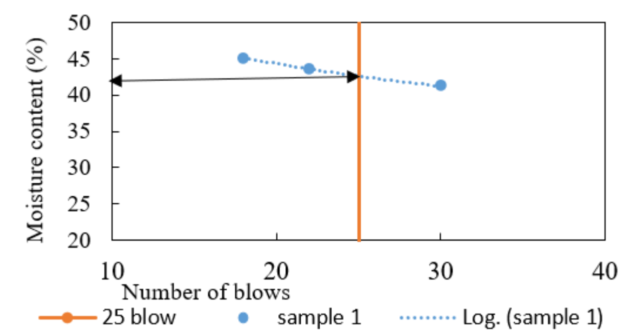

Figure 3: The graphical representation of liquid limit at 25 number of blows.

Determination of plastic limit

[46] specify before a soil sample begins to crumble in the presence of water, it must pass one of the consistency restrictions tests. Following the soil test, the plastic limit of the soil sample was determined to be 27.63%.

$$\text{Plastic Limit (pL)} = \frac{\text{weigh of moist soil}}{\text{weigh of oven dry soil}} \times 100 \text{ .... equation2.}$$

Determination No	Mass of Can	Mass of Can + Moist Soil	Mass of Can +Dry Soil	Mass of Water	Mass of Dry Soil	Percentage of Water Content
1	18.1g	24.2g	23g	1.2g	4.9g	(1.2÷4.9) ×100=24.49
2	17.8g	22.9g	21.7g	1.2g	3.9g	(1.2÷3.9) ×100=30.77
Percentage of Average Plastic Limit		27.63				

Table 3: Shows plastic limit test calculation datasheet asper ASTM D 4318.

Determination of linear shrinkage

The Texas Department of Transportation conducted the test on linear shrinkage [47]. A specimen with internal measurements of 140 mm long was moulded from stainless steel. The channel containing the wet material was put in a drying oven and dried at 110 C. In order to compute the results, the channel containing the specimen was removed and allowed to cool in the air.

$$\frac{(Lo - L1)}{Lo} \times 100 = \frac{(14 - 13.4)}{14} = 4.2857\% \text{ ... ... equation 3.}$$

The dried specimen's length (L_1) dropped to13.4 cm when compared to the copper mold's initial length (L_o), which was 14 cm. It is non-expansive if it is less than 12% and highly expansive if it is greater than 12%, according to the [48] definition. Based to the findings of the tests, non-expanding clay soil was used to make the stabilized blocks. Depending up on [44], all Atterberg limit tests were performed to determine the index property of the soil. The plasticity index specifies the volume of the water content range in which the soil exhibits plastic characteristics. For the soil sample, the PI deducted the liquid limit from the plastic limit.

$(PI = LL - PL - 13.4,3 - 27.63 = 15\%)$.

According to AASHITO, if the liquid limit is less than 41%, the soil is classed as clay or silt. However, the liquid limit of the soil sample in this investigation was 43%, which matched the first requirement for categorization under A-7. Even though the soil is classified as A-7, more standards were necessary for further sub-classification. If the soil's plasticity index is less than or equal to 30, it is classified as A-7-5; if it is more than or equal to 30, it is classified as A-7-6. Thus, 43% – 30% = 13%. Referring to the preceding explanation, PI=LL-PL, resulting in a plasticity index of 43-27.63=15% for the soil sample used to manufacture stabilized blocks. The plastic index of the soil sample was calculated to be 15%, which is larger than 13. This leads to the conclusion that the soil is classed as A-7-6.

Optimum moisture content and maximum dry density

As described by [47], the usual Proctor test was used to find the right water concentration that yielded the greatest density. In order to identify the appropriate moisture sample, two specimens with containers were taken from each representative and dried in an oven. To ascertain the precise moisture content, the weight of those items was measured both before and after drying. Figure 4 shows the optimal moisture content and maximum dry density of the sample, which were 25% and 12.6 Kn/m^3, respectively. However, because the block is created by hand from soft mud, it takes more water to be workable. During the pretest, 5% extra water was added, bringing the total amount of water to 30% of the dry mix.

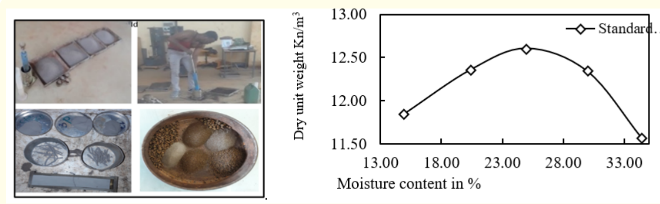

Figure 4: (a) Different tests of soil in the laboratory (b) Graphical presentation of MDD and OMC.

Specific gravity of soil sample

The soil's specific gravity was determined using the test technique described in [49]. The specific gravity of a solid material is calculated by dividing the weight of a specified volume of that substance by the weight of a volume of water at 20°C. The standards require the use of distilled water and all water and solids measurements to be taken at certain temperatures for each analysis. The average specific gravity of soil from three experiments is 2.244+2.217+2.779/3=2.25, implying that the soil sample sunk in water.

Index property of soil	Liquid limit	Plastic limit	Plasticity index	Linear Shrinkage	Specific gravity	MDD	OMC	AASHTO
Test method	ASTM D 4318	ASTM D 4318	ASTM D 4318	CTM 228 -A4	ASTM D 854	ASTM D 698	ASTM D 698	AASHTO table
Result	43.32%	27.63%	15%.	4.2857%	2.25	12.6KN/m3	25%	A-7-6

Table 4: Engineering property of soil.

Quality tests of block

Compressive strength stabilized block

Due to the predominance of clay soil as an ingredient, all tests on stabilized blocks were conducted in accordance with the specifications for burnt clay bricks. Compressive strength tests, water absorption tests, efflorescence tests, and dimensional tolerance tests were all carried out in accordance with ASTM standards.

Block Specimen	Control	5% FA	10% FA	15% FA	20% FA	25% FA	30% FA	35% FA	40% FA	45% FA	50% FA
7th day Strength	2.50	3.04	3.54	2.93	2.23	2.01	1.56	1.28	1.197	1.12	0.743
28th days c. strength	5.69	6.48	7.13	6.43	5.44	4.15	3.54	2.579	2.24	1.90	1.79
% H_2O Absorption	17.93	20.85	22.41	22.98	23.98	25.35	28.25	29.255	30.31	32.03	32.87

Table 5: 7th t and 28th mean compressive strength and water observation of stabilized blocks.

Several studies were conducted to find the optimal fly ash to cement ratio. According to the criteria, ten experimental groups and one control group were formed. The goal of the compressive strength test on the seventh day was to see how fly ash influenced early-stage block strength. However, the lack of a specific standard, as well as the intricate pozzolanic qualities of the materials (cement, fly ash, and soil), rendered the test findings untrustworthy. In compared to experimental control blocks, replacing 5%, 10%, and 15% fly ash for cement stabilizer enhances strength by 21.16%, 41.09%, and 16.77%, respectively. It goes without saying that increasing the amount of cement used in the soil stabilization technique will raise the compressive strength of the block. The study's most surprising discovery is that adding 5% and 10% class F fly ash to cement stabilizer increases the compressive strength of the block. The compressive strength of the control group is 5.69 N/mm^2 (12% cement stabilizer with 88% clay soil). However, replacing the same amount of cement with 5% and 10% more fly ash while maintaining the same amount of soil causes a 13.92% and 29.59% increase in the slope of compressive strengths, respectively. The compressive strength gradually decreases after the block reaches its maximum strength at 10% replacement before about equating to the strength of the experimental control group at 20% replacement. The strength gradually decreases throughout, peaking at 1.79 n/mm^2 at 50% replacement. As a result, the test results demonstrate that the compressive strength of the block rose along with the replacement cement by class-F coal fly ash up to 10% before progressively starting to decline beyond that.

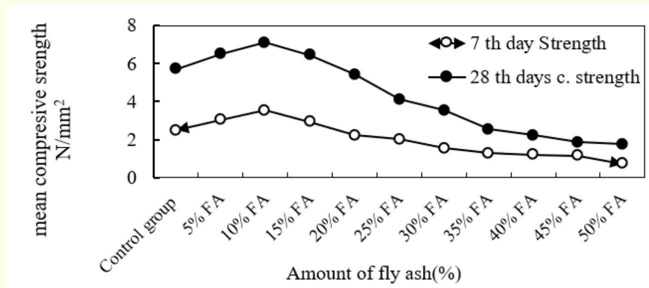

Figure 5: Mean compressive strength of block with 7 and 28 Curing days and water absorption.

Water absorption of stabilized blocks

Water absorption test was conducted on both experimental and control groups as per [49] test methods. This test was done after 28th curing days by immersing five samples of blocks in water for 24 hours at normal environmental temperature. The water absorption of experimental groups was increased with the amount of fly ash stabilizer. While increasing the amount of fly, ash the recorded dry weight of block became lightweight and existence of porosity in block increased the tendency of water to passthrough but expected to make the block non-durable. ASTM and Indian standards recommend that, the maximum permissible limit of the water absorption for brick shall not exceed 18 and 24% respectively. Hence As it has been revealed on table 5 and figure 6 the water absorption test results of experimental groups demonstrate that, replacement of fly ash by cement from 5% up to 20% satisfies the requirements of Indian standard for brick but not ASTM standard.

Dimensional stability test

According to the previously analyzed soil parameters (shrinkage limit and loss of ignition), which were 6 mm and 6.6 mm, respectively, the block constructed from this soil would be dimensionally stable. To conduct the test, steel moulds with internal dimensions of 1909090 mm were manufactured in

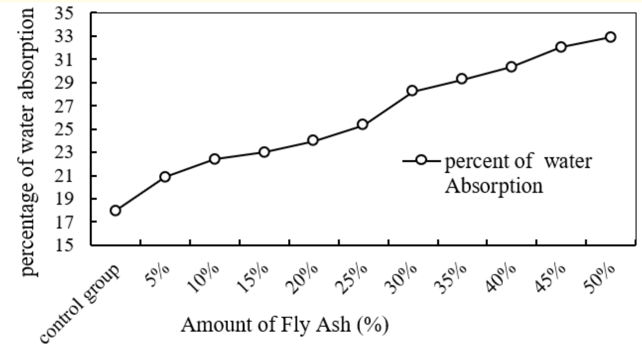

Figure 6: Water absorption test.

accordance with the specification [50]. By selecting 10 specimens from each sample and measuring the block's dimensions in both the longitudinal and transverse directions, stabilized blocks' dimensional stability was tested. Bricks can shrink up to 6.4 mm in length and 2.4 mm in breadth according to ASTM standards. The sizes of all experimental stabilized blocks were proportional to one another and equal. The largest documented shrinkage of all specimens was 2.7 mm in length and 2.3 mm in width, as shown in figure 7. As a result, all stabilized blocks could meet ASTM's guidelines for acceptable shrinkage. Low linear shrinkage of the soil sample and minimal loss of ignition from the chemical composition test result were the indicators of the soil sample's salability to support this scenario.

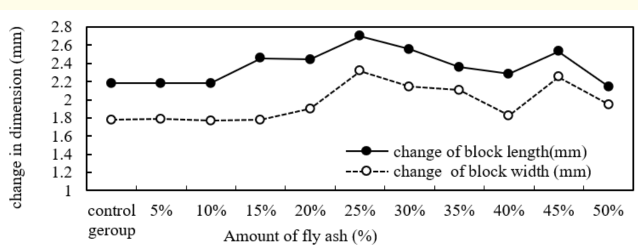

Figure 7: Dimension tolerance test results along length and width.

Efflorescence test

All stabilized blocks underwent efflorescence tests in accordance with ASTM C67. When heavy salts are dissolved by water, a visible white surface develops on the block or brick. After the experiment was carried out as shown in figure 8C, the presence of white salts on the block's surface was examined and contrasted with that of other dry blocks. Hence According to the test results, there was no discernible difference in colour between the dry and submerged blocks. In a different light, the results of the soil's chemical analysis (Table 1) allowed scientists to predict how much heavy salt is being mined, which prevented efflorescence from appearing.

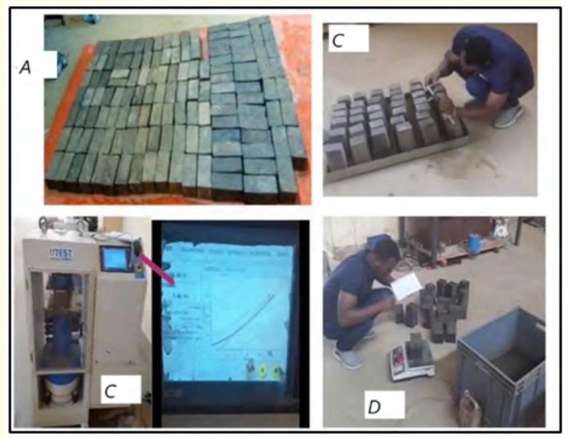

Figure 8: Different experimental tests of stabilized block in laboratory.

Optimum percentage of fly ash

To evaluate the optimum percentage of fly ash all conduced quality testes (compressive strength test, water absorption, dimensional tolerance, and efflorescence tests) has been considered. The quality of experimental blocks was compared with 12% of cement stabilized experimental control blocks. From over all experimental test results the optimum percentages of fly ash replacements by cement were found to be10%, 5%, 15% and 20% with compressive strength of 7.13, 6.49, 6.44 and 5.44 N/mm^2 respectively. The greatest compressive strength achieved at 10% replacement of fly ash by cement and this could pass the authorization Indian class2 brick standard which is 7.2 N/mm^2. In the same manner the compressive strength of other experimental groups 25%, 30%, 35% and 40% replacements were recorded 4.15, 3.5, 2.57 and 2.24 N/mm^2 in order. Those blocks meet requirements of class3, class20 and class30 Indian standards with compressive strength of 3.5, 1.96, 2.94 N/mm^2 separately. However, the compressive strength of experimental blocks couldn't satisfy the requirement of ASTM standard. The last two experimental groups (45 and 50%) replacements of flay ash couldn't satisfy any of brick standard.

But in order to determine the optimum amount of stabilizer water absorption was significant behavior of the block property. From the experiment it is known that, replacement cement from 5 - 20% fly ash satisfies the water absorption requirement of mentioned Indian standards of brick. Therefore, from all of those experimental groups the maximum percentage of cement replacement by fly ash was 10% which has low water absorption as the same time better compressive strength relative control group. Based on the results of investigation, for this type of soil the optimum percentage of fly ash that able to replace 12% of cement ranges from 5% - 20%. Replacement of cement by fly ash beyond this percent satisfies different brick standard compressive strength, but it has a great tendency of water absorption. Therefore, blocks with high water absorption needs special treatment during construction of block masonry.

Because this property of block will have adverse effect on the binding mortar by suck the water from it. So, to prevent the absorption of water mason shall immerse the block in water before laying the course.

Conclusion

The major goal of this research was to see if fly ash might be used as partial substitute for cement in the fabrication of stabilized soil blocks. Basically, the motivation for this study derived from the observation of Ethiopia's constantly rising housing demand. The investigation began with a review of soil engineering properties such as Atterberg limits, specific gravity, maximum dry density, optimal moisture content, ASSHITO classification, and chemical composition. Based on the test result the soil was categorized under the last ASSHITO class a-7-6 which needs the more cement stabilizer. Physical property and chemical composition tests were carried out on soil and fly ash. In addition, different tests on the block were conducted to check the performance of fly ash replacement. Compressive strength, water absorption, dimensional stability, and efflorescence tests were conducted and the results are presented as follow. 12% cement to dry weight of soil was determined as stabilizer by considering index property of specific soil sample. Stabilization of clay soil with 12% cement as experimental control group was found to increase the compressive strength of the blocks is up to 5.7 n/mm^2 and with replacement of standing cement by 5 - 50% fly ash is found to provide different strength. Although partial replacement of this cement quantity with 5-10% fly ash increased the compressive strength of the experimental group over those of control group, however replacement of cement with fly ash beyond this percentage leads to decline the block's compressive strength to gradually. In addition to the water absorption of the stabilized blocks were directly proportional to the quantity of fly ash stabilizer. Whereas the average and dimensional stability, efflorescence test was acceptable by every brick standard.

Bibliography

1. MM Maja and SF Ayano. "The impact of population growth on natural resources and farmers' capacity to adapt to climate change in low-income countries". *Earth Systems and Environment* 5 (2021): 271-283.
2. ISK HUB. "World Population to Reach 9.9 Billion by 2050| News| SDG Knowledge Hub| IISD". URL (2020).
3. UN Desa. Revision of world urbanization prospects". UN DESA: Department of Economic and Social Affairs 16 (2018).
4. M Wamukoya., *et al*. "The Nairobi Urban Health and Demographic Surveillance of slum dwellers, 2002-2019: Value, processes, and challenges". *Global Epidemiology* 2 (2020): 100024.
5. A Hailemariam. "Implementation of the population policy of Ethiopia: achievements and challenges". *Population Horizons* 13.1 (2016): 1-4.
6. DA Negash., *et al*. "Soil erosion risk assessment for prioritization of sub-watershed: the case of Chogo Watershed, Horo Guduru Wollega, Ethiopia". *Environmental Earth Sciences* 80.17 (2021): 589.
7. AI Saidu and C Yeom. "Success criteria evaluation for a sustainable and affordable housing model: A case for improving household welfare in Nigeria Cities". *Sustainability* 12.2 (2020): 656.
8. S Duffy. "Contested Subjects of Human Rights: Trans-and Gender-variant Subjects of International Human Rights Law". *The Modern Law Review* 84.5 (2021): 1041-1065.

9. NI Ewurum., *et al*. "Housing deficit attenuation through market-oriented polycentric management: Evidence from Nigeria". *Development* 10.3 (2020).

10. N Kumar., *et al*. "Agricultural activities causing water pollution and its mitigation-A review". *International Journal of Modern Agriculture* 10.1 (2021): 1-21.

11. YO Jorgo. "DETERMINANTS TO OWN A RESIDENTIAL HOUSING BY EMPLOYEES OF EDUCATIONAL INSTITUTION IN METTU TOWN, SOUTHWEST ETHIOPIA".

12. ZH Shikur., *et al*. "Impact of industrial policy on the regional economy in Ethiopia: A computable general equilibrium analysis". *The Journal of Developing Areas* 55.3 (2021): 265-290.

13. J Badamfirooz., *et al*. "Investigating the impact of existing and under construction industries on the air quality of Arak City using ADMS model". *Environmental Science* 20.1 (2022): 21-40.

14. D Zhao and J Chen. "An analysis of the impact of service inputs in manufacturing industries on eco-efficiency: evidence from China". *Environmental Science and Pollution Research* 28.43 (2021): 61825-61840.

15. M Mosurović Ružičić., *et al*. "Does a National Innovation System Encourage Sustainability? Lessons from the Construction Industry in Serbia". *Sustainability* 13.7 (2021): 3591.

16. GU Fayomi., *et al*. "Smart waste management for smart city: impact on industrialization". in IOP conference series: earth and environmental science". *IOP Publishing* (2021): 12040.

17. RP Valan and PK Muthukumar. "A STUDY ON SOCIAL IMPACT CAUSED BY CEMENT INDUSTRIES IN COIMBATORE, TAMIL NADU, INDIA". *Turkish Journal of Physiotherapy and Rehabilitation* 32.2.

18. K Vohra., *et al*. "Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem". *Environmental Research* 195 (2021): 110754.

19. F Kanwal., *et al*. "Co-combustion of blends of coal and underutilised biomass residues for environmental friendly electrical energy production". *Sustainability*13.9 (2021): 4881.

20. SS Alterary and NH Marei. "Fly ash properties, characterization, and applications: A review". *Journal of King Saud University - Science* 33.6 (2021): 101536.

21. BK Saikia., *et al*. "Geochemistry and petrology of coal and coal fly ash from a thermal power plant in India". *Fuel* 291 (2021): 120122.

22. E David and J Kopač. "Efficient removal of tar from gas fraction resulting from thermo-chemical conversion of biomass using coal fly ash-based catalysts". *Renew Energy* 171 (2021): 1290-1302.

23. G Liang., *et al*. "Reuse of waste glass powder in alkali-activated metakaolin/fly ash pastes: Physical properties, reaction kinetics and microstructure". *Resources, Conservation and Recycling* 173 (2021): 105721.

24. C Chen., *et al*. "Environmental impact of cement production: detail of the different processes and cement plant variability evaluation". *The Journal of Cleaner Production* 18.5 (2010): 478-485.

25. TE Aniyikaiye., *et al*. "Traditional Brick Making, Environmental and Socio-Economic Impacts: A Case Study of Vhembe District, South Africa". *Sustainability* 13.19 (2021): 10659.

26. MG/Hiwot. "Comparative Study on Compressive Strength of Locally Produced Fired Clay Bricks and Stabilized Clay Bricks with Cement and Lime In Jimma Town".

27. C Du Plessis. "A strategic framework for sustainable construction in developing countries". *Construction Management and Economics* 25.1 (2007): 67-76.

28. OS Ayanda., *et al*. "Characterization of fly ash generated from Matla power station in Mpumalanga, South Africa". *E-Journal of Chemistry* 9.4 (2012): 1788-1795.

29. M Đolić., *et al*. "Closing the loop: As (V) adsorption onto goethite impregnated coal-combustion fly ash as integral building materials". *The Journal of Cleaner Production* 303 (2021): 126924.

30. T Chompoorat., *et al*. "Solidification of sediments deposited in reservoirs with cement and fly ash for road construction". *International Journal of Geosynthetics and Ground Engineering* 7.4 (2021): 85.

31. AM Legese., *et al*. "Termite mound soils for sustainable production of bricks". *Studia Geotechnica et Mechanica* 43.2 (2021): 142-154.

32. S Amena. "Experimental study on the effect of plastic waste strips and waste brick powder on strength parameters of expansive soils". *Heliyon* 7.11 (2021): e08278.

33. H Alabduljabbar., *et al*. "Effects of incorporating wood sawdust on the firing program and the physical and mechanical properties of fired clay bricks". *Journal of Building Engineering* 35 (2021): 102106.

34. H Nouri., *et al*. "Life cycle assessment of earthen materials for low-cost housing a comparison between rammed earth and fired clay bricks". *International Journal of Building Pathology and Adaptation* (2021).

35. NTM Trang., *et al*. "Reuse of waste sludge from water treatment plants and fly ash for manufacturing of adobe bricks". *Chemosphere* 284 (2021): 131367.

36. D Li., *et al*. "Reuse of drinking water treatment sludge in mortar as substitutions of both fly ash and sand based on two treatment methods". *Construction and Building Materials* 277 (2021): 122330.

37. A Legesse. "Central Statistical Agency of Ethiopia". in Assessment on the availability of Agro food industry data on the annual Manufacturing industry survey of Ethiopia". *Presented in the FAO-UNIDO expert group meeting on Agro-industrial Measurement* (2015): 23-24.

38. A Sorsa., *et al*. "Engineering characterization of subgrade soils of Jimma town, Ethiopia, for roadway design". *Geosciences* 10.3 (2020): 94.

39. NH Batjes., *et al*. "Standardised soil profile data to support global mapping and modelling (WoSIS snapshot 2019)". *Earth System Science Data* 12.1 (2020): 299-320.

40. SA Shihata and ZA Baghdadi. "Simplified method to assess freeze-thaw durability of soil cement". *Journal of Materials in Civil Engineering* 13.4 (2001): 243-247.

41. ML Nehdi. "Clay in cement-based materials: Critical overview of state-of-the-art". *Construction and Building Materials* 51 (2014): 372-382.

42. J Mallela., *et al*. "Consideration of lime-stabilized layers in mechanistic-empirical pavement design". *The National Lime Association* 200.1 (2004): 1-40.

43. D 4-0 ASTM. "Standard test methods for liquid limit, plastic limit, and plasticity index of soils". D4318-10 (2010).

44. N Khalid., *et al*. "Influence of nano-soil particles in soft soil stabilization". *Electronic Journal of Geotechnical Engineering* 20.2 (2015): 731-738.

45. ACD18 on S and Rock. "Standard test methods for liquid limit, plastic limit, and plasticity index of soils". *ASTM International* (2010).

46. H Zhao., *et al*. "Effects of chemical stabilizers on an expansive clay". *The KSCE Journal of Civil Engineering* 18 (2014): 1009-1017.

47. ACD-18 on S and Rock. "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 Ft-Lbf/Ft3 (2,700 KN-M/M3)) 1". *ASTM International* (2009).

48. N Yesiller., *et al*. "Determination of specific gravity of municipal solid waste". *Waste Management* 34.5 (2014): 848-858.

49. R Wilhelm. "Manufactured Masonry Units". *ASTM Standardization News* 40.5 (2012).

50. SK Singh., *et al*. "Sustainable utilization of deinking paper mill sludge for the manufacture of building bricks". *The Journal of Cleaner Production* 204 (2018): 321-333.