A Study on Modified Clay Bricks with Paper sludge and Laterite Soil

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***Abstract*— Clay bricks have been used in the construction for thousands of years. Paper sludge is also a waste material that is produced from paper printing press. This residue sludge is generally deposited in landfills causing disposal and environmental pollution problems. Laterite soil is used for many construction activities due to their high clay content. They are also energy efficient and environment friendly material. In this study 5%, 10%, 15%, 20% of paper sludge was added along with the clay and a combination of 15% of laterite soil with paper sludge is also added to the clay bricks. The properties such as compressive strength, water absorption, efflorescence and thermal conductivity of those bricks are analysed and reported. It was found that all clay bricks made with these materials shows higher compressive strength than that of control bricks whereas the water absorption increases with increase in percentage of added material. All the bricks showed only slight efflorescence. The thermal conductivity of the entire bricks shows a decreasing pattern with increase in percentage addition when compared with control bricks. Based on the observations made it is clear that 10 class designation bricks (second class) with improved properties and light in weight developed by using these industrial byproducts.**

***IndexTerms*— Paper sludge, Laterite soil, compressive strength, water absorption, efflorescence, thermal conductivity**

I. INTRODUCTION

Brick, the most important tiny piece for construction works is used by human for many years back. A common structural material, till now brick is the cheapest one. This small unit is used very systematically by an expert hand for many different types of construction for long time. Technically, clay bricks fall under the category of heavy clay products. Heavy clay products are those that are mainly made from single clay with very little addition of other raw materials. Different types of bricks with different names in different parts of the world are being produced for structural purposes. Generally the classifications were done on the basis of size, colour, use and quality. With the use of modern technology such as the printing press and the highly mechanised harvesting of wood, disposable paper has become a cheap commodity. This has led to a high level of consumption and waste. With the rise in environmental awareness due to the lobbying by environmental organizations and with increased government regulation there is now a trend towards sustainability in the pulp and paper industry. The production and use of paper has a number of adverse effects on the environment which are known collectively as paper pollution. Pulp mills contribute to air, water and land pollution. Even paper recycling can be a source of pollution due to the sludge produced during de-inking. Paper waste like other wastes faces the additional hazard of toxic inks, dyes and polymers that could be potentially carcinogenic when incinerated, or commingled with groundwater via traditional burial methods such as modern landfills. Paper recycling mitigates this impact, but not the environmental and economic impact of the energy consumed by manufacturing, transporting and burying and or reprocessing paper products. Laterite soils are one of important soils and are widespread in tropical areas and subtropical climates. They are rich in aluminium and iron. All laterites are of rusty-red coloration, because of high iron oxide content. The significant features of the lateritic soils are their unique colour, poor fertility, and high clay content and lower cation exchange capacity. They are suitable for growing rich crops that need aluminium and iron. They give good aesthetics, easiness to cut and hardening with age, makes it unique compared to other natural stones. Laterite soils are cost effective, energy efficient and environment friendly material but they are treated as a weak rock for building applications, also as a soil group.

II. EXPERIMENTAL DETAILS

Clay is the primary material used for brick manufacturing. Day by day the cost of is increasing this can be reduced by adding alternate waste materials into it. Thus the disposal problem can be reduced. Paper sludge is such a material. To improve the properties laterite soil was also added to it.

A MATERIAL COLLECTION

The raw materials used for the brick manufacturing are Clay, Paper sludge 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) Paper Sludge (PS)

Paper Sludge is a waste material collected from the Hindustan News Print Limited (HNL), Velloor. PS is an innovative material that could be used as a soil stabilizing agent. Recycling and reuse of paper sludge has been a topic of international interest in the past few decades. The sludge behaves as a clay-like material consisting of short fibres, ink and other impurities. Specific gravity of paper sludge was 2.6.

Fig. 2. Paper sludge

3) Laterite soil

Laterite soil was collected from kakkanad. They have many engineering properties. It also contains minerals like kaolinite and illite. They are high iron oxide content soil. The significant features are they have high clay content, poor fertility and lower cation exchange capacity. The specific was 2.78.

Fig. 3. Laterite soil

B CASTING OF BRICKS

Clay bricks were made with Paper sludge and a combination of Paper sludge and laterite soil separately. They are hand moulded and were burnt in kiln. Paper sludge were added in 5, 10, 15 and 20%, whereas these percentage of Paper sludge was added to a constant percentage of 15% laterite soil. 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. After air drying process the bricks were transported to the kiln. 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.

III. TEST RESULTS AND DISCUSSIONS

Clay bricks made with Paper sludge and a combination of laterite soil and Paper Sludge were tested for analyzing the physical properties of bricks.

A COMPRESSIVE STRENGTH

The compressive strength test was determined as per IS 3495 (Part I) – 1992. 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 Paper sludge

Clay bricks were made by adding paper sludge in varying percentages of 5%, 10%, 15% and 20%. The bricks were tested in the compressive testing machine and the following results were obtained.

TABLE II
Compressive strength values of clay bricks with Paper sludge

Paper Sludge content (%)	Compressive strength (N/ mm^2)	Remarks
0	9.76	Compressive strength not less than 10 N/mm^2 for class designation 10
P5	9.99	
P10	10.33	
P15	10.21	
P20	10.02	

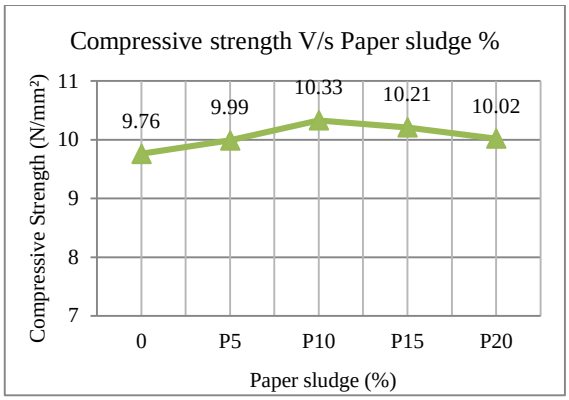

Fig. 4. Variation of compressive strength result of clay bricks with Paper sludge

10% addition of Paper sludge to clay bricks shows higher compressive strength compared to that control bricks. Beyond 10% the compressive strength decreases with increase in paper sludge content.

2) Compressive strength of clay bricks with Laterite soil and Paper sludge

The compressive strength of clay bricks made with laterite soil and paper sludge were analysed. In this laterite soil was taken in constant percentage and Paper sludge was added in varying percentages.

TABLE III
Compressive strength values of clay bricks with Laterite soil and Paper sludge

LP content (%)	Compressive strength (N/ mm^2)	Remarks
0	9.76	Compressive strength not less than 10 N/mm^2 for class designation 10
L15 + P5	10.15	
L15 + P10	10.46	
L15 + P15	10.39	
L15 + P20	10.32	

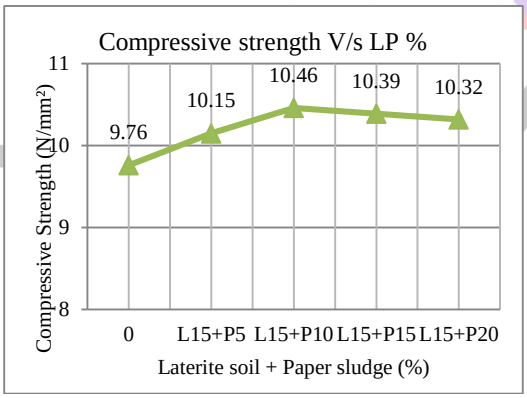

Fig 5 Variation of compressive strength result of clay bricks with LP

The compressive strength of the modified bricks increases upto 10% addition. Compressive strength depends mainly on the density and porosity of the bricks. It is observed that the results of clay bricks with Paper sludge and laterite soil shows a compressive strength of 10.46N/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. The water absorption test was conducted by immersing the brick in cold water for 24 hours.

1) Water absorption of clay bricks with Paper sludge

Clay bricks made with Paper sludge in 5, 10, 15 and 20%. The water absorption test was conducted by immersing the bricks in cold water for 24 hrs.

TABLE IV
Water absorption test results of clay bricks with Paper sludge

Paper sludge content (%)	Water absorption (%)	Remarks
0	15.35	Water absorption shall not be more than 20% upto class designation 12.5
P5	16.5	
P10	17.84	
P15	19.12	
P20	20.47	

Clay bricks made with Paper sludge show increase in water absorption. The minimum water absorption rate was 16.5% for bricks made with 5% of Paper sludge.

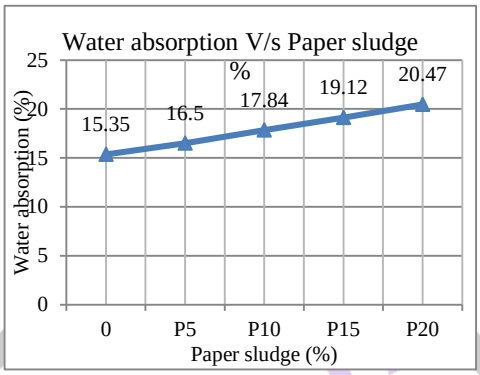

Fig 6 Variation of water absorption of clay bricks with Paper sludge

2) Water absorption of clay bricks with Laterite soil and paper sludge

Clay bricks made with a combination of Laterite soil and paper sludge. Paper sludge in varying percentages was added to a constant percentage of laterite soil.

TABLE V
Water absorption test results of clay bricks with LP

LP content (%)	Water absorption (%)	Remarks
0	15.35	Water absorption shall not be more than 20% upto class designation 12.5
L15 + P5	16.07	
L15 + P10	16.87	
L15 + P15	17.56	
L15 + P20	19.05	

Modified clay bricks show increase in water absorption. Lesser water absorption was for control bricks. Bricks belong to class designation 12.5.

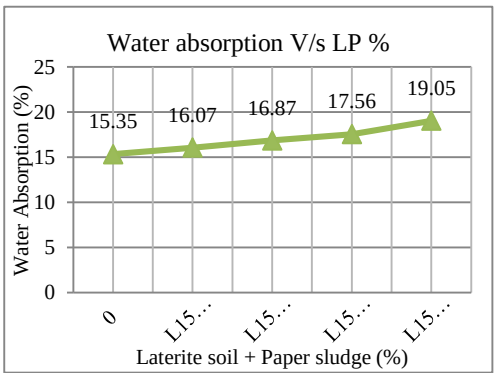

Fig 7 Variation of water absorption of clay bricks with LP

Water absorption increases with increase in the percentage of the addition of material. The bricks become weaker if it 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 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 8 Efflorescence test

The results obtained in this experimental work for all bricks was nil to slight efflorescence. As per IS 1077: 1992, not more than 10 percent of the exposed area of the brick is covered with a thin deposit of salts. Thus the bricks which were belong to second class brick.

D 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 9 Thermal conductivity test setup

1) Thermal conductivity of bricks with Paper sludge

Clay bricks were made of Paper sludge with different percentages of 5, 10, 15 and 20%. The following results were observed.

TABLE VI
Thermal Conductivity test results of clay bricks with Paper sludge

Paper sludge content (%)	Thermal Conductivity (W/m ^{0}C)
0	1.08
P5	0.91
P10	0.85
P15	0.79
P20	0.74

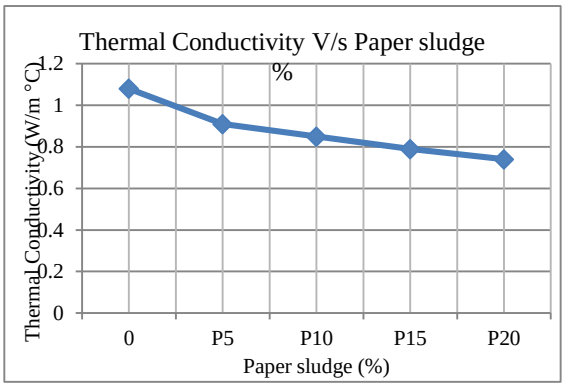

Fig 10 Variation of thermal conductivity of clay bricks with Paper sludge

2) Thermal conductivity of clay bricks with Laterite soil and Paper sludge

Clay bricks made with a constant percentage of laterite soil along with varying percentage of Paper sludge. Laterite soil was added in 15% and Paper sludge were added in 5, 10, 15 and 20%.

TABLE VII
Thermal Conductivity test results of clay bricks with Laterite soil and Paper sludge

LP content (%)	Thermal Conductivity (W/m ^{0}C)
0	1.08
L15 + P5	0.95
L15 + P10	0.8
L15 + P15	0.72
L15 + P20	0.65

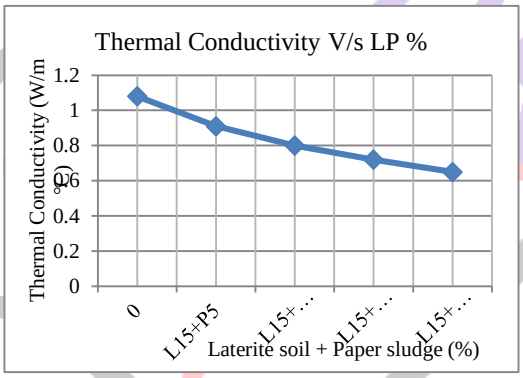

Fig 11 Variation of thermal conductivity of clay bricks with Laterite soil and Paper sludge

As the percentage of material increases, thermal conductivity decreases. Lesser thermal conductivity bricks shows lesser heat absorption. 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.

IV. CONCLUSION

Based on the aforementioned experimental results, following conclusions can be made:

- Clay bricks made with all the materials shows greater compressive strength compared to that of control bricks.
- Bricks made with 10% of paper sludge shows higher compressive strength. Modified bricks also show higher compressive strength than control bricks.
- Decrease in compressive strength is due to the porosity and density of bricks
- All cast bricks show increase in water absorption rate as increase in percentage content. The higher water absorption may be due to greater porosity of the brick.
- All the bricks have nil or slight efflorescence content.
- The thermal conductivity of all the material added bricks was less compared to the control bricks.

Due to all these properties the bricks can be classified as class designation 10 as per IS 1077:2007 (second class) and can be used for constructing interior works especially for wall construction but they may not be used for flooring. It also used for exterior work

when plastering is to be done and also used for building compound walls. Porosity was the main reason for the properties mentioned above. 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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