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Chemical and Mechanical Properties of Kaolin Hollow Blocks Using Bagasse Ash as Cement Replacement Materials

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Abstract

Background: *The construction industry is a major sector of the economy of the most nations. The construction methodology is changing from the thatched roofing house at major rural dwellers to the large apartment used in the major cities in Ethiopia. Most of the low graded Kaolin materials around Shashamane and Arsi Negele districts were used for selected backfill material in building structure and filler materials or sub base materials in rural road construction. Thus the aim of this study was to determine the mechanical properties of hollow concrete blocks produced using low graded Kaolin, Bagasse Ash and Sawdust for an alternative wall making materials*

Methods: *Kaolin materials collected from two sites were used to determine its detailed information on chemical composition and mechanical properties. Using Dangote and Habesha Ordinary Portland cement and Portland Pozzolanic cement Kaolin hollow concrete blocks were prepared and tested for its mechanical properties in laboratory. Indeed, Kaolin and Bagasse ash blended with both Portland cements were added with the percentage of 0%, 5%, 10%, 15 % and 20 % as partial replacement of the binding materials. Sawdust in the mixes was used with the percentage of 8%, 16% and 32%for partial replacement of sand.*

Results: *This study indicates that up to 10 % Bagasse Ash and Kaolin partial replacement of cement and up to 8% sawdust partial replacement for sand had improved compressive strength of kaolin hollow concrete blocks throughout its age of curing. The chemical composition test results of kaolin minerals of the selected sites show a low graded clay mineral oxides of* Al_2O_3 ***(12.68 %< 16%)*** *content.*

Conclusions: *the decrease in clay content and brightness in both kaolin deposits of selected sites were reliable on the occurrence of high percentage of alkaline and alkaline metal oxides. Furthermore, high percentage of this* K_2O, Na_2O, Fe_2O_3 *and* TiO_2, *point out that there is a needs for further alteration of parent rocks.*

Keywords: Bagasse Ash, Bulk Density, Compressive Strength, Hollow Blocks, Kaolin, Sawdust

1. INTRODUCTION

Kaolin is a unique industrial mineral that remains chemically inert over a wide pH range and offers excellent coverage when used as a pigment in coated films. It is widely used as filler in the plastics industries due to its inert chemical nature and its unique size, shape and structure. Most of the alternative wall making materials used in the tropical countries was making from stabilized earth blocks, which lose their fertile clay soil. Hence, it is better to replace this fertile stabilized earth block with loosen non fertile low graded kaolin clay blocks that can be found abundantly in most of the high land and low land area of Ethiopia (Haile Michael, et.al, 1998).

Ethiopia is known in the world as the museum of Ethnography, Archeology and Anthropology; for it is residence of path of civilization and the cradle of humankind. Therefore, the eminence of the country goes far in calling the attention of the world intellectuals on various fields including Architects, Civil Engineers and Geoscientists due to having historical building monument (Mines, M.O, 2011).

Hollow concrete blocks produced in the major local sites in Ethiopia is from different composite materials like fine gravel of different size (00 and 01 mm), Cement, Sand, Red Ash, Pumice, River dune sand, Scoria and water in predetermined proportions. The blocks used in the world have similar overall dimensions whereas, some have two hollow cores and the other might be three. Block dimensions vary, but in general, the length and depth are around 400mm and 190mm respectively. The blocks manufactured in plants using the "dry cast" process using a mix of kaolin, sand, fine gravel, Portland cement, Bagasse Ash, sawdust and a limited amount of water in predetermined proportions. The concrete mix was feeding into molds, using pressure and vibration for compaction, after which the block exits the mould (Svetlana Brzev and P.Eng 2012).

The successful application of kaolin clay and agro waste in building materials would not only serve as a cost-effective alternative to the current disposal method, but also offer a large potential market for its utilization in alternate building materials. At present, Ethiopia had little experience in the utilization of different construction materials. The conventional materials are produced from mortar, gypsum, clay, limestone and others materials, excavated from the ground. On the other hand, the demand of these building materials was not compatible with the supply. This had an impact on the rising of cost of cement and other construction materials (Abebe Dinku and Asnake 2003).

It was believed that there are numerous sources of kaolin clay in Ethiopia and currently exploration activities carried out throughout the country. There are so many resources not even partially utilize its potential in order to contribute to the construction industry (Haile Michael and Mengistu 2003). Hence, the study of both physical and chemical properties of these kaolin clays is very crucial due to its accessibility to different sites of hollow concrete block production in the districts.

This study basically focused on the usefulness of the kaolin clay material for the intended purpose by complying three factors by its proportion to ingredient raw material, compaction pressure and amount of water applied that satisfy the standard quality of the block

Objective

- To examine the chemical properties of kaolin clay minerals in the three selected sites for hollow block production
- To test the compressive strength of the hollow blocks made from the kaolin clay
- To examine the effect of using Partial Sugarcane Bagasse Ash and Kaolin in place of cement as a binding agent.
- To analyze effect of partial replacement of sand by sawdust in the making the kaolin hollow blocks.

2. Related Literature

2.1 Kombolcha Kaolin Deposits

As shown in **Figure 1** Kombolcha kaolin deposit was developed on pegmatite and granite rocks. These bodies mainly composed of feldspars, quartz, mica and clay minerals (Haile Michael, et.al, 1998).

Figure 1: Kombolecha Kaolin Outcrop (Haile Michael, et.al, 1998)

The Kombelcha kaolin bears a relatively lower alumina (33.24%), and higher total alkali and iron, averaging 2.54% and 2.63%, respectively as shown in **Table 1**. It also shows high shrinkage and low porosity values at lower temperatures mainly due to its higher alkali and iron contents. From firing properties, the verification temperature has inferred to as 1150ºC for the Kombelcha kaolin (Haile Michael, et.al, 1998).

Table 1**: Chemicals Analysis of Kombolcha Kaolin (Haile Michael, Fanta and Tibebu .M, 1998).**

Sample No	Interval	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	H_2O	LOI	MnO_2	TiO_2
S-49	0.2-2.0	48.1	34.2	1.94	0.4	0.3	0.4	1.10	1.20	12.4	0.1	0.61
S-48	2.0-4.0	47.4	33.2	2.79	0.7	0.3	0.2	1.30	1.20	12.1	0.1	0.62
S-47	4.5-6.0	47.5	34.3	2.48	0.5	0.4	0.4	1.30	0.70	12.5	0.1	0.57
S-46	6.0-8.0	47.3	32.6	3.2	0.9	0.4	0.5	1.90	1.20	11.2	0.1	0.74
S-45	8.0-10.2	48.4	31.9	2.64	0.6	0.2	1.6	1.80	1.00	11.4	0.1	0.60

2.2 Belesa Kaolin Deposits

As indicated in **Table 2** below the chemical composition of Belesa kaolin depicts very low level of total alkali (Na_20 +K_20) <0.2%) and generally low level of iron « 1.0%) and titanium < 1.0%). This suggests that the kaolin is of high purity with no harmful chemicals to restrict its application for various industries. Its high alumina content and low level of total alkali and alkali metals (Fe_20_3 + $Ti0_2$) makes it applicable for many industries such as fillers, ceramics, refractory's, chemicals, fiberglass etc. The chemical, mineralogical and physical properties of the clay are comparable to most of the commercial kaolin, which are applicable for filler, ceramics, and refractory and fiberglass industries (Haile Michael, M., 2003):

Table 2: Chemical Composition of Belesa Kaolin (Haile Michael, M., (2003)

Sample	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**Na_2O**	**K_2O**	**MnO_2**	**H_2O**	**LOI**	**TiO_2**	**P_2O_5**
HDS-01	68.98	20.40	0.34	<0.01	0.03	0.07	<0.01	0.01	0.51	7.76	0.22	0.02
HDS-02	45.83	36.86	1.03	"	0.04	0.01	0.03	0.01	0.65	13.62	0.71	0.02
HDS-03	45.38	37.00	0.25	"	<0.01	<0.01	0.14	0.01	0.66	14.74	0.50	0.04
HDS-04	70.33	19.26	0.86	"	<0.01	<0.01	0.21	0.01	0.43	7.78	0.03	0.02

Gaps identified:

- ✓ Most of the Kaolin materials used in different industries of Ethiopia have high clay contents and the low graded clay content material has not been given yet an attention.
- ✓ There is no clear method of improving the low graded kaolin materials to high quality to use in different industries.
- ✓ There is no practice of using the low graded kaolin materials as an alternative wall making materials rather than for some selected filler materials in roads and building structures.

2.2 Pozzolanic Materials

The pozzolanic reaction of any classification was given as in the (Eq. 2.2) followed.

Pozzolan + Calcium Hydroxide + water Calcium Silicate Hydrate (gel)

S + CH + H C-S-H…………………………………………………………. [Eq. 2.2]

It results in the consumption of the calcium hydroxide produced by the hydration of the cement which lowers its amount in the concrete. The C-S-H formed in this reaction is not very different from that formed in the regular reaction, except the slightly lower ratio of C/S, which is the case for most of the pozzolans. The normal C/S ratio believed to be around two (Meeravali1, K. V. (2014). Because of the diversity of pozzolans their chemical composition also varies. As classifying pozzolans only depending on their chemical composition would be difficult, the ASTM C 618 classifies pozzolans depending on performance basis (Biruk H and Abebe D, 2013).The percentage sum of the major oxide composition of sugarcane, Bagasse ash indicates value of 70%. Hence, the Bagasse ash, and the low graded kaolin materials used in this study can be applied as a replacement for partial cementing materials due to its pozzolanic properties.

Gaps identified:

- ✓ According to ASTM C 618, these low graded kaolin materials can be classified as Pozzolanic materials if the sum of its major oxides composition greater than 70% and available alkalis at max up to 1.5%. But the problem is that no clear method specified to minimize the alkalis content when it is up to 7-8% to use these kaolin materials.

2.3 Light Weight Aggregates

Local coarse aggregates are obtained from normal weight crushed basaltic stone and lightweight volcanic ash, which are a member of a family of igneous rock (scoria or pumice). Since, lightweight aggregates not commonly used for structural purposes; it was not possible to get sufficient number of test results. The reason for limited application of lightweight aggregates for structural concrete could be due to lack of confidence in using the material for structural purposes (Abebe Dinku, W. G).

Gaps identified:

- ✓ Lightweight aggregates will not be given attention due to no possible sufficient number of test results to have confidence of using this material for structural purpose.
- ✓ Kaolin materials were not classified as lightweight aggregates that can be used as an alternative wall making materials.

3 METHODOLOGY

3.1 Descriptions of the Study Area

Sembero Rogicha Kebele Kaolin site is found in Arsi Negele district along the Dalele river basin 5 km from main road to Goljota Kersa Munisa. The area covered by indigenous natural forest and manmade plantation forest by Arsi Forest and Wild Life Enterprise in Munesa branch. The second one is Hursa Kebele Kaolin site is found in Shashamane district along the Shashamane to Kofale town main asphalt road. The area covered by indigenous natural forest and manmade plantation forest by Arsi Forest and Wild Life Enterprise Sole branch. The two selected sites in the district had a large potential of kaolin clay mineral resources.

3.2 Method of Data Collection

The Kaolin samples from two sites were selected by drilling core on the surface at the deposits. Drill core samples of Sembero Rogicha (S-25) were typically brownish yellow in color whereas drill core samples of Hursa- Simbo (S-30) were typically light grayish in color. Both Kaolin deposits contain several thousands of tons of kaolin which is suitable for hollow concrete block and floor tile production. After mixing, the different samples drilled from the core on the kaolin deposits 2kg of each samples from selected sites would be taken to Geological Survey Institute of Ethiopia for the complete silicate analysis and other related chemical composition tests.

3.3 Kaolin

The chemical composition test results of Kaolin material of the three selected sites were identified by using complete silicate analysis at Geological Survey Institute of Ethiopia. Hence, the sample of kaolin weighs 2 kg taken from each site to the laboratory tests. Thus, form laboratory test results the sum of major oxides composition of two sites, Sembero Rogicha and Hursa-Simbo Kaolin indicates the values greater than 70% whereas Rafu Hargisa Kaolin indicates the values equal to 31% as shown in **Table 5**below. Therefore, the Kaolin material from two sites having a major Oxides composition greater than 70% can be use as pozzolanic material and the rest can be reject. Besides these, the cements used for these trial mixes selected randomly based on the locally available suppliers. Indeed, both Dangote and Habesha PPC and OPC were using for preparing the trial mixes. During the preparation of the trial mixes, the designed proportions adopt in order to undertake the trial mixes.

Table 5: Oxide composition of kaolin clays and Bagasse Ash as tested in Geological Survey center of Ethiopia

Kaolin Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	TiO_2	P_2O_5	H_2O	LOI
Sembero-Rogicha	70.46	11.89	3.64	0.1	1.02	2.68	4.52	0.08	< 0.01	< 0.01	1.16	3.96
Hursa-Simbo	63.34	13.68	7.42	< 0.01	0.74	2.72	2.9	0.12	< 0.01	< 0.01	1.79	5.81
Rafu-Hargisa	22.3	6.1	2.98	46.3	3.04	0.52	0.62	0.01	< 0.01	< 0.01	6.39	10.69
Wonji BA (Biruk.H & Abebe.D, 2013)	65.58	5.87	4.32	1.78	1.23	1.02	6.41	0.05	0.25	1.35	0.2	10.48
(SiO_2 + Al_2O_3 + Fe_2O_3)		**85.99 > 70 Sembero-Rogicha**		**84.44 > 70 Hursa- Simbo**			**31.38< 70 Rafu-Hargisa**			**75.77 >70 Wonji Bagasse Ash**		

In order to standardize the results, three sets of samples were prepared with conceptual framework of the specimen preparation. One is made of a standard concrete mix and the other of the kaolin -concrete mixes. This is necessary to compare the testing results to standard qualifications. Each of the sample-making process includes: Optimum mix ratio and the actual making of the specimens. The Kaolin clay resources from Sembero Rogicha kebele had a fine texture with plasticity of wet surfaces and light grayish white in color. The source of kaolin material is from alteration of sedimentation deposit of feldspars along the river basin(Figure 4).

a)Light Grayish white color kaolin b) Plasticity of kaolin surfaces c)Powdered Kaolin samples

Figure 4: Kaolin resource from Sembero Rogicha

The physical texture of Hursa- Simbo Kaolin was shown in the **Figure 5** below. The surface plasticity of the kaolin materials indicates its function as filler materials in different construction industries.

a) Plasticity of surface texture b) Powdered Kaolinblend with ingredients

Figure 5: Kaolin resources of Hursa- Simbo sites

3.2 Bagasse Ash

The Bagasse ash used for this research was taken from Wonji Sugar Factory located in Oromia Regional State - North Eastern Ethiopia. The Bagasse ash in this factory collected at each 8-hour interval from the furnace and dumped around the factory very close to the residence of the factory workers. Hence, due to its fine texture the dust of this Bagasse Ash simply blows to the workers and has a health risk during production. As shown in the **Figure 6** Bagasse Ash used for partial cement replacement materials have fine textures with quality grain size to blend with all types of Portland cement.

Figure 6: Bagasse Ash collected from Wonji Sugarcane factory

3.3 Sawdust

Sawdust is industrial waste material obtained from sawdust refuse dump from timber shade & saw mills, in various shapes and sizes as shown in **Figure 7** shown below. These main byproducts of sawmills, unless reprocessed in to particleboard, are burned in a sawdust burner and are used to make heat as fuel for local peoples. The most important aspect and main target of the experiment are proving that partial sawdust-cement-kaolin, partial sawdust-cement-pumice and partial sawdust-cement-gravel mixtures can prove to be more lightweight and cost efficient. Since sawdust is, a timber waste, which its cost would go down, as well as weight cause of its extremely light unit weight.

Figure 7: Sawdust used for production Kaolin concrete hollow blocks

3.4 Physical properties of the Composite materials used for Kaolin Hollow Concrete Block production

The physical properties from testindicates that the particle grading and plasticity results of the kaolin materials under investigation fall within the acceptable ranges.

Table 6: Physical Properties of Kaolin from selected Quarry sites

Sl. No	Property	Test results of raw materials			
		LanganoSand	Sembero Rogicha	Hursa Simbo	Sawdust(Kg/m^3)
1.	Bulk Density	2258	1493	1613	645
2.	Specific gravity	2.56	2.41	2.46	2.16
3.	Particle shape	Spherical	Spherical	Spherical	Spherical

3.5 Experimental Setup

The experiment would have a completely randomized design. Cementing materials (cement, Bagasse, and kaolin), aggregates (kaolin, gravel, sand and pumice), and time of curing (1, 2 and 4 weeks) are used as fixed effect. Thus the experimental test result developed as in the **Table 7** shown below.

Table 7: The experimental setup for the materials mix ratios with percentage of replacement

Experiment Numbers	Percentage of BA/ KC	Cement content %	Percentage of Sawdust	Sand Content (%)
I, II and III	0	100	0	100
	5	95	8	92
	10	90	16	84
	15	85	24	76
	20	80	32	68

The sample code S-25 and S-30 were used to indicate the kaolin sources from selected sites(Table 8).

Table 8: Clay sample code, name and source of the clay samples

Clay sample Code	Name	Source of clay samples
S-25	Kaolin	Sembero Rogicha inArsiNegele
S-30	Kaolin	Hursa-Simbo in Shashamane
PU	Pumice	Hawassa
GR	Gravel	Hawassa
KC	Kaolin Clay	From both sites

The Hydraulic machine used on compression testing machine shown in Figure 8 has two metal plates of dimension 25*45 cm were used to be placed both in top and bottom section of the kaolin hollow block. The main function of the plates was to help equal distribution of the axial load applied to the block over the gross area and particularly, on to the net area cross-section of the blocks. After all, while blocks failing to resist the load automatically applied over it, the value at the frailer point recorded. Based on the reading value the individual load bearing capacity of each block identified with respect to corresponding curing ages to determine the quality of the block produced to resist the supper imposed axial loads and horizontal wind loads The theoretical area at which servo Hydraulic machine adjusted to conduct compression strength test result was 80,000mm^2 with a rate of loading 1.0 kN/s and start load of 0.1kN.

Figure 8: 7 Days of KHB under Hydraulic Compression Testing Machine

3.6 Mix Design

Providing detailed technical and economic information on the production of Kaolin hollow blocks by assessing the potential of local materials (types of cement and Kaolin) is the purpose of this investigation. Thus, two types of cement from manufacturers, and a Kaolin samples from Hursa-Simbo and Sembero Rogicha of two districts are select and prepared. To this effect the following test programs are follow. Each specimen paired according on his or her predetermined dry times, which were range from seven (7), fourteen (14), and twenty-eight (28) days as in **Table 9**, shown below. All mixes have the same proportions of Class C mix or a 1:3:6 ratios of cement and aggregates used.

Table 9: Mix proportions of Dangote PPC/OPC –BA/KC of 18% by weight aggregates of Cement

Mix Code	Cement (gm)	Sand (gm)	Bagasse Ash (gm)	Kaolin (gm)	Sawdust (gm)	W/B	Water (lit)
S-25 BA0	3630	6200	0	16000	500	0.309	5.6
S-25 BA5	3448	6200	68.57	16000	500	0.329	5.6
S-25 BA10	3268	6200	137.14	16000	500	0.330	5.6
S-25 BA15	3086	6200	205.71	16000	500	0.331	5.6
S-25 BA20	2904	6200	274.28	16000	500	0.332	5.6
S-30 BA0	3630	6200	0	16000	500	0.309	5.6
S-30 BA5	3448	6200	68.57	16000	500	0.329	5.6
S-30 BA10	3268	6200	137.14	16000	500	0.330	5.6
S-30 BA15	3086	6200	205.71	16000	500	0.331	5.6
S-30 BA20	2904	6200	274.28	16000	500	0.332	5.6
Mix Code	**Cement (gm)**	**Sand (gm)**	**Bagasse Ash (gm)**	**Pumice (gm)**	**Sawdust (gm)**	**W/B**	**Water (gm)**
Pu BA0	3630	6200	0	16000	500	0.562	1.5
Pu BA5	3448	6200	68.57	16000	500	0.571	1.5
Pu BA10	3268	6200	137.14	16000	500	0.581	1.5
Pu BA15	3086	6200	205.71	16000	500	0.590	1.5
Pu BA20	2904	6200	274.28	16000	500	0.600	1.5
Mix Code	**Cement (gm)**	**Sand(gm)**	**Gravel (gm)**	**Kaolin Clay (gm)**	**Sawdust (gm)**	**W/B**	**Water (lit)**
GR-S-25KC 0	3630	6200	16000	0	500	0.620	1.5
GR-S-25KC 5	3448	6200	16000	140.40	500	0.626	1.5

GR-S-25KC10	3268	6200	16000	284.62	500	0.634	1.5
GR-S-25KC15	3086	6200	16000	426.96	500	0.641	1.5
GR-S-25KC20	2904	6200	16000	569.14	500	0.648	1.5
GR-S-30KC 0	3630	6200	16000	0	500	0.620	1.5
GR-S-30KC 5	3448	6200	16000	140.40	500	0.626	1.5
GR-S-30KC10	3268	6200	16000	284.62	500	0.634	1.5
GR-S-30KC15	3086	6200	16000	426.96	500	0.641	1.5
GR-S-30KC20	2904	6200	16000	569.14	500	0.648	1.5

Thus, the experiment would have a complete random design with five levels of cementing materials, three cases and three curing periods. Each experiment would replicate to two times the total number of sample is equal to 90(5 materials * 3 curing periods * 3 cases *2 replication). After mixes were laid and left to dry for a certain number of days, it can be tested under a hydraulic press machine for compressive strength tests. These tests assist to show the strength of compressive force that can be resisted by the mixes.

In the above experimental design, the linear statistical model of the following form best related to observed data:

$Y = \alpha+\beta_1X_1+\beta_2X_2+\varepsilon$……………………………………………………………... [Eqn.2.3]

Where Y is dependent variable (linear shrinkage and compressive strength); α is common intercept, X_1 and X_2 are effects of fixed factors; β_1 and $\beta_2$are slopes of fixed effects; $\varepsilon$is error terms. The R-software was used for statistical analysis. The material and days of curing were use as fixed effect. The mean difference was test using simple linear regression model.

4 RESULT AND DISCUSSION

As it can be seen from the chemical composition of laboratory, test results of three samples from selected sites, two of them meet the required kaolin mineral standard whereas, the sample taken from Rafu Hargisa Kebele fails to meet this. Therefore, the experimental sets up done were only in the samples, which meet the designed requirements. Besides, Bagasse Ash and kaolin by itself tested for its suitability as cement, replacing material and sawdust as partial replacement of sand analyzed and discussed in details. In this research the basic filler aggregates used by substituting both coarse aggregates and partial fine aggregate material were kaolin and sawdust respectively.

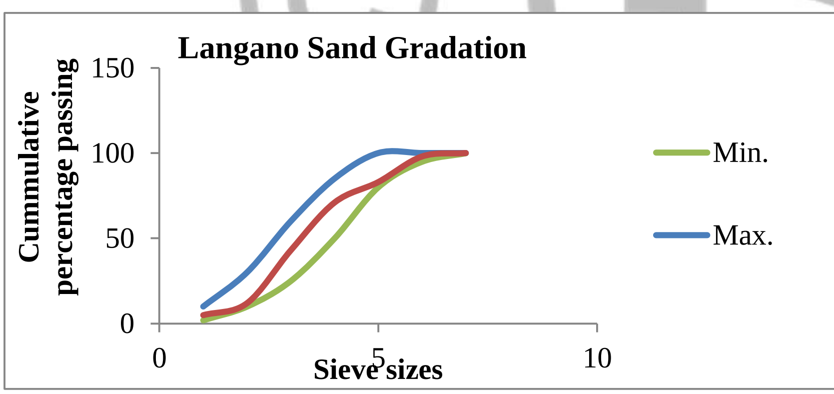
4.1 Kaolin Material Chemical and Physical Properties

The test result of kaolin is greater than 70% which mean that the Kaolin clays materials had pozzolanic properties. The loss on ignition (LOI) value for the kaolin clays from both sites found to be 3.96% and 5.81% respectively, indicates reduction in its value as per ASTM C-618 Specification that was 10%. These tell us the kaolin minerals from both sites have slighter change in mass by heating under specified condition. Moreover, the Kaolin clays for both sites found were contains high alkali content of K_2O, 4.52% and 2.90% respectively, implying high potential for alkali-silica reaction when used in concrete as silica reach aggregates.

As results show the physical properties of kaolin clay minerals selected from two sites indicates the density of the mineral altered based on the percentage composition of oxides in kaolin minerals which will in turn contribute to weight of the kaolin hollow concrete blocks. Thus, the higher percentage of Ferric oxides minerals was contributed to the larger aggregates weight. Nevertheless, the kaolin minerals from both sites were lightweight aggregating materials with a little higher density than pumice and scoria. The density of the kaolin minerals used for the intended hollow block production indicates that the materials have low densities as compared with the conventional hollow concrete block making materials. Thus the physical properties of kaolin materials test results prescribed as in **Table 6**above is the best opportunity for this investigation.

4.2 Gradation of fine aggregates

The test result obtained from sieve analysis indicates fines modulus of 3.82, which helps us to classify the sand materials as course aggregates. This indicates the sand used for production of the hollow concrete blocks is coarser grain size. As we can see in **Figure9** the result indicates that the sand used for molding the blocks had a good quality with relatively les



s silt content.

Figure 9: Grading Curve of fine aggregates used for production of KHB

4.3 Test Results and Discussions

In this section four points were analyzed on utilization of kaolin material for hollow concrete blocks production. The basic points in these discussions were:

- The effects of curing days on compressive strength of kaolin hollow blocks using different percentages of pozzolanic minerals as partial cement replacement were the importance,

- Percentage of sawdust required to be replaced sand in kaolin hollow blocks productions in order to obtain higher mean compressive strength.
- The percentage composition of Portland Pozzolanic Cement (PPC) or Ordinary Portland Cement (OPC) of different cement types which had an effect on compressive strength of kaolin hollow blocks was properly analyzed, and
- The change in compressive strength over gross area and net area of the hollow blocks with respect to percentage composition of cement contents would be briefly discuss.

Generally, the statistical data of the test result was properly analyzed and discussed for each tables tabulated and graph drawn as in the figures shown.

As in the **Table 10** shown below Kaolin hollow blocks were specimen prepared from Dangote PPC blended with BA. This accomplished in order to investigate how the Bagasse ash acts in the cement type. In fact, hollow block works with PPC does not arise any improvement on the compressive strength at any replacement percentage. Rather the compressive strength of the hollow blocks with Bagasse ash and PPC had shown a reduction with respect to pure cement concrete mix paste. Moreover, there was a change in compression strength among each percentage replacement of Bagasse ash while we comparing one with other individual blocks. This may be resulted from the reason that setting effect of the powder added to the cement and level of activation of pozzolanic material used in the concrete mix.

Table 10: Compressive strength of Dangote PPC-BA with S-25 & S-30 kaolin

Compression strength over gross area with 18 % wt. of aggregates				
S.No	Mix Code	7 days	14 days	28 days
1	S-25 BA 0	0.77	0.84	0.94
2	S-25 BA 5	0.65	0.94	1.05
3	S-25 BA 10	0.77	0.79	0.87
4	S-25 BA 15	0.87	0.84	0.93
5	S-25 BA 20	0.65	0.71	0.79
6	M-25	0.83	0.91	1.01
Compression strength over gross area with 18 % wt. of aggregates				
S.No	**Mix Code**	7 days	14 days	28 days
1	**S-30 BA 0**	0.7	0.99	1.1
2	**S-30 BA 5**	0.68	0.68	0.76
3	**S-30 BA 10**	0.55	0.73	0.81
4	**S-30 BA 15**	0.75	1.05	1.16
5	**S-30 BA 20**	0.59	1.04	1.16
6	**M-30**	0.68	0.86	0.79

Figure 10: Effect of curing days on compression strength of PPC-BA HCB

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As in statistical data of test, result shown in **Table 11**the days of curing had an effect on compressive strength for percentage of Bagasse ash blended with cement powders except for 15% of BA. Thus for all percentage of adding Bagasse ash were altering on compressive strength of the hollow blocks with respect to days of curing significantly beyond the stated strength with exclusion of 15% BA. i.e. the kaolin hollow block even attains its maximum compressive strength with increased age of curing. As seen from the statistical data analyses there was a significant difference between ages of curing ($p<0.005$).Hence, ages of curing was also concluded to be one of the vital factors that were affecting the compressive strength of the kaolin hollow blocks has no effect forall cement replacement.

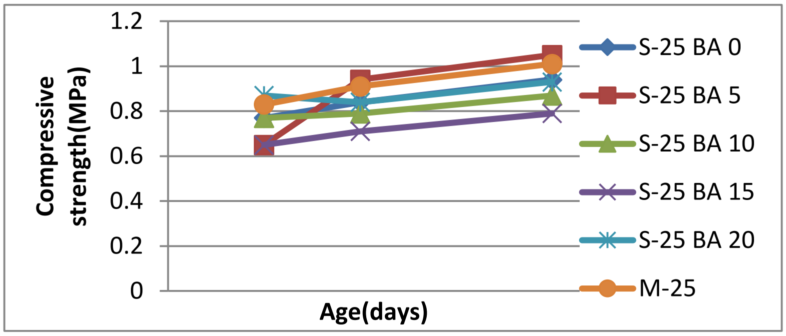

Table 11: **P-Values for KHB produced with 18 % wt. of aggregates over net area of S-25 kaolin**

Treatment	R^2	**P-value**
S-25 BA 0	0.98	0.056
S-25 BA 5	0.98	0.056
S-25 BA 10	0.98	0.056
S-25 BA 15	0.23	.0.423
S-25 BA 20	0.97	0.068
M-25	0.97	0.068

Average compressive during 7days, 14 days and 28 days were 0.66, 0.89 and 0.96 respectively. Thus the compressive strength over net area during 28 days in Figure 4.31 were 0.96 in average indicates the kaolin hollow block did not comply with the minimum compressive strength of class "C" were 1.8 MPa used in accordance to ESC D3.301.

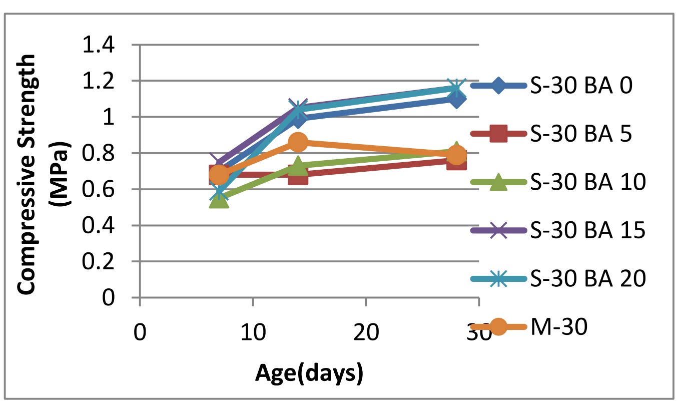

Figure 11: Effect of curing days on compression strength of PPC-BA hollow blocks produced over gross area

As in statistical data of test, result shown in **Table 12** the days of curing had an effect on compressive strength for percentage of bagasse ash blended with cement powders except for 10% of BA. Thus for all percentage of adding bagasse ash were alters on compressive strength of the hollow blocks with respect to days of curing significantly beyond the stated strength with exclusion of 10% BA i.e. the kaolin hollow block even attain its maximum compressive strength with increased age of curing. As it can seen from the statistical data analyses there was a significant difference between ages of curing ($p<0.005$).Hence, ages of curing was also concluded to be one of the vital factors that were affecting the compressive strength of the kaolin hollow blocks has no effect for all cement replacement.

Table 12: P-Values for hollow blocks produced with 18 % wt. of aggregates over gross area

Treatment	R^2	P-value
S-30 BA 0	0.97	0.068
S-30 BA 5	0.97	0.068
S-30 BA 10	0.68	0.260
S-30 BA 15	0.97	0.068
S-30 BA 20	0.97	0.068
M-30	0.97	0.068

4.4 Test Results and Discussions on Experiment-IV

Sawdust can use as alternative substitute for fine aggregate in concrete production. Sawdust should been washed and cleaned before use as concrete constituent because of large amount of bark, which can affect setting, and hydration of cement.

As in the Table 14 prescribed below Kaolin hollow block specimens prepared by using sawdust of 8%, 16% and 32% as partial replacement of sand and its effect on mean compressive strength be analyzed. Thus, the mean compressive strength of the hollow blocks varies with the percentage of sawdust used as partial replacement of sand. From the test results, mean Compressive, strength of 0.62MPa obtained during 28th days of curing with 32% replacement of sawdust with the sand and Dangote Portland Pozzolanic Cement content of 8.3% using pumice material over gross cross sectional indicated in Table 15. However, at this percentage of sawdust replacement by sand the mean compressive strength did not satisfy the minimum requirement of class “C”.

As it can be seen from, test results in Table 16 shown below analyzed with effect of 16 % replacement of sand by sawdust using 15% Dangote Portland Pozzolanic Cement (PPC) content. Thus, the maximum mean compressive strength attained during 28th day of curing by using gravel and S-25 kaolin materials were 1.10MPa and 0.72MPa respectively. Hence, with these values the hollow blocks made of using kaolin materials both as partial replacement and filler material as aggregates did not comply with mean compressive strength class "C" which was 2.0 MPa.

No. of research have been carried out on sawdust and agricultural waste to provide solution of getting low cost masonry blocks. According to Adebakin I. H, the percentage replacement of sand should not be 10 % to achieve better results in production of sand create blocks.

The third point was the effect of 8% sawdust replacement by sand using 18 % Dangote Portland Pozzolanic Cement (PPC) contents. As it can be seen from the test results, even the maximum mean compressive strength of 2.29 MPa and 0.96 MPa obtained using gravel and both kaolin materials respectively at 28th days of curing over gross cross sectional area. Therefore, at these percentages of sawdust as partial replacement of sand and kaolin as partial replacement of cement the mean compressive strength complies with that of hollow concrete block strength of class "C" which was 2.0 MPa.

According to LV. Savie (2010), the flexural strength increased from 1.43 N/ mm^2 at 7 days to 2.24 N/mm^2 at 28 days for control slab (i.e. about 57% increment). However, the strength of the 25% replacement by sawdust showed increased in flexural strength from 1.15N/mm2 at 7 days to 1.67 N/mm2 at 28days (45% increments).

Table 16: Compressive strength on various proportions of Cement: Sand: Saw dust.

S.No	Mix Code Exp.1	Cement content %	Sawdust % to replace sand	Mean Compressive strength (MPa)		
				7 days	14 days	28 days
1	S-25BA with % mix	18	8	0.74	0.82	0.92
2	S-30BA with% mix	18	8	0.66	0.89	0.96
3	Pu BA with % mix	18	8	0.52	0.67	0.83
4	Gr -S25 KC with % mix	18	8	2.04	2.06	2.29

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

1. Mineralogical and chemical composition analysis of the studied kaolin shows the progressive weathering of Pegmatite and granites of the parent rocks were the main sources of kaolinite of the studied areas.
2. The observation of this study, along with those of Haile Michael and Fanta (1998), leads to the conclusion that the decrease in clay content and brightness in both kaolin deposits of Sembero Rogicha and Hursa area was dependable on the occurrence of high percentage of alkaline and alkaline metal

oxides. Having this K_2O, Na_2O, Fe_2O_3 and TiO_2, indicates the needs for further alteration of parent rocks.

3. The kaolin hollow concrete blocks of sizes 400 x 200 x 200 mm made with the concrete grade 1:3:6 proportion gives the average compressive strength of 0.96MPa or 9.6 kg/cm^2considering the gross area and 1.81 MPa or 18.1 kg/cm^2considering net area were obtained by using S-25 kaolin clay materials. Whereas the average compressive strength obtained by using S-30 kaolin material should be analogous to that of S-25 that was 0.96 MPa or 9.6 kg/cm^2. Considering the gross cross sectional area, compressive strength of 1.96 MPa or 19.6 kg/cm^2 would obtain. Whereas the hollow concrete blocks of size 400 x 200 x 200 mm made with the concrete grade 1:3:6 proportions gives the average compressive strength of 2.29MPa and 4.46MPa for blended S-25 KC with gravel material could be obtained which best can comply with standard set for class "C" of ESC D3.301. Hence, the kaolin material used for hollow block production with the maximum cement content of 18% and sawdust contents of 8% to 16% should be use to cope with the required compressive strength standards.
4. The kaolin hollow block has a significance level of up to 15% were determined when blending PPC cement both Dangote and Habesha with pozollanic materials like kaolin and bagasse ash used as partial replacement for cement with percentage of 0% ,5% and 10% for 18% cement content. As seen from statistical data there was no almost significance level for both S-25 and S-30 kaolin material during 15% cement content used for hollow block production except for 5% to 10% over net area Compressive strength of the blocks with respect of curing dates. I.e. there were no more strength could be obtained with ages of curing it might get the maximum compressive strength value during 7^{th} days of curing.
5. On other hand as the percentage of cement content increased from 8.3%, 15% and 18% there were a significance level of kaolin hollow blocks with all percentage of blended powder amount except for 5% to 10% by using both bagasse Ash and kaolin as pre-determined.
6. Addition of sawdust on the kaolin hollow block production was an optimum percentage with high natural bonds whenever it lies between 8% up to 10%, be identified.
7. Bagasse ash and Kaolin minerals were used as a partial cement replacement material as if the chemical composition of the mineral prior analyzed
8. The analysis made on identification of the waste materials like Bagasse ash and sawdust in the application for kaolin hollow block production as an alternative wall making materials were the best opportunity for the clients, contractors and consultants and any other interested users as best opportunity which comply the desired strength.
9. The provision of this kaolin minerals from both selected sites for application to the ceramic industry to involve in the booming construction technology were the point, which require more emphasis.

5.2 RECOMMENDATION

Final recommendations of the study are given below.

1. Compressive strength of the hollow block is the major factor to be taking into account for the construction purpose. It values varies with the addition of the Bagasse Ash, sawdust and kaolin with pre-determined mix design ratios. As the present study emphasizes even if kaolin clay minerals can found abundantly the first steps to be done was testing for chemical composition of the minerals were the basic point to practice.
2. As in construction industry the need of conventional raw materials for concretes like coarse aggregates and fine aggregates are enhancing from day to day construction activities. It is the basic opportunity for the consultants, contractors and local hollow concrete production small micro enterprise to accomplish this kaolin clay mineral and agro waste material as input ingredients to enhance the compression strength of the hollow blocks to comply with the standards for it.
3. The provision of lightweight wall making material in the construction industry with credible strength develops a confidence on optimizing the dead load effect on the frame of the structure to undermine the designing cost. To comply with this, it is better to use percentage of pozzollanic material as partial cementing material up to 10%, which can best have hydrated through ages of curing.
4. Sawdust is one of the waste materials of sawmill in timber production. In order to use these raw materials as aggregates for partial replacement of sand the optimum percentage to make this filler material as reinforcement should be up to 8%with pre-determined empirical cement content and addition of admixture needed to activate the hydration activities more.
5. The kaolin hollow blocks at lower cement content can developed a very low compressive strength, which need high amount of water for workability. It is the additional work required for analyzing the optimum empirical cement content determined to adopt cost efficient kaolin hollow blocks production by using these low clay content minerals.

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