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A Comparative Study of Clay Bricks with GGBS and Laterite Soil

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Abstract- Bricks are the commonly used construction material used around the world. The cost of clay increases day by day. An alternate method to decrease the quantity of clay is by adding the waste materials. GGBS is a byproduct from iron industry. GGBS was added in 4%, 8%, 12%, 16%. Laterite soil is a soil type with high clay content. . It also contains minerals like kaolinite and illite.. To improve the properties of clay bricks, laterite soil is also added in 5%, 10%, 15% and 20%. 15 % of lateriate soil added to clay bricks was found as optimum percentage. To the optimum percentage of Laterite soil GGBS were added in varing percentages. Compressive strength, water absorption, efflorescence and thermal conductivity were analysed. 8% GGBS, and 15% laterite soil were separately added to clay bricks gives higher compressive strength. All bricks show higher strength than that of control specimens. Water absorption increases with addition of materials and thermal conductivity shows a decreasing trend with increase in material addition.

Keywords* — *GGBS, Laterite soil, compressive strength, water absorption, efflorescence, thermal conductivity

I. INTRODUCTION

CLAY bricks available in certain region are poor in quality, which have forced engineers to look for better materials capable of reducing the cost of construction. The infrastructure such as buildings for housing and industry, and the facilities for handling water and sewage requires large amounts of construction materials. Since the large demand has been placed on building material industry especially in the last decade owing to the increasing population, there is a mismatch between demand and supply management of these materials. Hence to meet the continuously increasing demand, researchers are attempting to design and develop sustainable alternative solutions for the construction material. The increase in the popularity of using environmental friendly, low cost and lightweight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting to the environment as well as maintaining the material requirements affirmed in the standards. Brick is one of the most accommodating masonry units as a building material due to its properties.The use of waste materials in bricks can improve the properties. To avoid excess consumption of useful fertile soil, incorporate organic particles into soil mixture. Recent reviews on bricks have shown that variety of organic and inorganic solid waste materials can be used as an additional material in brick making. GGBS is a by-product from iron and steel industry. The major components of GGBS are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and MgO (1-18%).The addition of GGBS to the stabilizer system has enhanced many engineering properties. It reduces the risk caused by alkali-silica reaction. Laterite soils are widespread in tropical and subtropical climates. The soil is rusty in colour, this is due to rich in aluminium and iron content. Soils are formed due to prolonged weathering of the parent rocks mainly in hot and humid tropical areas. Laterite soil is a good building material and laterite stone is a construction material. Laterite soil is available from the laterite quarries are also used for many engineering purposes. Laterite soil contains minerals and compounds contents including contents like Aluminium Oxides, micas, Potash mica, Black mica, Hematite, Iron Oxides, Manganese Oxides, Pyroxene, Plagioclase, etc. They are rich in clay content.

In this study clay bricks were made with GGBS and laterite soil separately along with clay. GGBS were added in 4%, 8%, 12% and 16%, Whereas Laterite soil was added in 5%, 10%, 15% and 20%. The compressive strength, water absorption, efflorescence and thermal conductivity were also analysed.

II. LITERATURE REVIEW

Mohamad Nidzam Rahmat et.al [2016] conducted a study on Strength and environmental evaluation of stabilised Clay- Pulverised Fly Ash eco-friendly bricks. In this research Lower Oxford Clay (LOC) was combined with Pulverised Fly Ash (PFA) as target materials were stabilised with Lime, Portland Cement (PC) and blended

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binders comprising of Lime and PC blended with Ground Granulated Blast-furnace Slag. This research illustrated that all the key parameters of compressive strength, and environmental properties were within the acceptable engineering standards for masonry units. Increased amount of stabiliser dosage resulted in increased UCS with increasing curing period for stabilised LOC-PFA bricks except when Lime alone was used as stabiliser. LOC-PFA bricks stabilised with Lime only shows water absorption capacity of 20– 22% from day 1 up to 56 days of soaking, while blended Lime: GGBS showed slightly lower water absorption of 16–18%. The blended PC-GGBS absorbed marginally more water at the beginning of soaking period when compared with PC, but ultimate absorption rate was minimal for both stabilisers, after 10 days of soaking period. The overall absorption for both PC stabilisers was between 7% and 10% with low energy used and no kiln firing required during production, this reduces the cost of the end products. The practical implications of this experimental programmed is that unfired bricks can be used for community based housing development and can be applied to internal wall construction, with the overall target of improving the quality, cost effectiveness and most importantly, it can be considered as part of sustainable building materials.

Malhotra and Tehri [1995] investigated the development of bricks from granulated blast furnace slag, a byproduct of the iron and steel industry. The slag was first mixed with hydrated lime and then the lime–slag mixture with Badarpur sand thoroughly. Brick specimens were made by pressing the mixture in a hydraulic machine at a pressure of 4.9MPa and then curing the molded specimens at 270–272^{0}C and 95% humidity over a period of 28 days. The cured bricks were tested for compressive strength (in saturated conditions), bulk density and water absorption properties. The study revealed that good quality bricks could be produced from a slag–lime mixture and sand.

Gaurav and Ajay conducted a study on an investigation on use of paper mill sludge in brick manufacturing [2017]. In this study an eco friendly light weight bricks were produced with a binary mix of paper mill sludge and soil. Here both laterite and alluvial soil types were used and bricks made on these two soil types along with paper mill sludge. The mix ratio was varied from 0%, 5%, 10%, 15% and 20%. The mix was tested by evaluating properties such as linear shrinkage, compressive strength, water absorption, mass loss on ignition, and bulk density of bricks as recommended by the relevant Indian and ASTM standard codes. X ray diffraction results confirmed that the addition of PMS does not show any phase transformation and only enhances the porosity thereby leading to weight reduction and the fluxing agents which aids in reducing firing temperature and possible energy saving. An optimum mix of 10% PMS with both soil types was found suitable for brick production at a firing temperature of 900^{0}C. Maximum compressive strength and lower water absorption shows on control bricks. Water absorption is related to durability thus firing at high temperature decreases water absorption and thus improves the durability.

Muraleedharan M A et. al (2017) conducted a study on bricks using laterite soil. In this study bricks were casted using laterite soil, 10% of 53 grade OPC, 1.5% of Magnesium Oxide and 1% of coir fibre all were added according to the weight basis. With these mix both modular and non-modular size bricks were prepared. These bricks have a compressive strength of 10.53N/mm^2 which comes under first class bricks category. Density and water absorption was obtained as more than that of clay bricks and fly ash bricks whereas the efflorescence was found as slight for these bricks. It was a good suggestion for important works and gives considerable saving in energy and waste laterite soil produced in the laterite quarry can be efficiently utilized.

Another study was conducted in Nigeria by Emmanuel A Okunade (2008). Different sample mixes were obtained by mixing the 70:30 parts by weight laterite – clay blend with varying proportions of saw dust and wool ash admixtures. The density of bricks made with the addition of sawdust and wood ash decreases whereas the compressive strength of the sample made with 10% wood ash and 0% saw dust show higher compressive strength than the control mix. Water absorption is closely associated with porosity of the material. The influence of saw dust increases the porosity and thus the water absorption, while the wood ash was decrease the water absorption. The increase in saw dust content produce opposite result of finished products, mainly due to the effect of producing a less compact structure in finished products.

Rahman M A (1988) again conducted a study on lateritic soil – clay bricks with rice husk ash (RHA). The clay was added in 40% by weight of lateritic soil along with that RHA was added in 5 – 20%. The bricks were burned at a temperature of 1000^{0}C for 2, 4 and 6 hours. The linear shrinkage decreases almost linearly with RHA content. Both dry and firing densities of bricks decrease with increase in RHA. The decrease in density indicates it produce light weight bricks. The compressive strength of both fired and unfired bricks increases with increase in RHA content. Higher compressive strength was more for 4 hour soaked bricks. The water absorption rate increase with increase in RHA content. 4-hour firing duration at 1000^{0}C was optimum for the firing of lateritic soil-clay- RHA mixed bricks.

Lateritic soil – clay bricks were manufactured using a mix of 20 and 40% clay by weight mixed with lateritic soil, this study conducted by Rahman M A (1987). The bricks were burned at 1000^{0}C for 2, 4 and 6 hours. For the results it was

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observed that addition of 40% of clay in lateritic soil was optimum for the production of bricks from lateritic soil.

III. EXPERIMENTAL DETAILS

Different raw materials are used for the manufacturing of clay bricks. GGBS and laterite soil were added separately in clay bricks and the physical properties were analysed.

A. MATERIAL COLLECTION

The raw materials used for the brick manufacturing are Clay, GGBS and Laterite soil.

1) Clay

The sample was collected from Aluva. This clay is mostly used for bricks manufacturing. The entire preliminary tests were conducted as per Indian standards.

Fig.1. Clay

TABLE I
Material Properties of Clay

Properties	Values
Specific Gravity of clay	2.7
Hydrometer	Silt size particles (%)= 70 Clay size particles (%)= 30
Soil classification (Indian standard classification system)	CH (Organic clay of high plasticity)
Liquid limit (%)	57
Moisture content (%)	20.55
Plastic limit (%)	19.37
Plasticity index (%)	37.63
Optimum moisture content (%)	22
Dry density (g/cc)	1.40

2) Ground Granulated Blast Furnace Slag (GGBS)

GGBS was collected from Palakkad. It was obtained by quenching molten iron slag from a blast furnace in water or stream. They are off-white in colour. Specific gravity of GGBS was obtained as 2.89.

Fig. 2. GGBS

3) Laterite soil

Laterite soil was collected from Kakkanad. They are available from laterite quarries which have manyengineering properties. It also contains minerals like kaolinite and illite. The specific was 2.78.

Fig. 3. Laterite soil

B. CASTING OF BRICKS

Clay bricks were made with GGBS and laterite soil separately. They are hand moulded and were burnt in kiln. GGBS were added in 4, 8, 12 and 16%, whereas laterite soil was added in 5, 10, 15 and 20%. The mixtures were prepared with the predetermined optimim moisture content values. The size of the bricks was selected as 230 x110x70mm non-modular bricks. It was decided as per IS 1077:1992. The prepared mix was forced into the mould and after removing the mould kept it for air drying Fig 4.1. The bricks were allowed to dry till they are left with 5 to 7 percent moisture content. The drying period was 10 days. After air drying process the bricks were transported to the kiln shown in Fig 4.2, where it was burned at a temperature of 870^{o}C – 1300^{o}C. Bricks were taken out from the kiln after cooling and the testing started only after 21 days of curing as per IS code.

C. TEST METHODS

The bricks were tested as per IS code for finding the physical properties. The burned bricks were cured for 21 days and only after that testing were started. Compressive strength, water absorption, efflorescence and thermal conductivity are the tests conducted on the bricks. These tests were conducted as per IS 3495 (PART I-III) and as per IS 3346:1980.

IV. TEST RESULTS AND DISCUSSIONS

Clay bricks made with GGBS, laterite soil and a comination of laterite soil and GGBS were tested for analyzing the physical properties of bricks such as compressive strength, water absorption, efflorescence and thermal conductivity.

A. Compressive strength

The compressive strength test was determined as per IS 3495 (Part I) - 1992 as shown in figure 4. It is one of the important tests and its result gives the strength of the brick. The test results are listed below.

1) Compressive strength of clay bricks with GGBS

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Clay bricks were made by adding GGBS in varying percentages of 4%, 8%, 12% and 16%. The bricks were tested in the compressive testing machine and the following results were obtained.

TABLE II
Compressive strength values of clay bricks with GGBS

GGBS content (%)	Compressive strength (N/ mm^2)	Remarks
0	9.76	Compressive strength not less than 10 N/mm^2 for class designation 10
G4	9.92	
G8	10.13	
G12	10.05	
G16	9.91	

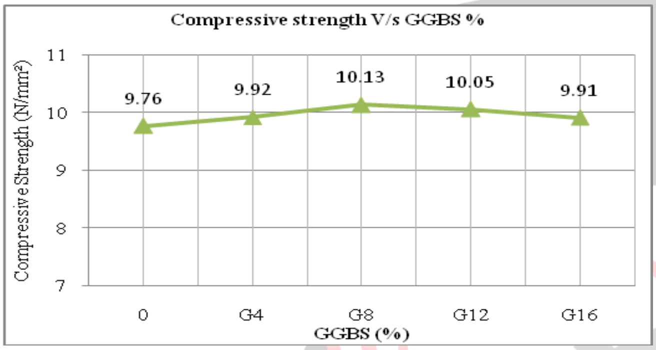

Fig. 4. Variation of compressive strength result of clay bricks with GGBS

8% addition of GGBS to clay bricks shows higher compressive strength compared to that control bricks. Beyond 8% the compressive strength decreases with increase in GGBS content.

2) Compressive strength of clay bricks with Laterite soil

Compressive strength of clay bricks made with different percentages of laterite soil with 5%, 10%, 15% and 20%. From the result, 15% of laterite soil to clay bricks shows higher compressive strength compared to the control bricks. Laterite soils have similar properties to that of clay. The maximum compressive strength is 10.37N/mm^2.

TABLE III
Compressive strength values of clay bricks with Laterite soil

Laterite soil content (%)	Compressive strength (N/ mm^2)	Remarks
0	9.76	Compressive strength not less than 10 N/mm^2 for class designation 10
L5	9.96	
10	10.19	
L15	10.37	
L20	10.29	

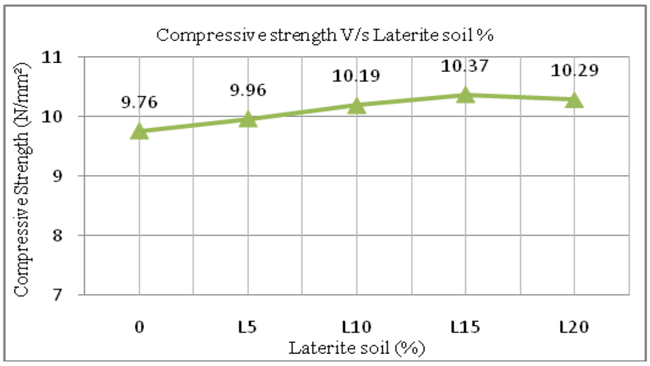

Fig. 5. Variation of compressive strength result of clay bricks with Laterite soil

3) Compressive strength of clay bricks with Laterite soil and GGBS

The compressive strength of clay bricks made with laterite soil and GGBS were studied. In this laterite soil was taken in constant percentage and GGBS was added in varying percentages.

TABLE IV
Compressive strength values of clay bricks with Laterite soil and GGBS

LG content (%)	Compressive strength (N/ mm^2)	Remarks
0	9.76	Compressive strength not less than 10 N/mm^2 for class designation 10
L15+G4	9.97	
L15+G8	10.21	
L15+G12	10.4	
L15+G16	10.36	

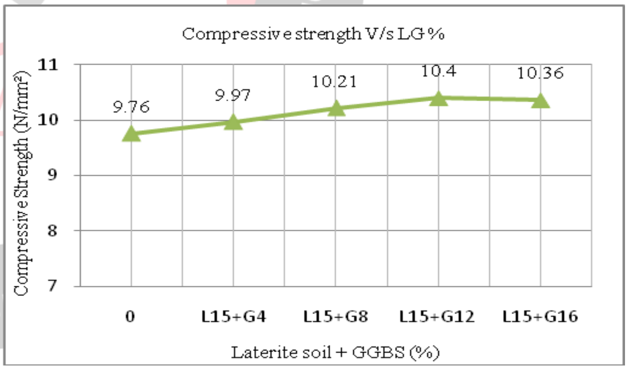

Fig 6 Variation of compressive strength result of clay bricks with LG

The compressive strength of the bricks depends mainly on the density and porosity of the bricks. It is observed that the results of clay bricks with GGBS and laterite soil shows a compressive strength greater than 10 N/mm^2, which belong to class designation 10 as per IS 1077 (second class bricks). All the modified bricks show higher strength than control bricks.

B. Water absorption

The water absorption test was determined as per IS 3495 (part II) – 1992, shown in figure 4.7. The water absorption

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test was conducted by immersing the brick in cold water for 24 hours.

Fig 7 Water absorption test

1) Water absorption of clay bricks with GGBS

Clay bricks made with GGBS in 4, 8, 12 and 16%. The water absorption test was conducted by immersing the bricks in cold water for 24 hrs.

TABLE V

Water absorption test results of clay bricks with GGBS

GGBS content (%)	Water absorption (%)	Remarks
0	15.35	Water absorption shall not be more than 20% upto class designation 12.5
G4	16.53	
G8	17.43	
G12	18.79	
G16	20.08	

Clay bricks made with GGBS show that the percentage of water absorption increases with increase in GGBS content. The minimum water absorption rate was 16.53% for bricks made with 5% of GGBS.

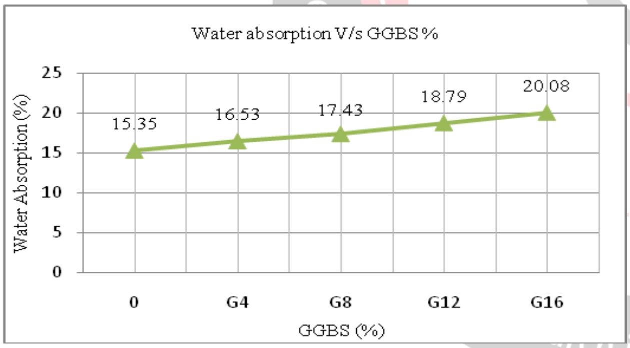

Fig 8 Variation of water absorption of clay bricks with GGBS

2) Water absorption of clay bricks with Laterite soil

Laterite soil is also added to the clay bricks in varying percentages for improving the properties of bricks. Thus laterite soil was added in 5, 10, 15 and 20%.

TABLE VI

Water absorption test results of clay bricks with Laterite soil

Laterite soil content (%)	Water absorption (%)	Remarks
0	15.35	Water absorption shall not be more than 20% upto class designation
L5	15.84	
L10	16.28	
L15	16.91	
L20	18.05	12.5

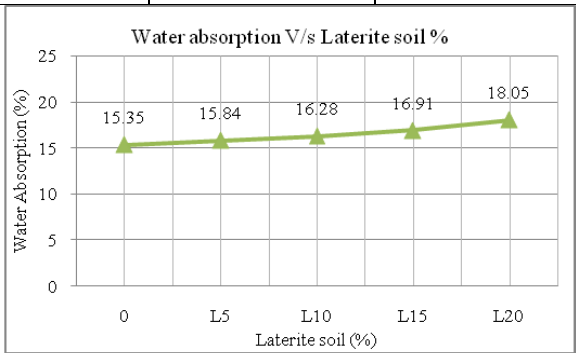

Fig 9 Variation of water absorption of clay bricks with Laterite soil

Bricks made with laterite soil have similar properties to that of control bricks compared to that of other bricks made with other two materials. Laterite soil- clay brick shows lesser water absorption rate compared to that of bricks made with GGBS and paper sludge.

3) Water absorption of clay bricks with Laterite soil and GGBS

Clay bricks made with a combination of Laterite soil and GGBS. In this Laterite soil content is kept in constant 15% and GGBS was added in varying percentages to it.

TABLE VII

Water absorption test results of clay bricks with LG

LG content (%)	Water absorption (%)	Remarks
0	15.35	Water absorption shall not be more than 20% upto class designation 12.5
L15+ G4	15.99	
L15+ G8	16.57	
L15+ G12	17.06	
L15 + G16	18.54	

Bricks made with 15% laterite soil and 4% GGBS with clay shows lower water absorption rate. But the water absorption rate increases with increase in laterite soil and GGBS content.

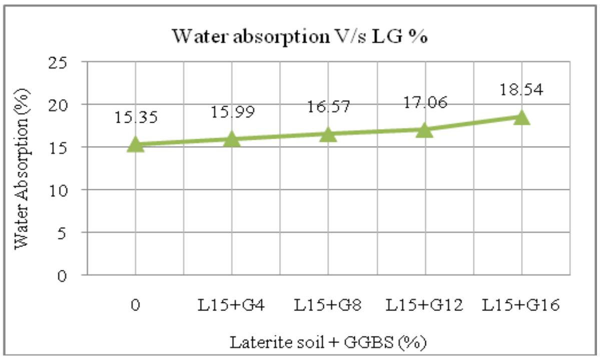

Fig 10 Variation of water absorption of clay bricks with LG

Water absorption increases with increase in the percentage of the addition of material. The bricks become weaker if it

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absorbs more water. It mainly depends on the porosity; increase in porosity might be the cause for increase in water absorption. As per IS 1077: 1992 the water absorption of bricks should not be more than 20% by weight up to classes 12.5.

C Efflorescence

Efflorescence was determined for find the alkaline salt content in bricks. The test was conducted as per IS 3495 (part III) – 1992 shown in figure. In this experimental work no perceptible deposit is observed on majority of samples but there is a very thin deposit of salts observed on some samples.

Fig 11 Efflorescence test

C. Thermal conductivity

Thermal conductivity test is performed based on the concept of steady state condition and as per IS 3346: 1980. In this test a heater coil was placed below the brick and a thermometer is also placed near heater coil to measure the temperature. Another thermometer was placed at other face which is exposed to air. The heater coil is connected to electric circuit through ammeter, volt meter and dimmer stat. The whole arrangement is kept in a closed room to avoid air flow which causes delay in formation of steady state condition. Then switch on the power to start the experiment and power input will be adjusted by dimmer stat. After switching on the power the temperature at heater coil raises and the temperature at outer face also raises after some time. After achieving the steady state condition temperatures at heater coil is noted as T_1 and temperature at outer surface is noted as T_2. The current supplied is noted from ammeter (i) and the voltage drop is noted from voltmeter (v). Thermal conductivity for sample is calculated by using the equation,

$$\text{Thermal conductivity (k)} = \frac{i * v * l}{A * (T_1 - T_2)}$$

Fig 12 Thermal conductivity test setup

1) Thermal conductivity of bricks with GGBS

Clay bricks were made of GGBS with different percentages of 4, 8, 12 and 16%. Then it was tested for thermal conductivity and the following results were observed.

TABLE VIII
Thermal Conductivity test results of clay bricks with GGBS

GGBS content (%)	Thermal Conductivity (W/m ^{0}C)
0	1.08
G4	0.95
G8	0.9
G12	0.88
G16	0.86

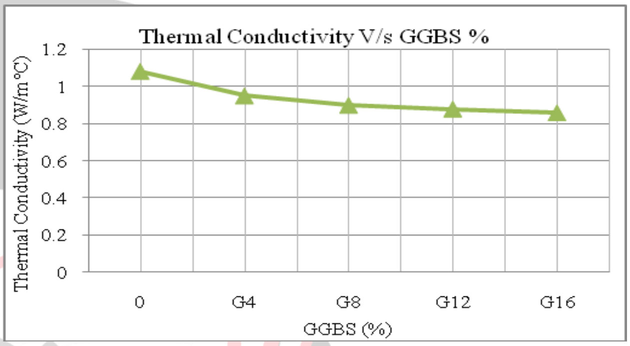

Fig 13 Variation of thermal conductivity of clay bricks with GGBS

2) Thermal conductivity of bricks with Laterite soil

Thermal conductivity of clay bricks made with laterite soil results shown below.

TABLE IX
Thermal Conductivity test results of clay bricks with Laterite soil

Laterite soil content (%)	Thermal Conductivity (W/m ^{0}C)
0	1.08
L5	0.99
L10	0.91
L15	0.84
L20	0.76

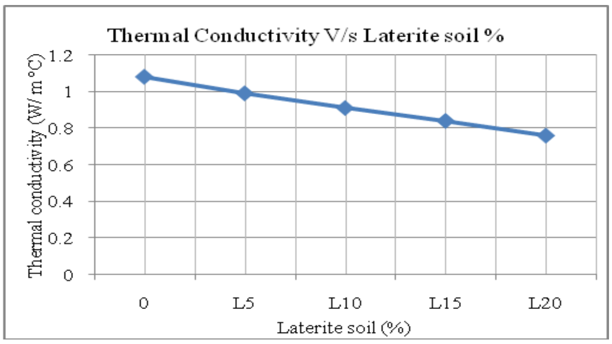

Fig 14 Variation of thermal conductivity of clay bricks with Laterite soil

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3) Thermal conductivity of clay bricks with Laterite soil and GGBS

Clay bricks made with a constant percentage of laterite soil along with varying percentage of GGBS. Laterite soil was added in 15% and GGBS were added in 4, 8, 12 and 16%.

TABLE X
Thermal Conductivity test results of clay bricks with Laterite soil and GGBS

LG content (%)	Thermal Conductivity (W/m ^{0}C)
0	1.08
L15 + G4	0.93
L15+ G8	0.86
L15+ G12	0.8
L15+ G16	0.75

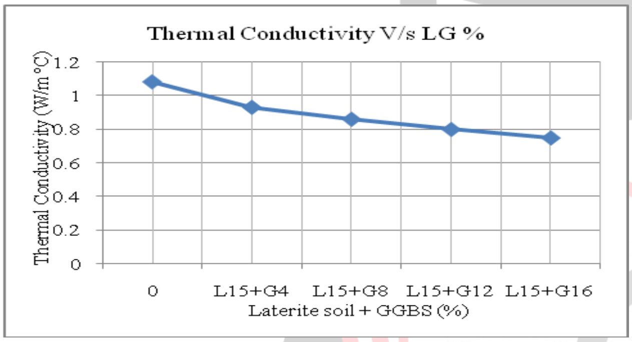

Fig 15 Variation of thermal conductivity of clay bricks with Laterite soil and GGBS

Thermal conductivity is the ability to conduct heat. Good bricks should have low thermal conductivity so that houses keep cool in summer and warm in winter. Lower the thermal conductivity prevents the energy loss from the buildings. Bricks have to minimize the heat flow from one side of the brick to the other side. The thermal conductivity depends on the density and therefore porosity of the material.

V. Conclusion

This study shows the feasibility of GGBS and Laterite soil for brick making. Based on the aforementioned experimental results, following conclusions can be made: Modified clay bricks show increase in compressive strength upto a particular percentage, beyond that point compressive strength decreases. This is due to the porous nature and density of the modified bricks. Water absorption increases with increase percentage addition of materials. Increase in water absorption is due to the porous nature of the bricks. This is due to the lesser soil particles in bricks and it become coarser; this results in higher water absorption. All the bricks have nil or slight efflorescence content. This shows the alkaline salt content in those bricks are less. The thermal conductivity of all the material added bricks was less compared to the control bricks. Thermal conductivity is closely related to the porosity of bricks. Porous structure of bricks is due to CaO rich particles in GGBS and paper sludge. Good bricks should have low thermal conductivity so that houses keep cool in summer and warm in winter. These clay bricks which may be used for the following applications,

- For interior walls
- For interior works but not used for flooring
- For compound walls
- For exterior works (when plastering is to be done)

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