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ALTERNATE LOW-COST CONSTRUCTION TECHNIQUES

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Abstract: Housing is a great requirement in today's world. The dream of owning a house, particularly for low-income and middle-income families is becoming a difficult reality. Hence, it has become a necessity to adopt cost effective, innovative, and environment-friendly housing technologies for the construction of houses and buildings for enabling the common people to construct houses at affordable cost. The most basic building material for construction of houses is conventional burnt clay brick. A significant quantity of fuel & Labor is utilized in making these bricks. Also, continuous removal of upper surface of soil mass, in producing conventional bricks, creates environmental problems. A study was undertaken on the comparison of Fly ash bricks and conventional clay bricks to solve the problems related to the shortage of construction materials and at the same time to build houses economically by utilizing industrial wastes. The compressive strength of fly ash bricks and conventional clay bricks are investigated. It is observed in past research that fly ash bricks have sufficient strength for their use in low-cost housing development. I have considered a simple house plan and compare its estimate with Fly ash brick and clay brick. The compressive strength of Fly Ash-Concrete blocks with different mix designs was also tested in our project. In some past research tests were also conducted to study the influence of type of curing on the increase in strength and hardening of the bricks and blocks with time, and it was observed that the hot water curing leads to a greater degree of hardening and higher strength, earlier compared to ordinary water curing. However, The Main aim of low-cost housing construction techniques is to reduce the construction cost by following effective processes, methods, and by utilizing good alternative materials and this paper presents the same.

Index Terms - Cost-effective, Innovative, Environment-friendly, Affordable Cost, Clay & Fly-Ash bricks, compressive strength, mix designs

I. INTRODUCTION

For any human being, Food, Clothes, and shelter are three basic needs, without these anyone cannot survive. It is one of the basic needs of an individual and not all of them do have shelter for their survival. In India alone 27 million units of housing has been traced to be in shortage. In depth maximum of population *who lack housing are the economically weaker section and the middle class*. There is a general migration of rural population to the cities due to the rapid industrialization or job creation in developing countries. Also, because of growth in urbanization, the cost of land/houses in cities/towns are rising. The infrastructure to support these cities, such as buildings for housing and industry, mass transit for moving people, goods, and facilities for handling water and sewage will require large amounts of construction materials. Enhanced construction activities, shortage of conventional building materials and abundantly available industrial/Agricultural wastes have promoted the development of new low-cost building materials.

As there is a major growing demand of industries & rapid increase in the capacity of thermal power generation in India to meet out the electricity demand has resulted in the production of a huge quantity of fly ash, which is approx. 50 million tons per year. The prevailing disposal methods are not free from environmental pollution and ecological imbalance. Large stretches of scarce land, which can be used for any kind of productive activities/purposes i.e., shelter, agriculture, are being wasted for disposal of fly ash.

Fly ash, lime and gypsum are available in mutual proximity in many areas. Lime and gypsum are usually available either from mineral sources or may be procured from industrial wastes. An economical alternative brick will be available instead of conventional burnt clay bricks if these waste materials can be used to make bricks and hollow blocks of adequate strength.

Around 259 billion bricks are being produced in a year that are being used for all kinds of construction works. According to the statistics to manufacture 60 billion bricks around 185 million tons of top fertile soil are being used up. In comparison to that, a total of 7500 hectares of fertile land are being deliberately eroded to meet the demands of clay bricks for construction in a year. These activities may harm our environment critically.

Phosphogypsum is an important by-product of phosphoric acid fertilizer industry. It consists of $CaSO_4.2H_2O$ and contains some impurities i.e., phosphate, fluoride, organic matter and alkalies. Approx. 5 million tons of phosphogypsum is produced each year in India and causes serious storage and environmental problems. The impurities of phosphogypsum seriously restrict the industrial use of phosphogypsum in cement industry as a retarder.

Cementitious binder, Fa-L-G, finds extensive application in the manufacturing of building components and Materials such as bricks, hollow bricks, and structural concretes. Fa-L-G technology enables production of bricks with a simple process of mixing, pressure-free molding, and water curing. Due to such appropriate technology apart from economy, conservation of energy and pollution control are also achieved.

Chemical Properties of the materials should be kept in mind to remove impurities which may affect the mix proportion with a very considerable amount. The materials used are (i) Fly Ash, (ii) Phosphogypsum, (iii) Lime, Etc. The chemical properties of these materials are as shown in Table (1), Table (2), Table (3).

Table - 1 Chemical Analysis Of FlyAsh Table

CONSTITUENTS	PERCENTAGE (%)
Loss of Ignition	5.9
SiO_2	57.01
Al_2O_3	23.83
Fe_2O_3	6.66
CaO	3.34
MgO	1.77
SO_3	0.56

Table - 2 Chemical Analysis Of Phosphogypsum

CONSTITUENTS	PERCENTAGE (%)
$CaSO_4.2H_2O$	91.12
SiO_2	1.05
Fe_2O_3	0.3

Table - 3 Chemical Analysis Of Lime

CONSTITUENTS	PERCENTAGE (%)
Loss On Ignition	5.65
CaO	63.25
$SiO_2+Al_2O_3$	25
MgO	4.7

Building Cost: The building construction cost can be divided into two parts namely:

a) **Building material cost: 65 to 70%** **b) Labour cost: 65 to 70%**

Now in low-cost housing, building material cost is less because we make use of the locally available materials, and the labour cost can be reduced by properly making the time schedule of our work. Cost reduction is achieved through the selection of more efficient material or by an improved design.

The Cost-Effective, Environment Friendly (CEEF) technology is working hard to incorporate advanced programming and architectural planning, logical and structural designs, work organization, execution, and management, and the use of new materials and construction devices.

A. *Manufacturing of Low-Cost Building Materials: -*
   a) Environmentally friendly b) Improve technologies for production. C) Reduction in waste generation

B. *Use of Recycled Waste as Building Materials*
   b) Waste produced can be used as a production of a material cheaper in cost.

C. *Use of Natural Low-Cost Building Materials*
   a) Natural materials are sustainable and environmentally friendly.
   b) Materials like stone, lime, bamboo, sand have low embodied energy.

D. *Use of local building materials*
   a) *Reduces transportation dependence. b) Suitable for local environment*

E. *Use of non-toxic Building materials*
   c) Materials to be free from any kind of toxins.
   d) Higher air cycling is required if any highly organic volatile compounds are used.

F. *Longevity, Durability and Maintenance*
   e) Use of durable construction materials decreases the maintenance cost.
   f) Low maintenance cost saves a lot of Building operating costs.

G. *Recyclability and Reusability*
   a) In a form so that it can be recycled or reused. Eg.Plastic.

H. *Biodegradability*
   a) Decompose naturally when discarded. B) Not produce toxic gases while decomposition

Areas from where cost can be reduced are: -

1) Reduce plinth area by using thinner wall concept i.e., solid concrete block wall.
2) Use energy efficiency materials which consume less energy like concrete blocks.
3) Use environmentally friendly materials i.e., R.C.C. Door and window frames.
4) Pre plan every component of a house and rationalize the design procedure for reducing the size of the component in the building.
5) By planning each component of a house, the wastage of materials due to demolition of the unplanned component of the house can be avoided.

2. LITERATURE REVIEW AND ASSESSMENT

So many authors have reported the use of fly ash brick in the replacement of conventional clay brick, for the purpose of cost reduction, and the utilization of industrial waste to reduce environmental pollution. Many papers have been published on Low-Cost Housing, some of them are mentioned below:

A Sravan Kumar Reddy and K Hemanth Raja (2021) carried out study on A Hybrid Low-Cost Construction Techniques and Materials in Construction Project, it is observed that Low budget housing is a type of idea which deals with efficacious costing and following of techniques which avail in truncating the cost of production via the usage of remote to be had material in the juxtaposition of and technology amended adeptness without losing the puissance, overall performance, and existence of the structure. Advantages of low-price building material are pollution aversion, truncating energy intake and usage of natural materials, and reusability of building substances.

Maitry Chauhan (2019) carried out study on low-cost housing, it is observed that new concept which deals with effective budgeting and following of techniques which help in reducing the cost construction using locally available materials along with improved skills and technology without sacrificing the strength, performance, and life of the structure.

Vivek Kumar (2017) carried out study on low-cost construction techniques and material, it is observed that the Alternate construction materials and techniques for building design in the field of civil engineering. It comprises the important analysis and results from the experimental and literature of many authors. The most basic building material for construction of houses is conventional burnt clay brick. A significant quantity of fuel is utilized in making these bricks. Also, continuous removal of upper surface of soil mass, in producing conventional bricks, creates environmental problems. A feasibility study has been done on the comparison of fly ash brick and conventional clay brick.

Preetpal Singh et al (2016) carried out study on Low-Cost Housing: Need for Today's World; it is observed that Construction cost in India is increasing at around 50 per cent over the average inflation levels. It has enumerated an increase of up to 15 per cent all year, mainly due to the cost of basic building materials such as steel, cement, bricks, timber, and other inputs as well as the cost of labour. As a result, the cost of building by means of conventional construction materials and construction is becoming beyond the affordable limits particularly for low-income groups of population as well as a big cross section of middle - income groups. So, there is essential to adopt cost-effective construction methods either by up-gradation of traditional technologies using local resources or applying current construction materials and methods with well-organized inputs leading to economic solutions. By using Low-Cost Housing Technologies, we can reduce approx. 25% of the total cost of housing.

Bredenoord J (2016) carried out study on sustainable Housing and Building Materials for Low-income Households; it is observed that sustainable goals for low-cost housing and applications are achievable. Measures concerning the physical development of neighborhoods, such as urban density and connectivity are equally as important as measures concerning community development. The final comprise support for community-built organizations, small housing cooperatives (or similar forms of cooperation) and individual households – or small groups – that build and increase their houses incrementally. Adequate design, social organization & support are preconditions for achieving sustainability in incremental housing.

Iwuagwu ben ugochukwu et al (2015) carried out study on Local building materials, it is observed that the paper recognizes the problem of inadequate housing as a critical challenge to sustainable urban growth and cities development. Extensive use of recycled materials help conserve restores and preserves the ecosystem. Green buildings wastes management ensures resources and energy efficiency. The closeness of materials saves cost and decreases pollution by fuel through transportation.

Tomas.U.Ganiron et al (2014) carried out study on Prefabricated Technology in a modular home, it is observed that one of interesting perceptions in the study is that prefabricated components has a significance change in the terms of a construction cost & Time as relate to the old-fashioned methods due to the materials and fast band short time duration of construction.

R.Caponetto et al (2013) carried out study on Ecological materials and technologies in low cost building systems, it is observed that the high recyclability of natural materials that can be used in low cost building associated with construction techniques capable of exploiting the principles of bioclimatic architecture for liveliness needs allow us to create building environmentally conscious and responsible.

Swaptikchowdhury et al (2013) carried out study on Prospects of low cost housing in India, it is observed that alternative construction materials mainly natural material such as bamboo, straw, usage of Bagasse –cement boards and panels, bagasse – PVC boards, Coir-CNSL board, Jute coir composites, coconut and wooden chips roofing materials, Manmade materials i.e., fly ash, Aerocon panels, ferro cement, rice husk were studied and the potential of these materials to be used as alternate building materials is brought out.

SenguptaNilanjan et al (2013) carried out study of appropriateness of cost-effective building construction technologies, observed that the acceptability and adaptability potential of different cost-effective building constructions through field survey/literature study/technical calculations and tried to find out the most appropriate one among those.

F.Pachecotorgal et al (2012) carried out study on Earth construction and Building materials, it is observed that earth construction has a major expression in less developed countries, on the other hand the mimetic temptations near more poisoning construction techniques based on reinforced concrete and bricks that fired up are likely to favor a change near a clear unsustainable design. To disclosure and highlight the importance of earth construction this article reviews some environmental benefits such as non-renewable resource consumption, waste generation, energy consumption, carbon dioxide emissions and indoor air quality.

Kuo-Liang Lin (2011) carried out study on Human Resource allocation for remote construction projects, it is observed that when allocating human resources for the management team of distant projects sites, these firms have the strategies between assigning regular staff and hiring local temporary employees. This paper first proposes a decision-making model for human resource allocation in remote construction cost. The case study results show that regular project administrators, who can reduce managerial flaws and cut down project losses, are favored over local ones.

John M.Hutcheson (2011)carried out a study on project management of low cost housing in developing countries; it is observed that the study of this paper include designs, cost control systems, communications , contract law and planning. An appreciation of the evidence compounded from the problems portrayed throughout the paper leads to decisions of the need for simplifications of designs, the impact of inadequate local support and hence the need for detailed and complete advanced planning. In addition, the conclusions stress the need for the careful collection of self-supportive teams of multi-disciplined professionals and sub professionals.

3 CASE STUDY/RESEARCH

Various techniques have been come in account by which we can reduce our cost of construction, these techniques are technically advanced that consume the time of construction and utilize the various waste materials and recycled them into useful constructional materials, which we can further use in construction process. Modern housing techniques brings the revolutionary change in the field of Civil Engineering fly ash clay bricks, wood without tree, Fluor gypsum Plaster Etc. are the Major milestones of these techniques by which the durability and life span of the structure increased with the considerable amount. Low-cost Housing and Alternate technique have a very vast scope in future. The experimental work has been done by the author, which are as follows:

3.1 EXPERIMENTAL WORK

3.1.1 Materials

The materials used for Fa-L-G bricks and hollow blocks were fly ash, lime, calcined phosphogypsum and water. The chemical compositions of fly ash, lime and Calcined phosphogypsum used in the cementitious binder are given in Tables 1–3.

3.1.2 Mix Proportion The mix proportions of Fa-L-G bricks and hollow blocks are given in Table 4.

MIX DESIGNATION	CONSTITUENT MATERIALS (%)		
	Fly ash	**Lime+66**	**Calcined phosphogypsum**
Bricks			
M-1	90	5	5
M-2	80	15	5
M-3	80	10	10
M-4	80	5	15
M-5	70	20	10
M-6	70	15	15
M-7	70	10	20
M-8	60	30	10
M-9	60	20	20
M-10	60	10	30

Table (4) Mix Proportion of Fa-L-G Brick

3.1.3 Mixing of Raw Material

The calcined phosphogypsum and fly ash were sieved through a 4.75-mm sieve. The weighed quantity of sieved fly ash and calcined phosphogypsum were mixed thoroughly in dry state. The hydrated lime was prepared in the laboratory by adding water to a weighed quantity of unslaked lime. Then, complete slaking of lime for 6–8 h was allowed. The slaked lime slurry was sieved through a 1.18-mm sieve. The sieved slurry of hydrated lime was added to the mixture of fly ash and calcined phosphogypsum. Water was added further, and the ingredients were mixed thoroughly by kneading until the mass attained a uniform consistency. Water was added to the mixture of dry materials and the water content was decided as described below. A standard normal consistency test was performed and the water content for the normal consistency was determined.

3.1.4 Preparation of Bricks

Wooden moulds of internal dimension 220 mm=100 mm=75 mm was used. The size of bricks was kept approximately the same as those of the normal burnt clay bricks available in northern India. The Fa-L-G mix was placed in moulds in two layers and was properly compacted on a vibration table.

3.1.5 Testing of Fa-L-G Bricks

The testing procedure recommended in Indian codes of practice for burnt clay bricks were adapted here for Fa-L-G binder. The bricks were taken out from water one day prior to the testing and were tested for compressive strength after 24, 72 and 96 days of casting as per the procedure laid down in relevant Indian codes of practices. The bricks and hollow blocks cured under sulphate solution were tested for their compressive strength after 72 days of casting. The specimens cured for compressive strength at two different temperatures were tested after 24, 48, 72 and 96 days of casting. The test results of the specimens are expressed in terms of the average compressive strength of six specimens. As per the code, if the individual variation was more than "15% of the average", that value was not considered in calculating the average value.

The specimens were crushed between 3-ply plywood sheets approximately 3 mm thick. The load was applied axially at a uniform rate of 14 N/mm2/min until the failure occurred. The strength of Fa-L-G cementitious binder increases with age at a faster rate initially and at a relatively lower rate later. In a separate study, which was reported elsewhere, it was observed that almost full compressive strength of Fa-L-G cementitious binder was reached within the first 4 months. The strength gain beyond 4 months was not technically significant. However, long-term studies of the properties of Fa-L-G binders certainly need to be carried out.

After 96 days of casting, bricks and hollow blocks were tested for water absorption. These bricks and hollow blocks were taken out from water curing tanks and were allowed to drain water by placing them on a 10-mm wire mesh. Visible surface water was removed with a damp cloth and immediately specimens were weighed. After obtaining the saturated weight, these bricks and hollow blocks were kept in an oven at 105ºC; the codes, however, recommend a drying temperature range between 110 and 115 8C. They were dried to a constant mass and taken out from the oven and were weighed at room temperature. From the wet and dry weight of these bricks and hollow blocks, water absorption was calculated.

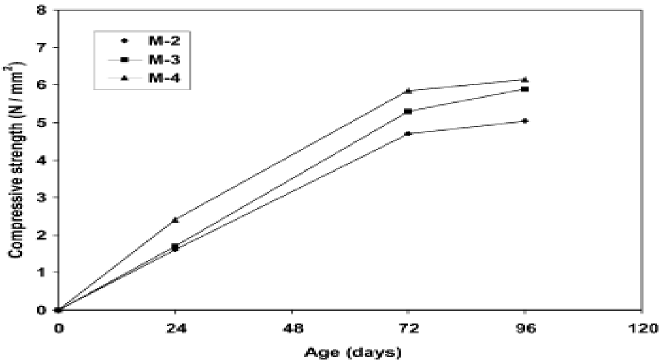


Fig. 1 Compressive strength Fa-L-G brick (FlyAsh 80%) **Fig.2 Compressive strength of Fa-L-G brick (Fly ash 60%)**

3.2 FLYASH

Fly ash is a fine, amorphous (glass) powder recovered from the gases of burning coal during the production of electricity. Thermal power plants use coal for combustion. The quality of coal depends upon its rank and grade. The coal rank arranged in an ascending order of carbon contents is Peat << Lignite << sub-bituminous coal << bituminous coal << Anthracite.

Indian coal is mostly of sub bituminous rank followed by bituminous and lignite (brown coal). The ash content in Indian coal ranges from 35 % to 50%. The coal properties including calorific values differ depending upon the colliery. The calorific value of the Indian coal (~ 15 MJ/Kg) is less than the normal range of 21 MJ/kg to 33 MJ/kg (gross).

There are generally three categories of coal ashes available from thermal power stations:

- **Dry fly ash – collected from different fields of electrostatic precipitator in dry form. The fly ash produced from the burning of pulverized coal in a coal-fired boiler is a fine- grained, powdery particulate material that is carried off in the flue gas and usually collected from the flue gas by means of electrostatic precipitators, baghouses, or mechanical collection devices such as cyclones.**
- **Bottom ash – collected at the bottom of the boiler furnace and is characterized by better geotechnical properties.**
- **Pond ash – Fly ash and bottom ashes are mixed with water to form slurry which is pumped to the ash pond area. In the ash pond the ash gets settled and excess water is decanted. This deposited ash is pond ash.**

These micron-sized elements consist primarily of silica, alumina, and iron. When mixed with lime and water the fly ash forms a cementitious compound with properties very similar to that of Portland cement. Because of this similarity, fly ash can be used to replace a portion of cement in the concrete, providing some distinct quality advantages. The concrete is denser resulting in a tighter, smoother surface with less bleeding.

Fly ash is a fine residue composed of unburned particles that solidify while suspended in exhaust gases. Fly ash is carried by stack gases from a boiler unit and is collected by mechanical methods or electrostatic precipitators. Because it is collected from exhaust gases, fly ash is composed of fine spherical silt size particles in the range of 0.074 to 0.005 mm (Ferguson 1993). Fly ash collected using mechanical precipitators usually has coarser particles than fly ash collected using electrostatic precipitators.

S. No.	CHARACTERISTICS	REQUIREMENTS	
		Grade I	Grade II
1	Fineness-Specific surface in m²/kg, minimum	320	250
2	Lime reactivity- Avg Compressive strength in M/mm², minimum	4	3
3	Compressive strength for PPC	Not less than 80% of the corresponding plain cement mortar cubes	
4	Dry shrinkage, maximum	0.15	0.1
5	Soundness-Expansion of specimen, %, maximum	0.8	0.8

Table 5 Physical Requirements of Fly ash

S.No.	Chemicals	Requirements
1.	Silicon dioxide + aluminum oxide + iron oxide ($SiO_2+Al_2O_3+Fe_2O_3$)	70%
2.	Silicon dioxide (SiO_2)	35%
3.	Aluminium oxide (Al_2O_3)	15-30%
4.	Carbon (in the form of unburnt fuel)	Up to 30%
5.	Alkalis (Na_2O)	1.5%
6.	Magnesium oxide (MgO) (maximum)	5%
7.	Sulphur trioxide (SO_3) (maximum)	2.75%
8.	Loss on ignition by mass (maximum)	12%

Table 6 Chemical requirements of Fly ash

3.3NEED FOR UTILIZATION OF FLYASH

Considering that the Ninth plan (1997-2002) had proposed a pivotal place to thermal power generation it was estimated that it shall increase at an annual rate of around 8-10%. Consequently, fly ash generation shall touch the 100 million tons / year mark by year 2000 & 125 million tons by 2003-2004.

The major sources of fly ash production in India are the thermal power units. It is estimated that by the end of the tenth plan period (March 2007) an additional 124000 MW of power sector expansion will be required in India to meet the rising energy demand. Though the state of Orissa is not thickly industrialized, the fly ash generation in the state is to the tune of 93 lakh tones per annum. As far as thermal power sectors in Orissa are concerned about 22.6% of fly ash is being utilized. This trend in future may require a large amount of land area for disposal of fly ash.

According to Central Electricity authority of India, there are around 85 major coal fired thermal power plants and 305 hydro plants existing in India. As per the ministry of power statistics, the total installed generating capacity (Thermal + wind) during 2003-2004 was about 79838 MW and hydropower generation was 29500 MW. In addition to this, there are more than 1800 selected industrial units which had captive thermal power plants of greater than 1 MW capacity.

Some of the prominent Power Plants which are also producing and providing good quality Fly Ash include the following:

Ropar	Kota	Trombay
Annapara	Dadri	Rihand
Vindyanchal	Raichur	Ramagundam
Unchahar	Chandrapur	Dahanu

Present Scenario on Fly Ash in India

Over 73 % of the total installed power generation is thermal. 230 - 250 million MT coal is being used every year. High ash contents varying from 30 to50%. Presently 65,000 acres of land occupied by ash ponds. Presently as per the Ministry of Environment & Forest Figures, 30% of Ash is being used in Fillings, embankments, construction, block & tiles, etc.

The fly ash produced because of burning of Indian coal has tremendous potential to be utilized for different applications. Rough estimates of existing utilization are around 30% of the total generated fly ash as against 10 % in 1999 and 3-5% in 1994. The fly ash being generated from the various industries will continue to increase in the subsequent years. The current percentage of utilization of fly ash in India is very less as compared to the other countries like Germany, Netherlands etc. where the utilization is above 90 %. As nearly 73% of the country's total installed power generation capacity is thermal of which coal-based generation is 90%. Some 85 thermal power stations, as well as several captive power plants use bituminous and sub-bituminous coal and produce large quantities of fly ash. High ash content (30% - 50%) coal contributes to these large volumes of fly ash. Also, the country's dependence on coal for power generation has remained unchanged. Thus, fly ash management is a major cause of concern for the future.

3.4 EFFECT OF FLY ASH ON CEMENT CONCRETE

On Amount of Mixing Water, the use of fly ash in limited amounts as a replacement for cement or as an addition to cement requires a little more water for the same slump because of fineness of the fly ash. It is generally agreed that the use of fly ash, particularly as an admixture rather than as a replacement of cement, reduces, segregation and bleeding. If the sand is coarse the addition of fly ash produces beneficial results; for fine sand, its addition may increase the water requirement for given workability.

On Strength in Compression since the pozzolanic action is very slow, an addition of fly ash up to 30% may result in lower strength at 7 and 28 days but may be about equal at 3 months and may further increase at ages greater than 3 months provided curing is continued.

On Modulus of Elasticity, it is lower at early ages and higher at later ages. Curing Condition is like Portland cement concrete. On Shrinkage of Concrete Coarser fly ashes and those having a high carbon content are more liable to increase drying shrinkage than the finer fly ashes and those having a low carbon content. On Permeability the permeability of concrete reduces on addition of fly ash to cement. 28 days pulverized fly-ash-concrete may be three times as permeable as ordinary concrete but after 6 months it may be less than one quarter permeable. On Resistance to Chemical Attack Fly ash slightly improves the resistance of concrete to 30% fly ash and may result in a reduction of 50-60% heat of hydration. On Air Entrainment The presence of fly ash reduces the amount of air entraining agent. Setting Time: A 30% substitution of fly ash may result in an increase of initial setting time up to 2 hours.

3.5 FLY ASH BRICKS

Fly ash brick is a building material, specifically masonry units, containing class fly ash and water. Compressed at 28 MPa (272 atm) and cured for 24 hours in a 66 °C steam bath, then toughened with an air entrainment agent, the bricks last for more than 100 freeze-thaw cycles. Owing to the high concentration of calcium oxide in class C fly ash, the brick is described as "self-cementing". The manufacturing method saves energy, reduces mercury pollution, and costs 20% less than traditional clay brick manufacturing.

3.6 ROW MATERIALS FOR FLY ASH BRICK

The row material for fly ash bricks is as shown in below table no 7:

Material	Mass
Fly Ash	60%
Sand/Stone Dust	30%
Ordinary Portland Cement (Lime + Gypsum)	10%
Total Formula of Material	100%

Table-7 Row Materials for Fly Ash Brick

The strength of fly ash brick manufactured with the above compositions is normally of the order of 7.5 N/mm2 to 10 N/mm2. Fly ash bricks are lighter and stronger than clay bricks.

There are three important ingredients of fly ash which affect the strength and look of fly ash brick.

Loss on Ignition (LOI) Fly ash loses weight when it burns at about 1000°C due to presence of carbon and water. Weight loss happens due to carbon combustion and moisture evaporation is called "Loss on Ignition (LOI)". This is expressed as percentage. The lower the loss of Ignition, the better will be fly ash. As per BIS it should not be more than 5%.

1) **Fineness** the fine fly ash has more surface area available to react with lime, thus more will be the pozzolanic activity of fly ash. The greater pozzolanic activity contributes to the strength of fly ash brick. As per BIS it should not be more than 320 m2/kg.
2) **Calcium (CaO) content** the pozzolanic reactivity of fly ash is more in high calcium fly ash. The greater the pozzolanic activity leads to higher the strength of fly ash brick. For C class fly ash CaO should be more than 10% and for F class it might be lower than 10%.

3.7 ADVANTAGES

1) It reduces deadload on structures due to light weight (2.6 kg, dimension: 230 mm X 110 mm X 70 mm).
2) The same number of bricks will cover more area than clay bricks.
3) High fire Insulation.
4) Due to high strength, practically no breakage during transport and use.
5) Due to uniform size of bricks mortar required for joints and plaster reduces almost by 50%.
6) Due to lower water penetration seepage of water through bricks is considerably reduced.
7) Gypsum plaster can be directly applied on these bricks without a backing coat of lime plaster.
8) These bricks do not require soaking in water for 24 hours. Sprinkling water before use is enough.

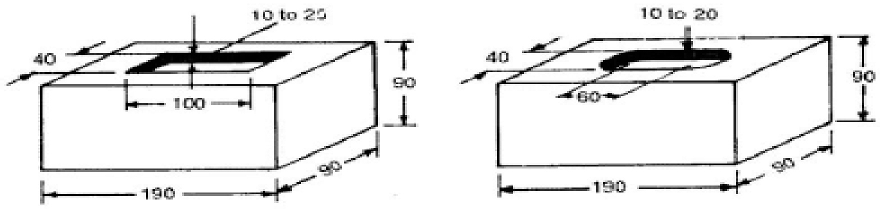
3.8 DISADVANTAGES

1) Mechanical strength is low, but this can be rectified by adding marble waste or mortar between blocks.
2) Limitation of size. Only modular size can be produced. Large size will have more breakages.

3.9 CLAY BRICKS

One of the oldest building materials, brick continues to be the most popular and leading construction material because of being cheap, durable, and easy to handle and work with. Clay bricks are used for building up exterior and interior walls. Partition, piers, footings, and other load bearing structures. A brick is rectangular in shape and of size that can be conveniently handled with one hand. Brick may be made of burnt clay or mixture of sand and lime or of Portland cement concrete. Clay bricks are commonly used since these are economical and easily available. The length, width and height of a brick are interrelated as below: **1.** Length of brick = 2 x width of brick + thickness of mortar **2.** Height of brick = width of brick the size of standard brick (also known as modular brick) should be 19x9x9cm and 19x9x4cm. When placed in masonry the 19x9x9 cm brick with mortar becomes 20x10x10 cm.

However, the bricks available in most part of the country still are 9”x4½”x3” and are known as field bricks. The weight of such a brick is 3kg. An indent called frog, 1-2 cm deep, as shown in fig (1), is provided for 9cm high bricks. The size of frog should be 10x4x1 cm. The purpose of providing a frog is to form a key for holding the mortar and therefore, the brick are laid with frog on top. Frogs are not provided in 4cm high bricks and extruded bricks.



3.10 CLASSIFICATION OF BRICKS

3.10.1 on Field Practice

Clay bricks are classified as first class, second class, third class and fourth class based on their physical and mechanical properties.

- **First class brick:**
    1. **These are thoroughly burnt and are of deep red, cherry, or copper colour.**
    2. **The surface should be smooth and rectangular. With parallel sharp and straight edges and square corners.**
    3. **These should be free from flaws, cracks, and stones.**
    4. **These should have uniform texture.**
    5. **No impression should be left on the brick when a scratch is made by a fingernail.**
    6. **The fractured surface of the brick should not show lumps of lime.**
    7. **A metallic or ringing sound should come when two bricks are struck against each other.**

Uses First class bricks are recommended for pointing, exposed face work in masonry structures, flooring, and reinforced brick work.

- **Second Class Brick** These are supposed to have the same requirements as the first-class ones except that-

1. **Small cracks and distortions are permitted.**
2. **A little higher water absorption of about 16-20% of its dry weight is allowed.**
3. **The crushing strength should not be less than 7.0 N/mm2.**

Uses: Second class bricks are recommended for all important or unimportant hidden masonry works and cantering of reinforced brick and reinforced cement concrete (RCC) structures.

- **Third Class Brick These are under burnt. They are soft and light-colored producing a dull sound when struck against each other. Water absorption is about 25 per cent of dry weight.**

  Uses: It is used for building temporary structures.
- **Fourth Class Brick These are over burnt and badly distorted in shape and size and are brittle in nature.**

  Uses: The ballast of such bricks is used for foundation and floors in lime concrete and road metal.

3.10.2 On the Basis of Use

- **Common Brick** is a general multi-purpose unit manufactured economically without special reference to appearance. These may vary greatly in strength and durability and are used for filling, backing and in walls where appearance is of no consequence.
- **Facing Bricks** are made primarily with a view to have good appearance, either of colour or texture or both. These are durable under severe exposure and are used in fronts of building walls for which a pleasing appearance is desired.
- **Engineering Bricks** are strong. Impermeable, smooth, table moulded. hard and conform to defined limits of absorption and strength. These are used for all load bearing structures.

3.10.3 On the Basis of Finish

- **Sand faced Brick** has textured surface manufactured by sprinkling sand on the inner surfaces of the mould.
- **Rustic Brick** has mechanically textured finish, varying in pattern.

3.10.4 On the Basis of Manufacture

- **Handmade** These bricks are hand moulded.
- **Machine-made** Depending upon mechanical arrangement, bricks are known as Wire-cut bricks-bricks cut from clay extruded in a column and cut off into brick sizes by wires. Pressed - bricks- when bricks are manufactured from stiff plastic or semi-dry clay and pressed into moulds.
- **Moulded bricks-** when bricks are moulded by machines imitating hand mixing.

3.10.5 On the Basis of Burning

- **Pale Bricks** are under burnt bricks obtained from the outer portion of the kiln.
- **Body Bricks** are well burnt bricks occupying the central portion of the kiln.
- **Arch Bricks** are over burnt also known as clinker bricks obtained from inner portion of the kiln.

3.10.6 On the Basis of Types

- **Solid** Small holes not exceeding 25 per cent of the volume of the brick are permitted alternatively. frogs not exceeding 20 per cent of the total volume are permitted.
- **Perforated** Small holes may exceed 25 per cent of the total volume of the brick.
- **Hollow** The total of holes, which need not be small, may exceed 25 per cent of the volume of the brick.
- **Cellular** Holes closed at one end exceeding 20 per cent of the volume.

3.11 CHARACTERISTICS OF GOOD BRICK

- The essential requirements for building bricks are sufficient strength in crushing regularity in size, a proper suction rate, and a pleasing appearance when exposed to view.
- **Size and Shape** The bricks should have uniform size and are plain. rectangular surfaces with parallel sides and sharp straight edges.
- **Colour** The brick should have a uniform deep red or cherry colour as indicative of uniformity in chemical composition and thoroughness in the burning of the brick.
- **Texture and Compactness** The surfaces should not be too smooth to cause slipping of mortar. The brick should have pre compact and uniform texture. A fractured surface should not show fissures, holes grits or lumps of lime.
- **Hardness and Soundness** The brick should be so hard that when scratched by a finger nail no impression is made. When two bricks are struck together. a metallic sound should be produced.
- **Water Absorption** should not exceed 20 percent of its dry weight when kept immersed in water for 24 1hours.
- **Crushing Strength** should not be less than 10 N/mm2.

3.12 INGREDIENTS OF GOOD BRICK EARTH

For the preparation of bricks, clay or other suitable earth is moulded to the desired shape after.Subjecting it to several processes. After drying.it should not shrink and no crack should develop. The clay used for brick making consists mainly of silica and alumina mixed in such a proportion that the clay becomes plastic when water is added to it. It also consists of small proportions of lime, iron, manganese. Sulphur. Etc. The proportions of various ingredient are as follows as shown in table.8:

Table-8 Ingredients of Good Brick

Silica	50-60%
Alumina	20-30%
Lime	10%
Magnesia	<1%
Ferric Oxide	<7%
Alkalis	<10%
Carbon dioxide	Less than 20% water
Sulphor trioxide	
Water	

IV. RESULTS AND DISCUSSION

4.1 COMPARISION OF COMPRESSIVE STRENGTH OF FLY ASH BRICK AND CLAY BRICK

6.1.1 COMPRESSIVE STRENGTH OF FLY ASH BRICK MEAN STRENGTH OF FLY ASH BRICK: -9.50 N/mm²

SAMPLE	SIZE (mm)	COMPRESSIVE STRENGTH N/mm²
1	230x110x70	9
2	230x110x70	10.5
3	230x110x70	9

6.1.2 COMPRESSIVE STRENGTH OF CLAY BRICK MEAN STRENGTH OF CLAY BRICK: -7.53 N/mm²

SAMPLE	SIZE (mm)	COMPRESSIVE STRENGTH N/mm²
1	230x110x70	7.9
2	230x110x70	7.2
3	230x110x70	7.5


4.2 COMPARISION OF COMPRESSIVE STRENGTH OF FLY ASH CONCRETE BLOCK

6.2.1 M20 GRADE FLY ASH CONCRETE BLOCK

SAMPLE	SIZE (mm)	COMPRESSIVE STREBGTH N/mm²
1	70.7x70.7x70.7	22.3
2	70.7x70.7x70.7	24.5
3	70.7x70.7x70.7	22.9

MEAN COMPRESSIVE STRENGTH: **-23.23 N/mm²**

6.2.2 M25 GRADE FLY ASH CONCRETE BLOCK

SAMPLE	SIZE (mm)	COMPRESSIVE STRENGTH N/mm²
1	70.7x70.7x70.7	23.8
2	70.7x70.7x70.7	28.6
3	70.7x70.7x70.7	27.5

MEAN COMPRESSIVE STRENGTH: **-26.63 N/mm².**

4.3 COMPARISION OF COST B/W FLY ASH BRICK AND CLAY BRICK

4.3.1ABSTRACT OF COST OF CLAY BRICK

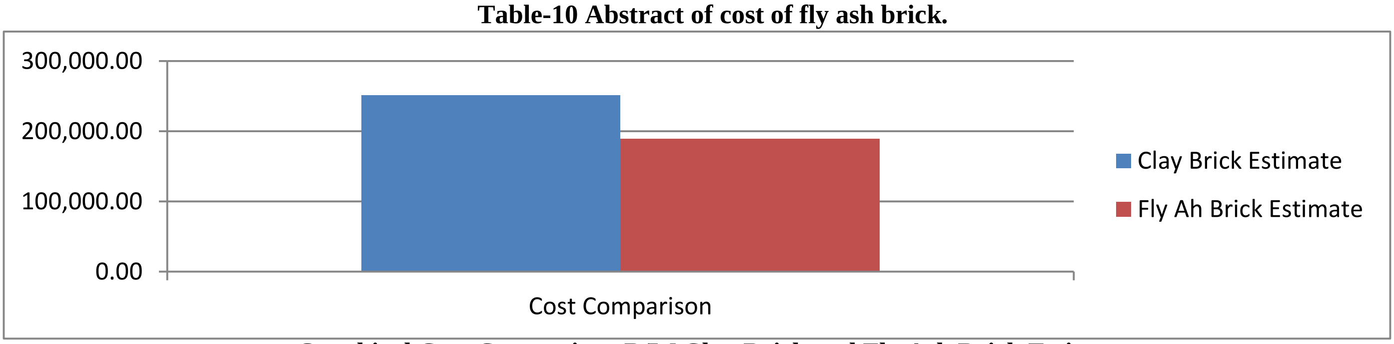
• S.NO.	• NAME OF ITEMS	• QUANTITY	• RATE	• PER	• AMOUNT
1-	Masonry Work				
(A)	First Class Brick Work in Foundation and Plinth.	22.12 m3	4850	m3	107,282.00
(B)	First Class Brick Work in Super structure.	29.63 m3	4850	m3	143,705.50
				TOTAL	**250,987.5**

Table-9 Abstract of cost of clay bricks.

- **4.3.2 ABSTRACT OF COST OF FLY ASH BRICK**

S.NO.	NAME OF ITEMS	QUANTITY	RATE	PER	AMOUNT
1-	Masonry Work				
(A)	First Class Brick Work in Foundation and Plinth.	22.12 m3	3650	m3	80,738.00
(B)	First Class Brick Work in Super structure.	29.63 m3	3650	m3	108,149.50
				TOTAL	**188887.5**

Table-10 Abstract of cost of fly ash brick.



Graphical Cost Comparison B/W Clay Brick and Fly Ash Brick Estimate

4.4 Results: -Many experimental works have been done on fly ash bricks with different mix and proportions. Combinations were made: (i) fly ash, clay, sand and (ii) fly ash, cement, stone dust and (iii) fly ash, Lime, sand, & Gypsum. Maximum compressive strength found 94.15 Kg/cm2 for mix 30:40:30, 106 Kg/cm2 for mix 35:07:58 and 173.50 Kg/cm2 for mix of 40:30:20:10 respectively.

5. CONCLUSION

The dream of owning a home is becoming more difficult for low- and middle-income families. To build affordable, innovative, and environmentally friendly housing, it is essential to use cost-effective, creative, and environmentally friendly housing technologies.

The above said list of suggestion for reducing construction cost is of general nature and it varies depending upon the nature of the Building/Structure/Component to be constructed, budget of owner, geographical location where the Building/Structure/Component are to be constructed, availability of the building material, good construction planning & management practices etc. however it is necessary that good planning and designing methods shall be adopted by utilizing the service of an experienced Designer/Architecture/Engineer/Supervisor and information Technology as well for executing the work as per specification, thereby achieving overall cost effectiveness to the extent of 23% - 25% in actual practice. The test conducted on the fly ash brick and traditional clay brick shows the variation in cost and strength of the brick which can affect our construction cost and the durability of the structure. However, it may also be noted that reducing the cost of construction may affect the strength of the structure. Our report shows the variation between cost of the structure and respective strength of the structure and the cost-effectiveness of using low-cost housing technology versus conventional construction methods was compared.

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