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Study on Flyash Mixed Laterite-Cement Bricks

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***Abstract*— India is the second largest producer of the brick in the world after China. The brick production in India is estimated at 140 billion bricks, consuming 24 million tonnes of coal along with huge quantity of biomass fuels. The total CO_2 emissions are estimated to be 41.6 million tonnes and it accounts for about 4.5% of total GHG emissions from India.**

In this study, the results of experiments conducted for various percentages of laterite soil and fly ash mixed with 5% and 10% of cement are discussed. The main objective of this study is to obtain a best percentage of fly ash that can be added with soil and cement as stabilizing agent to manufacture bricks at a low cost which can fulfil the requirement of homeless people in the rural and urban parts of the country. Hence bricks in different fly ash, soil and cement mix were stabilized.

The laterite soil waste was collected from Aletty near Sullia. A mould of size 20x10x10cm was prepared. Bricks of different mix proportions were prepared. Of each mix proportion, six bricks were prepared and tested for compressive strength in the compressive testing machine (CTM). To reduce the cost and increase the speed of construction, the wall interlocking system was adopted. The results and graphs were presented for easy comparison.

Using laterite stone is one way of cutting down construction cost. For all materials, it is required to know well in advance the approximate cost. Therefore, an attempt is made to work out the cost of a brick which is giving considerably good strength.

From the compressive strength test results it was observed that compressive strength of Fly ash mixed laterite-cement brick is 9.5 N/mm2 which is 4.5 times higher than laterite stone. Thus, due to the higher compressive strength, the Fly ash mixed laterite-cement brick can be used as a load bearing walls.

Keywords*— *Laterite soil, Fly ash, Laterite-Cement bricks, Laterisation

I. INTRODUCTION

India is the second largest producer of the brick in the world after China. The brick production in India is estimated at 140 billion bricks, consuming 24 million tonnes of coal along with huge quantity of biomass fuels. The total CO2 emissions are estimated to be 41.6 million tonnes and it accounts for about 4.5% of total GHG emissions from India.

A . Fact Sheet of the Indian brick industry

1. Brick production: > 1400 billion/year
2. Annual turnover: > Rs 100 billion
3. No of units: > 0.1 million
4. Employment: 80 to 100 million people
5. Energy and Environment
6. Coal : 24 million tonnes
7. CO2 generation – 42 million tones
8. Top Soil: 350 million tones

B. Laterites

Laterites are soil types rich in iron and aluminium, formed in hot and wet tropical areas. They consist predominantly of mineral assemblages of Geothite, Hematite, Aluminium hydroxide, Kaolinite minerals and Quartz. Nearly all laterites are rusty-red because of iron oxides and are hard in dry state. They are developed by intensive and long-lasting weathering of the underlying parent rock. Tropical weathering (Laterisation) is a prolonged process of chemical weathering which produces a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils. The majority of the land areas with laterite soil are between the tropics of Cancer and Capricorn.

Historically, laterite was cut into brick-like shapes and used in monument building. After 1000 CE construction at Angkor Wat and other Southeast Asian sites changed to rectangular temple enclosures made of laterite, brick and stone.

Francis Buchanan-Hamilton first described and named a laterite formation in southern India in 1807. He named it laterite from the Latin word later, which means a brick; this rock can easily be cut into brick-shaped blocks for building. The word laterite has been used for variably cemented, sesquioxide-rich soil horizons. A sesquioxide is an oxide with three atoms of oxygen and two metal atoms.

The lateritic soil covers an area of about 1 lakh sq.km and extends over the states of Kerala, Karnataka, Maharashtra, Orissa and West Bengal. Laterite covers are thick in the stable areas of the coastal district of Karnataka, where the Laterite formation has cap at elevation higher than 610m. The regions of Dakshina Kannada and Northern parts of Kerala are good reservoirs of laterite soils, due to which lot of quarrying of laterite bricks takes place. In each of those quarries the laterite bricks are made with the help of cutting machines which produce 20 to 30% of soil wastes.

C. Fly Ash: An Overview

Fly ash is the by-product of coal combustion collected by the mechanical or electrostatic precipitator (ESP) before the flue gases reach the chimneys of thermal power stations in very large volumes. All fly ash contain significant amounts of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3), iron oxide (Fe_2O_3), calcium oxide (CaO), and magnesium oxide (MgO). However, the actual composition varies from plant to plant depending on the coal burned and the type of burner employed. Fly ash also contains trace elements such as mercury, arsenic, antimony, chromium, selenium, lead, cadmium, nickel, and zinc.

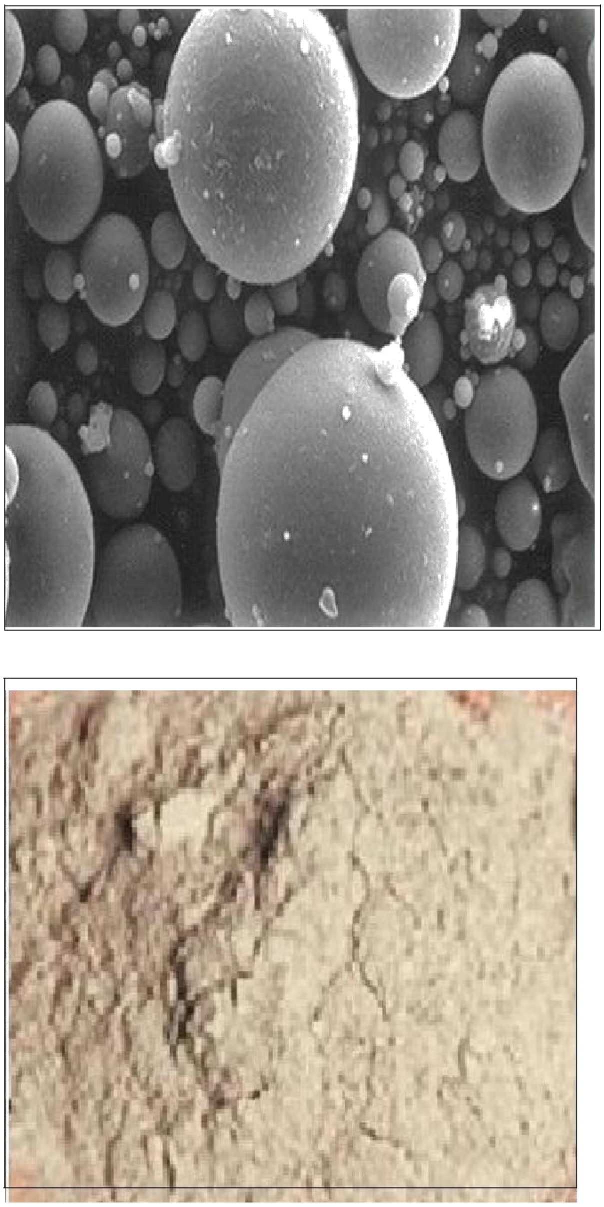

Fig.1: Fly ash: the modern pozzolan

These particles solidify as microscopic, glassy spheres (see fig.1) that are collected from the power plant’s exhaust before they can —fly away — hence the product‘s name: Fly Ash. Chemically, fly ash is a pozzolan. When mixed with lime (calcium hydroxide), pozzolans combine to form cementitious compounds.

Fly ash is one of the numerous substances that cause air, water and soil pollution, disrupt ecological cycles and set off environmental hazards. It also contains trace amounts of toxic metals which may have negative effect on human health and on plants and the land where the fly ash decomposed not gets reused.

India's power generation has undergone a tremendous growth since independence. The production of ash also increased from 110-130 million tonnes in 2010-11 to 150-170 million tonnes in 2020-21, likely to cross 200 million tonnes in next decade.

Table 1: Generation of Fly ash during different Five Year Plans

Plan Period	Terminal Year	Power Generation MW	Coal (MT)	Fly Ash (MT)
8th Plan	1996 - 97	50,000	210	80
9th Plan	2001 - 02	87, 000	285	110
10th Plan	2006 - 07	1,16,400	400	140
11th Plan	2011-12	1,38,300	500	175
	Note: Fly ash Generation during 2009-2010 – 160MnT (source DST)			

The ash should be managed properly or otherwise it will cause land, air and water pollution and there is a serious concern about utilizing it to the maximum extent. It is obvious that building the infrastructure will require large quantities of construction materials. At the same time, due to the growing worldwide concern for climate change caused by the "greenhouse" gases such as CO_2 emissions. So, in order to pursue the goal of infrastructure development in a sustainable manner it would be necessary to use much larger amount of industrial by-products such as fly ash in place of virgin raw materials.

Unfortunately, despite increasing awareness of potential of fly ash, the response of Indian builders and material manufactures towards fly ash utilization has been quite lukewarm until recent past with the level of utilization in Indian context being a meagre 5% utilization in construction industry mostly by brick manufacturing. Gainful utilization of fly ash in the production of bricks/blocks could serve the dual purpose of conserving valuable agricultural land and augmenting brick production in the country.

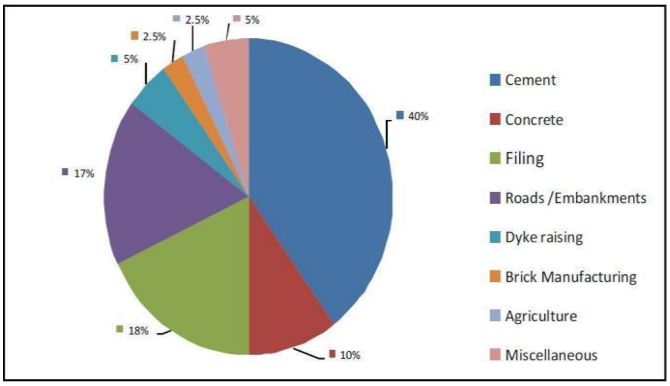

Fig. 2 Present Utilization of Fly ash in different segments

Fly ash has potential for the development of new environment friendly, economical and safe building materials. Further Fly ash mixed laterite cement bricks have many advantages like -

- Light weight
- Saving of fertile land, pure water
- More compressive strength
- Use of wastage etc.
- Minimizing environmental impact of direct disposal
- Minimizing disposal costs
- Procuring financial returns from the sale of the by-product
- Replacing scarce or expensive natural resources.

With view to giving fillip to the increased use of fly ash-based building components, the Government of India has been announcing concessions and incentives in the past three Union Budgets. Excise duty has been exempted on materials and components having 25 percent or more fly ash content.

Apart from the cost of materials used in making blocks for walling units, the cost of cement mortar used in bonding the blocks together also contributes to the exorbitant cost of building works. The technique of building with interlocking blocks eliminates the need for mortar in walling units and consequently reduces building costs.So keeping all the above issues in mind, our project is an attempt to utilize the laterite wastes for the manufacture of laterite-cement bricks mixed with different percentages of Flyash and cement, where cement is a stabilizing agent.

II. PRELIMINARY TEST RESULTS

A. GENERAL:

To study the engineering behaviour of the flyash mixed laterite-cement bricks it is necessary to know about the properties of soil, cement and fly ash. This has been determined by different laboratory tests. The properties used in soil identification and classification are water content, density, consistency limits, and grain size analysis. Also the properties like fineness, consistency and initial setting time of cement, will help to identify the cement type. These properties will give an overall impact on our bricks properties.

B. PROPERTIES OF SOIL:

a. Water Content:

Water content of a soil has a direct bearing on its strength and stability. It is the ratio of the weight of water to the weight of soil in a given soil mass. The knowledge of water content is necessary in soil compaction control, in determining consistency limits of soil, and for the calculation of stability of all kinds of earth work and foundations. The following methods used to find the water content namely Oven drying method, pycnometer method, Sand bath method, Calcium carbide methods or Rapid moisture tester method.

b. Specific Gravity:

The specific gravity of the soil is the ratio of the weight of given volume of soil to the weight of equivalent volume of water at 400C .The value of specific gravity of soil grains is required in the determination of unit weight of soil, void ratio ,degree of saturation water content. It is also useful in determination of particle size by wet analysis. Hence, the specific gravity of soil solids should be determined in great precision. The specific gravity of soil can be determined by two methods, pycnometer method or Density bottle method. Pycnometer method is used only for coarse-grained soil but density bottle method is suitable for all types of soils.

c. Unit weight:

Unit weight of soil is the weight of soil per unit volume. There are different types of unit weight, they are bulk unit weight, dry unit weight, saturated unit weight and submerged unit weight. Dry unit weight has an important role in compaction specifications and field control.

d. Grain size analysis:

In the grain size classification the soils are designated according to grain size or particle size. Particle size distribution is the important soil grain property. Particle size distribution of coarse grain soil is carried by sieve analysis where as fine grained soils are analyzed by hydrometer analysis.

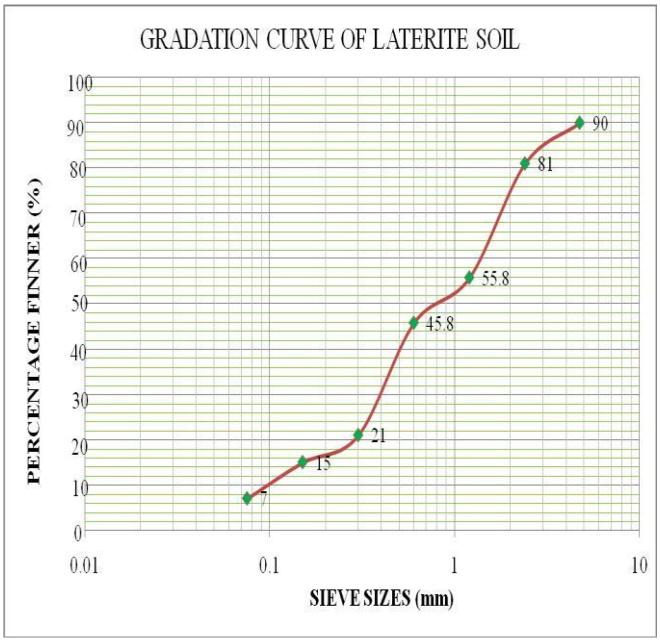

Fig. 3 Gradation Curve of Laterite Soil

Gravel = 10%

Sand = 83%

Silt & Clay = 7%

Uniformity co-efficient (Cu) = 15.31

Co-efficient of curvature (Cc) = 1.03

The Cu > 15 & Cc is between 1 and 3 hence it is considered as well graded soil.

e. Atterbergs's limits:

In 1911, Swedish scientist 'Atterberg' considered the consistency of soil and divided the entire range from liquid o solid states. The transition of water content from one state to another is termed as Atterberg limit. The three important Atterberg limits are as follows.

Liquid limit: The transition from liquid state to plastic state is termed as liquid limit. All soil possesses certain shear strength at this transition stage.

Plastic limit: The transition from plastic state to semisolid state in limited water content is termed as plastic limit. The 3 mm diameter thread of crumble soil at a water content can also called as plastic limit.

Shrinkage limit: The volume of soil mass does not get reduced due to the decrease in the volume of moisture content at maximum water content.

f. Optimum Moisture Content and Optimum Dry Density:

Compaction of soil will give a direct relation between soil water content and degree of dry density. The water content at which maximum density is achieved for a specified amount of compaction energy application is known as optimum water content. The maximum density of soil achieved is optimum dry density. The compaction of soil can be done by two test, Standard proctor test and Modified proctor test.

Liquid limit:

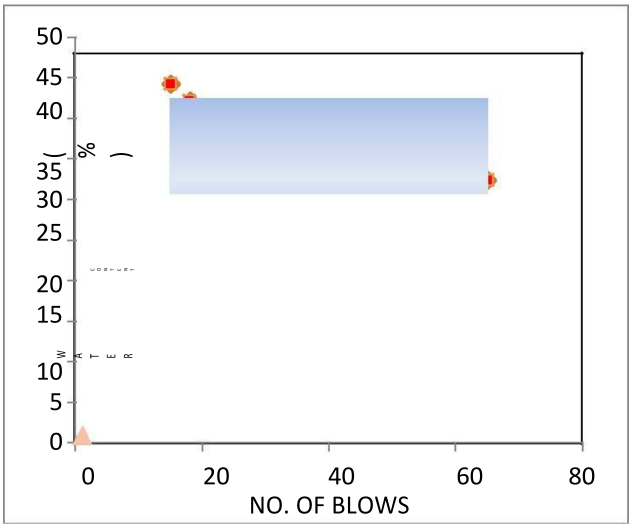

Fig. 4 Liquid Limit

Table 2: Index Properties of Laterite soil, Sullia

Experiments	Results
Water Content (%)	10.7
Specific Gravity	2.48
Unit Weight (g/cc)	1.59
Liquid Limit (%)	38.50
Plastic Limit (%)	27.48
Shrinkage Limit (%)	13.48
Optimum Moisture Content (%)	21.40
Optimum Dry Density (g/cc)	1.78

C. PROPERTIES OF CEMENT:

a. Fineness of cement:

The strength of cement depends on the degree of fineness. It can be determined by sieving or air-permeability. Weight of cement residue after sieving of cement for 15 minutes in IS: 90 micron sieve will give the fineness value. Fineness is taken as percentage residue.

b. Specific Gravity of Cement:

The specific gravity of the cement is the ratio of the weight of given volume of cement to the weight of equivalent volume of water. In this experiment empty weights of the density bottle, bottle with some cement, bottle with cement filled with kerosene, bottle full of kerosene and bottle full of water are taken separately and using these weights the specific gravity of cement is calculated using gravity bottle method.

c. Consistency of cement:

Consistency will give an idea of softness, hardness and strength of cement. The determination of consistency of cement is helpful for other test like setting time compressive strength and soundness. Vicat's Apparatus is used to find the consistency of cement. The plunger of 10 diameter that penetrate up to a depth of 5mm to 7 mm above the bottom of vicat's mould will give the water by weight of cement to produce a consistency.

d. Initial Setting Time:

The time of change from fluid state to solid state of cement water mixture is called setting time. The time at which the solidification of cement-water mixture starts is called initial setting time. Vicat's apparatus with a non porous plate and 1 sq mm needle is used for finding initial setting time. The needle which penetrates in test block up to 5 to 7mm from the bottom is taken as the initial setting time.

Table 3: Index Properties of Cement

Experiments	Results
Fineness of cement	1.25 %
Specific Gravity of cement	2.84
Normal Consistency of Cement	32 %
Initial setting time	32 min

Table 4: Properties of Flyash

Experiments	Results
Specific Gravity of flyash	2.1
Normal Consistency of Cement	26%
Initial setting time	40 min

III. EXPERIMENTAL RESULTS

A. GENERAL:

In this chapter, the results of experiments conducted for various percentages of laterite soil and fly ash mixed with 5% and 10% of cement are discussed.

B. EXPERIMENTAL WORKS CONDUCTED:

The main objective of this study is to obtain a best percentage of fly ash that can be added with soil and cement as stabilizing agent to manufacture bricks at a low cost which can fulfill the requirement of homeless people in the rural and urban parts of the country. Hence bricks in different fly ash, soil and cement mix were stabilized.

The laterite soil waste was collected from Aletty near Sullia. When the laterite stone is cut from the quarry nearly 20-30% of laterite waste is obtained. This waste were sieved in a 2.36 mm IS sieve. This sieved laterite soil was brought to our laboratory for preparation of bricks. This soil was sundried to reduce the water content.

A mould of size 20x10x10cm was prepared. Bricks of different mix proportions were prepared, for each brick varying percentage of laterite soil and fly ash where added with 16% of water by the weight of soil based on the test done on laterite soil and w/c=0.6. Each mix was prepared for 5% cement as well as 10% cement by manual compaction. The mix was done using trowel. Compaction is done by modified proctor rammer dropping from 45cm height with 25 blows for 4 layers, eachlayer was scratched for better bonding between layers. After compaction, the brick is demoulded. Eventually, it is kept for drying for 1day and water is sprinkled on the brick for 28 days.Of each mix proportion, six bricks were prepared and tested for compressive strength in the compressive testing machine (CTM).

C. COMPRESSIVE STRENGTH OF FLY ASH MIXED LATERITE- CEMENT BRICKS:

Compressive strength of fly ash mixed laterite-cement brick is shown in the table.

Fig. 5 Graph for Compressive strength of Fly Ash mixed Laterite-Cement Bricks using 5% cement

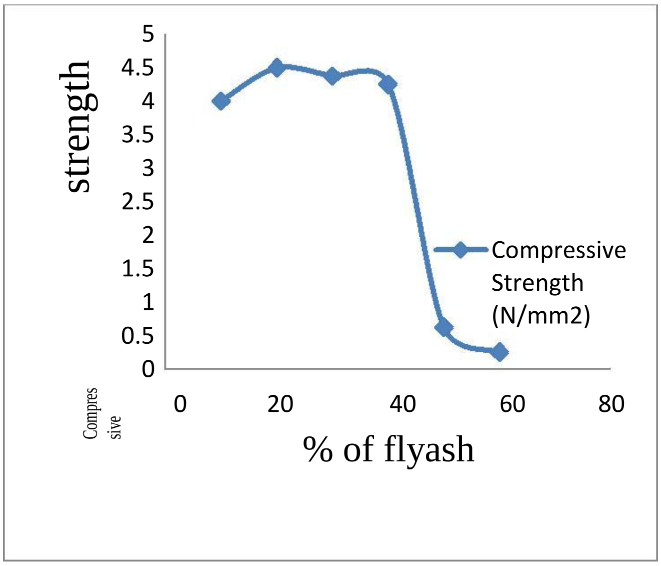

Table 5: Compressive strength of Fly Ash mixed Laterite-Cement Bricks using 5% cement

% Cement by weight ofsoil	% Flyash by weight ofsoil	Trial 1(kN)	Trial 2(kN)	Trial 3(kN)	Trial 4(kN)	Trial 5(kN)	Trial 6(kN)	Average(kN)	Compressive Strength(N/mm2)
5	0	85	5	80	5	5	80	80	4
5	0	85	5	95	5	0	90	90	4.5
5	30	85	90	85	85	90	90	87. 5	4.375
5	40	85	85	80	90	85	85	85	4.25
5	50	15	10	15	15	10	10	12.5	0.625
5	60	5	5	5	5	5	5	5	0.25

Table 6: Compressive strength of Fly Ash mixed Laterite-Cement Bricks using 10% cement

Percentage ofCementbyweightofsoil(%)	Percentage of Flyashbyweightofsoil(%)	Trial 1(kN)	Trial 2(kN)	Trial 3(kN)	Trial 4 (kN)	Trial 5 (kN)	Trial 6 (kN)	Average(kN)	CompressiveStrength(N/mm)
10	10	70	75	70	75	70	75	72.5	.625
10	20	190	190	195	190	185	190	190	9.5
10	30	80	90	85	90	75	80	85	4.25
10	40	20	20	25	20	15	20	20	1
10	50	16	16	16	16	16	16	16	0.8
10	60	6	6	6	6	6	6	6	0.3

Fig. 6 Graph for Compressive strength of Fly Ash mixed Laterite-Cement Bricks using 10% cement

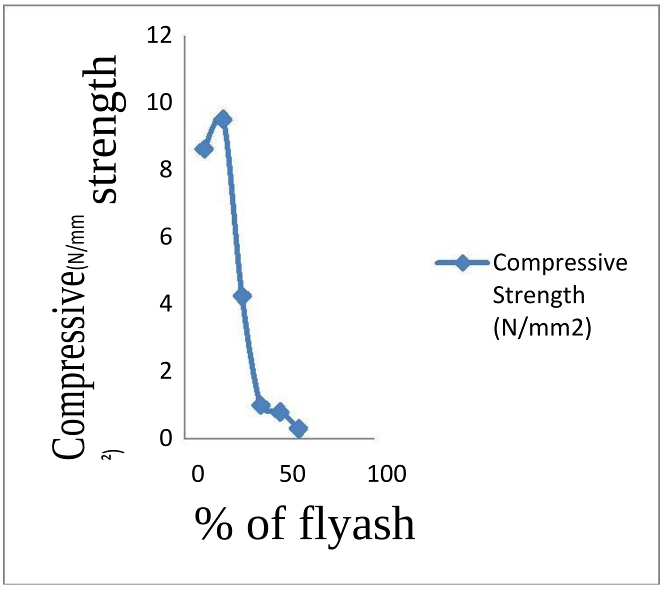

Table 4.4: Compressive strength of laterite stone (30x20x15cm)

Material	Trial 1 (kN)	Trial 2 (kN)	Average (kN)	Compressive Strength (N/mm^2)
Laterite stone	126	126	126	2.1

Water Absorption:
Fly Ash mixed Laterite-Cement Brick =14.00 %
Laterite Stone =14.97%

From the result, Laterite-Cement Brick has less water absorption than laterite stone and it is considered as first class brick because water absorption is less than 20%.

D. *WALL-INTERLOCKING SYSTEM*

To reduce the cost and increase the speed of construction, the wall interlocking system was adopted.10% of cement content, 20% of fly ash, 70% of laterite soil ,16% of water by the weight of soil and 60% of water by the weight of cement(w/c=0.6) is mixed and compacted to form a 30x20x18cm interlocking brick with grooves of size 5x1.5cm and projections of 4.8x1.5cm on both horizontal and vertical faces respectively. The mixing and compaction is done same as the 20x10x10cm brick but 6 layers of soil with 35 blows each.

These grooves locks one brick with another and does not allow them to move away from each other. The entire wall is constructed without any mortar in between the bricks. The construction of wall is done same as laterite wall; the continuous vertical joints are eliminated. In corners like L-junctions, T-junctions the queen post and king post are prepared by chiselling the interlocking bricks.

IV. ANALYSIS AND DISCUSSION OF RESULTS

A. *GENERAL:*

In this chapter, brief description of the test results obtained from the addition of cement and fly ash to laterite soil bricks has been presented. For this purpose, the results and graphs presented in the previous were used for easy comparison.

B. CHARACTERISTICS OF LATERITE SOIL BRICKS USING CEMENT AND FLYASH:

The study showed that the strength of bricks was dependent on the pressure applied during production, percentage of cement, fly ash used and the particle size distribution of the laterite. In this experiment, it was found that as the cement content increased the compressive strength also increased and the variation in the quantity of flyash with the constant cement quantity resulted in the increase of compressive strength in the beginning providing good binding and then decreased with the increase fly ash quantity. From this investigation, we have selected an optimum proportion of cement and fly ash mix with laterite soil which gives considerably good compressive strength along with water absorption within permissible limits. The optimum mix so selected has the following proportion of the ingredients.

Laterite : 70%
Fly Ash : 20%
Cement : 10%

The above proportion has the compressive strength of 9.5 N/mm^2 with % of water absorption which is 4.5 times higher compressive strength than laterite stone.

V . CONCLUSION

- The results obtained from the rate analysis prove that the cost associated with the laterite-cement bricks decreases 50% of the wall construction cost when compared to ordinary laterite stone.
- Compressive strength of Fly ash mixed laterite-cement brick is 9.5 N/mm^2 which is 4.5 times higher than laterite stone.
- Due to the higher compressive strength the Fly ash mixed laterite-cement brick can be used as a load bearing walls.
- In the wall interlocking system, the interlocking bricks are placed without any mortar and the wall is raised very fast compared to the laterite stone. Therefore construction time is reduced.
- Plastering is not required, as the interlocking laterite-cement brick gives an aesthetic appearance.
- Utilizing Fly ash has made the brick Eco- Friendly.
- Less water absorption giving better durability than laterite stones.

VI. FUTURE SCOPE OF THE PROJECT

This particular project has the following scope for the future works:

- The test results presented in the previous chapter are based on only cement, fly ash and laterite soil using admixtures and improving binding and can provide better compressive strength.

- This particular project is tested for water absorption in unburnt condition. However, this can also be tried by burning the bricks in the hot furnace for better results.
- The bricks in this project were compacted manually by a machine that was designed specifically for this project. However, this can be tried with mechanically operated compacting machines.
- The bricks in this project were made by mixing the fly ash and laterite–soil with Cement which is a stabilizing agent. However, it can be tried with other stabilizing agents lime, bitumen, etc.
- To increase the speed of construction the wall interlocking system is adopted but for future progress precast lintel with wall lock is adopted.

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