Production Of Stabilized Mud Block Using Areca-Nut Husk Ash

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ABSTRACT

Stabilized mud blocks (SMBs) are a cost-effective and environmentally friendly alternative to traditional bricks. They are made by mixing soil, stabilizer and water, which is then compressed into blocks and left to dry. Cement is used in the production of SMB, production of cement contributes CO_2 emissions, and however the use of cement cannot be replaced completely in the construction field. We can reduce the use of cement in the production of SMB. One of the challenges in making SMBs is the lack of suitable stabilizers, which can increase the strength and durability of the blocks. Areca-nut husk ash (AHA) is a waste product that is generated during the processing of areca-nuts. It is abundant in certain regions of India and has been proven for having good pozzolanic properties, making it a potential stabilizer for SMBs. This study aimed to investigate the feasibility of using AHA as a stabilizer for SMBs. In this study, the blocks were produced using a mix of soil, clay, lime and AHA in varying proportions to produce SMBs. The compressive strength of the blocks were then tested. The results showed that the usage of AHA in the mix showed a significant strength. The blocks prepared only using AHA had a compressive strength of 4.2 MPa. However, the blocks made using both AHA and lime showed strength of 4.5 MPa which is well above the minimum requirement of 3.5 MPa for load-bearing walls. Overall, the study demonstrated that AHA can be used as a stabilizer for SMB.

Keywords—SMB, Areca nut husk ash, building block

I. INTRODUCTION

Cement is an essential building material used in the construction industry. The widely recognized reality is that the production of cement is a major contributor to global CO2 emissions, posing a significant challenge to the development of affordable and environmentally friendly construction materials. According to the Global Carbon Project, cement manufacturing accounts for about 8% of global carbon emissions, making it one of the largest industrial sources of carbon pollution. The production of cement involves a complex process that requires high temperatures, resulting in the release of significant amounts of carbon dioxide (CO2). The primary origin of CO2 emissions during cement manufacturing stems from the chemical transformation that takes place when limestone, clay, and other substances are subjected to heat, resulting in the formation of clinker, which constitutes the core element of cement. The cement industry has made efforts to reduce its carbon footprint by investing in cleaner technologies, such as using alternative fuels like biomass, waste, or using carbon capture and storage (CCS) techniques. However, the deployment of these technologies has been limited by the high costs associated with them [17].

In this study, an attempt has been made to adopt Areca-nut husk ash (AHA) as an additive in stabilized mud blocks to replace the use of cement in them. Areca plantation is extensively grown in Dakshina Kannada region. Usually, areca-nut husk is either used instead of firewood or it is used for mulching in agriculture. So, an effective use of areca-nut husk is to be done. Hence, we have used the ash of the areca-nut husk in this SMB as an alternative to cement. Utilization of lime and husk ash for soil stabilization may produce considerable strength gain and other geotechnical properties of the stabilized soil blocks. Areca-nut husk ash is used as the filler along with soil to prepare the blocks. The areca-nut husk ash from the furnace is rich in amorphous silica. Mixture of lime and AHA acts as stabilizer in SMB. Sandy soil, clay, AHA and water is mixed in desired proportion and this mixture is moulded and dried and is tested for various strength parameter.

A. Stabilized Mud Block

Stabilized mud blocks are eco-friendly and cost effective alternative to conventional bricks used in construction. They are aesthetic in appearance, easy to handle and durable. They are made from mixture of soil, stabilizer and water. Manufacturing of SMB involves two processes, one is densification (i.e, densifying the soil by compression, ramming or any other means) and another is stabilization. Upon mixing the soil with water in proper proportions, mixture gains plasticity. The plastic mass which include a wetted mixture of soil, sand, and stabilizer can be easily moulded, compacted and dried to prepare the high-density blocks for the constructional utility. A density of 2 g/cc is to be achieved while compacting. The stabilizer used in SMB can vary, but they typically include materials like cement, lime, fly ash or a combination of these. The stabilizer improves the properties of soil by reducing its water absorption and increasing its strength, making it suitable for use in construction. Upon blending hydrated lime with clay particles, enduring cementitious connections are forged. Lime's capacity to diminish soil's propensity for expansion, lower its liquid limit, decrease plasticity index and peak dry density, while enhancing its optimum moisture content, shrinkage limit, and robustness, has been well-documented [18]. The pivotal quality criteria for blocks encompass compressive strength and water absorption, which establish their capability to endure loads and withstand weathering. To craft blocks possessing suitable physical and mechanical attributes, indispensable additives imbued with diverse beneficial traits are incorporated. The alteration of block properties becomes evident with the introduction of different input additives. In the realm of construction materials, the current worldwide need is centered around high-density blocks that offer elevated compressive strength and minimal water absorption [6].

SMB can be manufactured by soil which is a locally available material and would be cheaper. Since soil is major constituent, therefore these blocks are environment friendly. It requires no high skilled labours. It also provides good aesthetic view. Even after demolition, the building won't contribute pollution as the blocks are made of soil. These blocks provide better sound absorption. Thermal insulating property is good in mud blocks; hence it is suitable for both hotter and colder climatic conditions.

Some of the disadvantages of SMB [6]

In high rainfall region, these blocks are difficult to use. Blocks can be affected by water in long term exposure and can be deteriorated. High maintenance is required. Since it is made by soil, it can be affected by termite so, termite protection is required. After casting, time required for drying is more.

B. Areca nut Husk Ash (AHA)

Areca nut (Areca catechu), a tropical plant, is commonly referred to as betel nut, owing to its widespread use in the country for chewing alongside betel leaves. Belonging to the Arecaceae family, areca nut is a species of palm tree. As per the 2017 statistics from the Food and Agriculture Organization (FAO) of the United Nations (UN), India stands as the largest global producer of areca nuts, constituting 54.07% of the total worldwide output, and these nuts are traded to numerous countries. Within India, for the year 2013-14, the highest share of crop production, at 62.69%, is attributed to Karnataka, followed by Kerala and Assam. Notably, within Karnataka, the Uttara-Kannada and Shimoga districts are prominent hubs for extensive cultivation of this crop. Generated during the betel nut preparation process, areca nut husk ash emerges as a by-product within the areca nut industry. This ash results from the combustion of areca nut husks, which are an integral part of the process. Renowned as a chewing stimulant across numerous regions globally, particularly in South and Southeast Asia, areca nut holds significant popularity. The Ministry of Agriculture and Farmers' Welfare, under the Government of India, reports that the total areca nut production in India reached approximately 5.79 lakh metric tonnes for the crop year 2020-21, spanning from July to June [19]. The ash is rich in minerals and nutrients, making it a valuable resource for a variety of applications. One of the primary uses of areca-nut husk ash is as a fertilizer. Areca-nut husk ash can also be used as a soil amendment to improve soil structure, water-holding capacity, and nutrient retention. It can reduce soil acidity and improve the growth of plants. In addition to its use in agriculture, areca-nut husk ash has insecticidal properties and can be used as a natural pesticide to control pests such as termites, ants, and cockroaches. It is also used in water treatment as a coagulant to remove impurities from water. Areca-nut husk ash is believed to have medicinal properties and is used in traditional medicine to treat various ailments. It is rich in minerals such as calcium, magnesium, and potassium, which are essential for good health.

Some of the advantages of the AHA given by the various researchers ([20] [21] [22] [23] [24]) are,

Pozzolanic Properties: Areca-nut husk ash (AHA) contains high silica content, making it a suitable pozzolanic material. When combined with lime or cement, it reacts to form additional cementitious compounds, enhancing the strength and durability of the construction material. Environmental Sustainability: Utilizing areca-nut husk waste as a raw material reduces environmental impact by diverting it from landfills. This waste-to-resource approach contributes to waste management and promotes sustainability in the construction industry. Improved Workability: AHA improves the workability of concrete due to its finer particle size and spherical shape. It enhances the flowability and cohesiveness of the concrete mix, facilitating easier placement and compaction. Reduced Carbon Footprint: AHA-based materials offer reduced carbon emissions compared to traditional cement-based materials. By incorporating AHA, the cement content can be partially replaced, resulting in lower CO_2 emissions during production. Enhanced Durability: The pozzolanic reaction between AHA and cementitious materials leads to denser concrete with reduced permeability. This improved density results in higher resistance to water absorption, chemical attack, and chloride penetration, thereby enhancing the durability of structures.

Some of the disadvantages of the AHA given by the various researchers ([25] [26] [27] [28]) are,

Limited Availability and Regional Suitability: The availability of areca-nut husk ash may be limited to regions where areca-nut cultivation is prevalent. This restriction can hinder the widespread use of AHA-based materials in certain areas. Lack of Standardization: The manufacturing processes and quality control standards for AHA-based materials may vary, leading to inconsistencies in product quality. The absence of standardized procedures can affect the performance and reliability of these materials. Long-term Performance and Durability: Although AHA has shown promising results in short-term studies, long-term research on the durability and performance of AHA-based materials is limited. Further studies are necessary to evaluate their long-term behaviour under various environmental conditions. Skill Requirements and Training: The production and utilization of AHA-based materials may require specialized knowledge and training. Adequate skills and expertise are essential to ensure proper mix design, manufacturing, and quality control, which could increase costs and complexity.

II. Literature Review

Researchers produced Geo-polymer blocks which Constituents used are Rice husk ash + egg shell powder + caustic soda were used as additives. Optimum mix proportions of constituents were studied. ESP (egg shell powder) to RHA (rice husk ash) ratio (10:90, 20: 80, 30:70, and 40:60) were studied.10:90, 20:80 were suitable for block production. Tests conducted: Density, moisture absorption, compressive strength, flexural tensile strength, impact strength [1]. Their opinion says, it exhibits high strength, low creep, very minimum water absorption and good erosion resistance. About 20-25% of dry volume soil is replaced by a combination of fly ash with the addition of a geo-polymer solution. Waste materials bring the compressed stabilized earth block as eco-friendly to the environment and cost effective [2]. In another research work, Red soils, fly ash, Groundnut shell ash, Bagasse Ash, Ground granulated blast furnace slag (GGBFS) were used. Here Geo-polymer is used in manufacturing of Stabilized mud blocks as a binding agent. Geo-polymer manufacturing needs 60% less energy with 80% less CO2 compared to OPC (Ordinary Portland Cement).Low-cost manufacturing and environmental friendliness and it are alternative for OPC. Here 13.25% of was added to soil to prepare the mixes. The fly ash, ground nut ash, Bagasse Ash and GGBFS were added to produce stabilized mud blocks, in these the GGBFS had a good strength and durability. The 45 to 50 percentage partial replacement of GGBFS to red soil with the addition of 13.25% geo-polymer combination shows better results among the other mix proportion [3]. Blocks manufactured from soil (A-4, A7-5) and alkali activated binder. Fly ash with high content of unburnt carbon (up to 39%) was used as a Precursor. Paving blocks using soil type A-4 reported compressive strength of 17 MPa at 28 days. Global warming potential of these blocks was reduced up to 75% compared to commercial pavers. Blast furnace slag and lime were used as calcium sources. According to this study, texture of the soil is very important in SMB, as soil with high sand content (A-4) showed high dry density. Hence, contributed lower percentage of permeable pores thus, low water absorption was observed and also 17 MPa compressive strength [4]. Compressive strength investigates about strength of Mud blocks both in dry and wet conditions. Water absorption and density tests were conducted. The blocks produced from 5% cement with red soil, fly ash, quarry dust,10% lime, River sand have the test results values are more. Increase in the cement content results in the increase in the Compressive strength value of block, by increasing 2 to 5% of cement content it yields 58.3% increment in Compressive strength value of block. Increasing lime content to 6 to 10%, increase, it yields 6.33% increase in Compressive strength of block [5].

To achieve economical composition, the bricks consist of 7% cement and 1% fly ash, rendering them suitable for constructing two-storied buildings. Stabilized mud blocks exhibit a dry density ranging between 1.80 and 1.85 g/cc. The production of stabilized mud blocks involves two distinct material ratios: the first substitutes cement with fly ash, while the second utilizes a combination of cement, quarry dust, mud, and fly ash. A comparative analysis is performed between the compressive strength and cost of SMBs and the corresponding metrics of standard bricks. The compressive strength is 3.52N/mm2 for 8% cement replaced by 1% fly ash, which is greater than the standard value prescribed for bricks [6]. Enhancing the potency and durability of lateritic soil blocks is achieved by integrating MHA (Metakaolin) and bitumen as additives. The experimentation involves treating the lateritic soil with varying proportions of MHA, specifically 0%, 10%, 15%, 20%, 30%, 40%, and 50% by weight of the laterite. Subsequently, this mixture is combined with different percentages of cutback bitumen, ranging from 0% to 14%, in increments of 2%. The outcomes reveal the dual role of MHA and bitumen as pozzolanic agents. Optimal strength results are achieved with 30% MHA-laterite blend and 20% MHA combined with 8% laterite, yielding strengths of 10.8 MPa and 10.9 MPa respectively.

Moreover, when 50% MHA is blended with a 14% bitumen solution, it ensures effective water resistance, adding to the material's quality [7] [8].

In a separate investigation, the cement employed was Ordinary Portland Cement (OPC). This study involved the amalgamation of OPC and Silica Fume (SBA), which were then incorporated into block production. Blocks with 4% and 10% OPC content were tested, while SBA was introduced in ratios of 4%, 6%, and 8% by the dry weight of the soil. Notably, all the blocks were cast at uniform densities. The outcomes of the tests aligned with the specifications outlined by the Bureau of Indian Standards (BIS). The introduction of SBA resulted in heightened compressive strength and a minor elevation in water absorption; however, these changes were within acceptable limits according to BIS standards [9]. Bricks offer expedited construction timelines coupled with economical benefits. Notably, finer soil particles, specifically those passing through a 600µ sieve, yield superior outcomes in comparison to other grain sizes. The incorporation of various admixtures leads to a substantial enhancement in maximum compressive strength, resulting in a noteworthy 1.65 N/mm^2. To explore the impact on compressive strength, bagasse ash is introduced as an additive to compressed earth bricks, thus investigating its influence on structural behaviour [10]. The evident disintegration of the initial specimens during the water absorption test underscores the necessity of cement stabilization. Employing static compaction in conjunction with cement stabilization effectively mitigates water absorption. A cement stabilization ratio of 10-15% results in a reduction of water absorption to levels that conform to the specifications set by the Bureau of Indian Standards (BIS). The recorded sorptivity values exhibited a range spanning from 0.984 to 0.304 mm [11]. For this investigation, five distinct levels of stabilization (0%, 5%, 10%, 15%, and 20%) were employed, utilizing corn husk ash. The resulting compressive strength values were 4.177 MPa, 4.380 MPa, and 4.053 MPa for blocks blended with 0%, 5%, and 10% corn husk ash, respectively. Notably, the blocks containing 20% corn husk ash showcased the highest compressive strength at 5.311 MPa, while the 15% mixture exhibited a strength of 4.917 MPa. A notably robust negative correlation of 0.754 was observed between the abrasion coefficients and the water absorption coefficients of the soil blocks [12]. Utilizing lime and rice husk ash in the production of unfired bricks leads to enhanced outcomes. The incorporation of lime and rice husk ash contributes to an enhancement in the compressive and flexural strength of the clay bricks. The optimal blend of lime and RHA is achieved at a 1:1 weight ratio. The introduction of sand further augments the water retention capability, resulting in additional improvements [13].

Strength of brick with increasing fly ash increases with the age. All mix proportions gives satisfactory higher value of compressive strength. Brick will be light in weight [14]. The wool and alginate increases the compressive strength of stabilized soil. To understand better bond between soil matrix and fibre, prevention of visible shrinkage cracks due to the drying process. Low percentage of wall fibre 0.25%, can be more effective than a higher content of wool [15]. The areca nut husk comprises rich content of silica in it hence mixed with clay in various ratio to prepare the husk-based class II bricks. Bricks prepared had very low water absorption ability and had superior compression strength [16].

III. PROBLEM IDENTIFICATION AND OBJECTIVES

A. Problem Identification of the present study is

Effective utilization of Areca-nut husk is missing

Avoiding usage of cement in SMB

Production of engineering quality bricks

B. Objectives of the present study is

To produce the SMB using areca nut husk ash as a replacement to cement

To study the strength parameters of SMB made using AHA (Areca nut husk ash) as an additive

IV. MATERIALS AND METHODOLOGY

A. Materials

Raw materials required for the production of this stabilized mud blocks involves

- 75 % of sandy soil is used
- 15 % of clay is used
- Lime and Areca-nut husk ash (AHA) as additive (10%) is used

The soil essential for producing Stabilized Mud Blocks (SMB) is sourced from the vicinity of Kelthaje, Belthangady. The extracted soil undergoes sun-drying, followed by meticulous sieving through a 1.18 mm sieve, as depicted in Figure 1. Predominantly, sand consists of minuscule fragments of weathered rocks, characterized by its coarse texture. Among various soil particles, sand possesses the largest size. Within sandy soil, the majority of particles exceed 2 mm in diameter. Notably, sandy soil exhibits commendable frictional attributes**.**

Fig. 1 sandy soil

The clay required for the production of SMB was obtained from Didupe, Belthangady. The clay obtained was in large masses and chunks. These chunks were further crushed and powdered is shown in Fig. 2. The powdered clay was further sieved with a 600µ IS sieve. The sieved clay passing 600µ was used in the production of SMB. The distinctive mechanical characteristic of clay lies in its plasticity when in a wet state and its capacity to solidify upon drying or exposure to heat. Clays exhibit a wide spectrum of water content within which they display pronounced plasticity. This range spans from the uppermost water content, known as the liquid limit, where the shaped clay retains its form with minimal moisture, to the lowermost water content, termed the plastic limit, where the clay possesses sufficient moisture to be malleable.

Fig. 2 clay

Lime is an inorganic material composed primarily of calcium oxides and hydroxide. The lime required for the SMB was bought at a retailer store. The purchased lime was a hydrated lime in a powdered form is shown in Fig. 3. Hence there was no need for slaking of the lime.

Before use, quicklime is hydrated, that is combined with water, called slaking, so hydrated lime is also known as slaked lime, and is produced according to the reaction:

$$CaO + \overset{\text{water}}{H_2O} \longrightarrow \overset{\text{calcium hydroxide}}{Ca(OH)_2}$$

Dry slaking is slaking quicklime with just enough water to hydrate the quicklime, but to keep it as a powder; it is referred to as hydrated lime.

Fig. 3 Lime

Given the widespread cultivation of areca plantations in the Dakshina Kannada region, the husk of the areca nut has been chosen as the primary raw material for the block production. The husks were introduced into the furnace, maintained at temperatures ranging from approximately 600°C to 800°C. [16]. The husk was subjected to the furnace for a duration of 5-6 hours. The ash derived from the furnace operation is depicted in Figure 4. The resultant ash extracted from the furnace-contained significant amounts of amorphous silica. The yield of ash amounted to 10% of the initial husk weight. Following the sieving process, the net weight of the purified ash constituted 90% of the entire burnt ash weight. Consequently, the ash procured accounts for approximately 9-10% of the original husk weight.

Fig. 4 Areca-nut Husk Ash

B. Methodology

Preparation of Blocks

● Sieving of soil: The soil shown in the Fig. 5 is excavated near Kelthaje, Belthangady. The soil is of sandy soil type. The soil is sieved in 1.18 mm IS sieve.

● Burning of areca-nut husk: The husk is burnt in a furnace for about 6 hours at 600-800^{o}C. The ash is taken out of the furnace only after the husk is completely burnt and cooled. The burning process and the furnace used for preparing the AHA is shown in the Fig. 6.

● Fig. 7 is sieved through 600μ sieve which helps to separate out any large particles or impurities that may be present in the ash. In SMB a uniform particle size of the ash can result in bricks with consistent strength and durability.

Fig. 5 sieving of soil

Fig. 6 Burning of Areca-nut husk

Fig. 7 Sieving of AHA

- **Dry mixing of raw materials:**

Mix proportion (with lime): since, lime and AHA are very fine particles, the lime (5%) and AHA (5%) is blended for about 30 minutes to ensure proper mixing of these constituents as shown in Fig.8. Then the soil (75%), clay (15%) and previously prepared mix is all together mixed and blended evenly as shown in Fig. 9.

Mix proportion (without lime): soil (75%), clay (15%) and AHA (10%) are mixed thoroughly until the mixture is uniform.

Fig. 8 Blending AHA and lime

Fig. 9 Dry mixing of raw materials

- **Wet mixing of raw materials:**

Water is added to the mixture at a specified quantity determined by conducting standard proctor test. Water content is based on optimum moisture content which signifies maximum dry density of the soil mixture. At this stage, the soil is plastic in nature as shown in Fig. 10 and can be moulded to any desired shape.

Fig. 10 Wet mixing of materials

● Casting & Testing of blocks: The blocks were casted in a mould of size 10*8*5 inch shown in Fig. 3.11. The soil mixture is placed inside the mould in 3 layers and compressed every time using CTM. The blocks were casted so as to achieve a density of 2g/cc. The blocks were tested for compressive strength for 7, 14 and 28 days in a CTM as shown in Fig. 3.12.

Fig. 11 Casting of blocks

Fig. 12 Testing of blocks

C. Test on soil to determine the optimum moisture content

Standard proctor test

Weight the empty proctor mould (W1) with base plate removing collar. Apply grease on inner surface of mould and base plate. Place collar on top of assembly. Take about 3kg of dry soil passing through 4.75mm IS sieve in a mixing tray, add water to get moisture content, starting around 5%. After leaving soil-water mixture for few minutes, place it in layers inside mould. Using rammer, compaction is carried out with specific number of hits for each layer as shown in Fig. 13. Take weight of mould with compacted soil (W2) without collar. Trim excess soil using knife. Measure the dimension of mould to calculate volume (V). Conduct trials till there is a decrease in trend or no change in wet compacted weight of soil.

Wet density of soil is

$$\gamma_{wet} = \frac{W_2 - W_1}{V}$$

Fig. 13 Standard proctor test

D. Method to the determine the compressive strength of SMB

Compressive strength is the capacity of material or structure to resist or withstand under compression. The Compressive strength of a material is determined by the ability of the material to resist failure in the form of cracks and fissure.

The steel bearing plates are kept on and below the blocks while placing in the CTM so as to distribute the load throughout the surface and the centroid of the blocks are aligned with the CTM are compressing faces. The block is firmly fixed within the faces of CTM using a rotating handle on top of the CTM. Then, a constantly increasing load is applied on the block until a failure is observed in the block. The failure load is recorded. 3 trials are conducted and the average of the three value is determined as the failure load and compressive strength based on the failure load is calculated.

V. RESULTS AND DISCUSSIONS

A. Standard Proctor Test

In the Table No. 1, the trend line gradually increases while there is an increase in both water content and dry density. After certain water content, the increasing in dry density stops and further addition of water decreases the dry density and there is a gradual fall in the trendline. The maximum value of the dry density obtained for a specific moisture content is the optimum moisture content (OMC). Optimum moisture content of the soil mix (with lime) is 22%.

Table No. 1 Standard proctor test (with lime)

Percentage of water	5%	10%	15%	18%	20%	22%	25%	27%
Weight of mould + compacted soil (w_2) Grams	5950	6050	6100	6200	6250	6300	6295	6250
Weight of compacted soil ($w_2 - w_1$) Grams	1200	1300	1350	1450	1500	1550	1545	1500
γ_{wet}	1.52	1.65	1.71	1.84	1.90	1.97	1.96	1.90

The trend line gradually increases while there is an increase in both water content and dry density. After certain water content, the increasing in dry density stops and further addition of water decreases the dry density and there is a gradual fall in the trendline. The maximum value of the dry density obtained for a specific moisture content is the optimum moisture content (OMC).
Optimum moisture content of the soil mix (without lime) is 19%.

Table No. 2 Standard proctor test (without lime)

Percentage of water	5%	10%	12%	15%	17%	19%	22%	25%
Weight of mould + compacted soil (w_2) Grams	5970	6020	6090	6150	6200	6300	6280	6200
Weight of compacted soil ($w_2 - w_1$) Grams	1220	1270	1340	1400	1450	1550	1530	1450
γ_{wet}	1.55	1.61	1.70	1.78	1.84	1.97	1.94	1.84

B. Compressive strength test

Compressive strength of Stabilized Mud block= average load / area of specimen Density of the SMB = weight of the block / volume of the block
Cross sectional area of the block = length * breadth
= 254 *203.2 mm
= 51612.8 mm^2

Table No. 2 Compressive strength test on blocks (with lime)

Sl. No	Curing Periods (days)	Average Compressive Strength (MPa)
1	7	1.60
2	14	2.99
3	28	4.38

Table No. 3 Compressive strength test on blocks (without lime)

Sl. No	Curing Periods (days)	Average Compressive Strength (MPa)
1	7	2.81
2	14	3.80
3	28	4.20

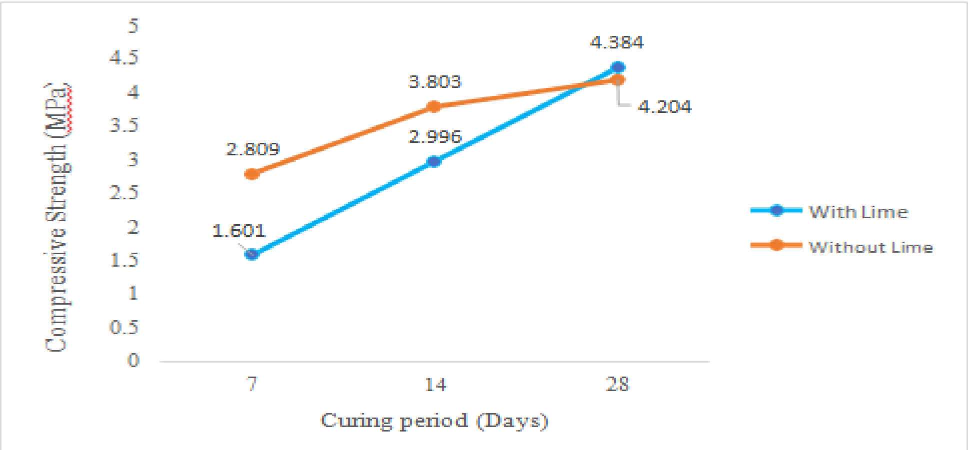

Fig. 14 Curing period Vs Compressive strength

By analyzing Fig. 14, we can observe that the block prepared using lime initially had very less strength. After 14 days, we can observe a drastic increase in strength from 1.601 MPa to 2.996 MPa. Similarly, after 28 days of curing, the strength gained by the block is 4.384 MPa. This is because of the reaction between calcium present in the lime and silica in AHA, which forms Calcium Silicate. The reaction between the two components results in superior bonding ability. The final strength obtained by the block with lime and without lime are 4.384 MPa and 4.204 MPa, respectively In the block without lime, there is no significant variation in the strength since, there is no any significant reaction taking place with AHA. Here the AHA acts as filler material which fills in the small pores in the soil structure and improves the density of the block and hence increasing the strength.

C. Compressive strength of SMB (with cement)

Table 4 [29] shows the compressive strength of SMB with cement as an additive at various curing periods.

Table No. 4 Compressive strength of SMB with cement

Sl.no	Cement percentage	Compressive strength (MPa)			
		7 days	14 days	21 days	28 days
1	5	1.43	2.12	3.28	3.65
2	6	1.51	2.38	3.36	3.79
3	7	1.65	2.70	3.45	4.00

D. Density of SMB

Density of SMB (with lime)

Table No. 5 Density of block (with lime)

Sl. No	Curing Periods (days)	Average Density (g/cc)
1	7	1.847
2	14	1.774
3	28	1.667

Density of SMB (without lime)

Table No. 6 Density of block (without lime)

Sl. No	Curing Periods (days)	Average Density (g/cc)
1	7	1.825
2	14	1.776
3	28	1.743

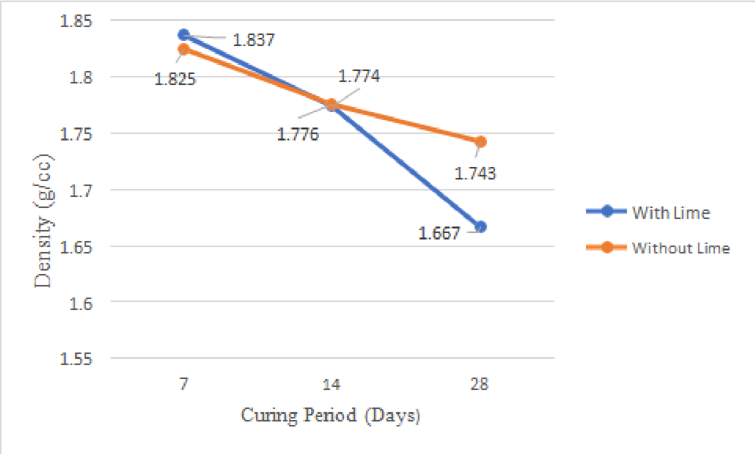

Fig. 15 Curing period Vs Density

Initially, the blocks were casted for a density of 2g/cc. By observing the Fig. 4.4, the density of blocks with lime and without lime after 7 days of curing are 1.837 g/cc and 1.825 g/cc respectively. After 14 days, the densities of both the blocks are reduced to 1.774 g/cc and 1.776 g/cc respectively. Similarly, after 28 days, densities of both the blocks have been reduced to 1.667 g/cc and 1.743 g/cc respectively. initially, the block containing lime had greater density but, after 28 days, it had the lesser density than the block having only AHA because, density of AHA is 2.69g/cc whereas lime is 2.4 g/cc. Therefore the block prepared without using lime retained greater density than the block prepared using lime.

VI. CONCLUSIONS

Based on present research, following conclusions were drawn,

- SMB was produced using AHA as an additive without compromising the compressive strength.
- The Compressive strength of SMB with lime is 4.384 MPa and compressive strength of SMB without lime is 4.204 MPa at the age of 28 days. Only a marginal difference of 0.18MPa was observed.
- Compressive strength of SMB with cement as an additive [29] is 4.00 MPa. Hence, compressive strength of SMB with cement and SMB with AHA is comparable.

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