Fly-ash Enriched Earthen Un-Burnt Bricks for Low-cost Housing

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Abstract. In spite of various major steps taken by the Governments, housing problem in rural India is becoming bad to worse due to population explosion and their low income. Various low-cost housing schemes has been floated through use of cheaper construction materials. Therefore, development of new cheaper materials has become need of the day. This can be possible by production of new materials produced from various by-products or wastes justifying the slogan converting ‘Wastes into Wealth’. Fly ash, a coal combustion by-product available in power plants is one such material available in plenty in our surroundings those are posing problem to the environment. Presently, these are utilised by mixing various cementitious materials in production of bricks, those are substituting conventional bricks, for their cost effectiveness. But, the extreme poor people of tribal areas are deprived of using these bricks in their houses due to non-availability and financial constraints. Most of tribal houses in KBK districts of Odisha, Eastern and Central rural of Chhattisgarh, some parts of Jharkhand, Bihar and West Bengal are made of walls with twigs plastered with mud and Nauria tiled roofing. To bridge the gap a new product ‘Fly ash Enriched Earthen Unburnt brick’ has been proposed. Necessary laboratory tests for the proposed product has been carried and their suitability is presented in this paper. Poor people who can’t afford for standard bricks for their houses, this can be an alternate cheaper solution for them.

1. Introduction
Most of tribal houses in KBK districts of Odisha, Eastern and Central rural chunk of Chhattisgarh, some parts of Jharkhand, Bihar and West Bengal are made of walls with twigs plastered with mud and Nauria tiled roofing. (Figure 1). General poor people who can’t afford for burnt clay bricks for their houses, ‘Fly ash Enriched Earthen Unburnt Brick’ can be an easy solution for them. In arid zones of central India, KBK districts of Odisha, Jharkhand, Chhattisgarh having low rainfall these can use this material for construction [1-6]. Fly ash can be mixed with the local earth irrespective of its quality in production of bricks which can be used unburnt in construction of low-cost housing. These types of materials would be environment friendly. It is a simple technology i.e., only substitution of materials for brick and to be used un-burnt. These bricks shall be made of local earth enriched with fly ash. It can be produced anywhere, irrespective of availability of any type of earth and would be much cheaper material affordable by poor. The bricks can be manufactured fairly simply using local labour and will also have a positive impact on local employment. It can save huge numbers of trees every year though it is the substitute of trees [7-10].
If we look to the historical facts around the globe the case of the Taos Pueblo in New Mexico may be the most appropriate example, where the Pueblo group of people are residing since about last thousand years. They construct of their residential houses with the sun-dried bricks made of mud those are plastered with special mud prepared from local clayey soil, known as caliche mixed with finely-cut straw or some local suitable fibrous materials for smooth finish and that adds to the surface strength. Facility of additional one more floor is provided by making the walls thicker and the roofs with planks made from cedar trees, with added provision of wooden ladders from outer side of the house for the approach to higher floor. The statistical information reveals an estimated 180 billion tons clay burnt bricks are utilized annually for the above purpose. This figure is likely to increase with the demand for further housing units which may exceed the figure 80 million for lower and lower-middle class habitants. At present the housing sectors in our country is also facing a deficit of 20 million housing units for its lower and lower-middle class which may face a surge of about 22.5 million units in near future. In this situation to cope up the exponential growth of demand fly ash enriched mud brick can be a feasible solution to support the poorest of the poor ones. Dr Andrew Heath [4], a faculty of the University of Bath has presented an overview for field application of the said technology. Mauro Sassu, Ignasio Ngoma [10] have presented collective initiatives of the organizations, ‘Earthquake Engineering Research Institute (EERI)’ and ‘International Association for Earthquake Engineering (IAEE)’ in their comprehensive report of “World Housing Encyclopaedia”. In their report they have emphasized that about 45% of housing of the country, MALAWI and in the adjacent countries, i.e., Zambia and Tanzania are constructed having thatched roof supported by unburnt mud brick wall with mud mortar. Mike Lawrence et.al. [6] has stated that unburnt bricks made of local clay can deliver workable and sustainable substitute as an alternate to conventional burnt brick masonry or concrete blocks for both load-bearing and non-load bearing walls. Sadek Deboucha and Rostan Hashim [9] have reviewed the state-of-the-art utilization of mud bricks and compressed earthen blocks. Daniel Maskell et.al. [11] have discussed in their paper regarding use of other cementing materials such as cement and lime along with the conventional masonry for stabilizing the earthen masonry. Andrew Heath et.al. [4] summarizes results of extensive testing on viability of mass-production of unburnt clay bricks commercially. The focus of the paper is to investigate the properties effecting the compressive strength of these products.

2. Materials and Methods
For production of the proposed fly-ash enriched bud brick two major materials required are earth and fly ash apart from water. Those are described briefly here.

2.1. Fly ash
It is needless to mention the status of accumulation of fly-ash, a bye-product of coal based thermal power plants and their possible utilization in various activities. It is a fact that about 72% of power plants of our country are coal fed with annual generation of approximately 40 million tons of fly ash. These are separated by use of the cyclone converter in almost all power plants and industries using coal as a fuel. This fly ash is a threat as a major atmospheric pollutant. Mostly these are disposed as land fill. Presently a small part of it is used as a raw material for manufacture of bricks, construction of roads etc.
2.1.1. Current Status of fly ash
Thermal Power Generation units are the major source energy supply addition to the present hydropower installations and other alternate energy sources in our country. These are serving as backbone of power capacity and are mostly Coal/Lignite based. It is an established fact that coals available in India are of lower quality having ash content of about 30% to 45% and on the hand imported coals of having much lower ash content of nearly 10% to 15%. Thus, large amount of ash is generated at these thermal Powerhouses which is real threat to environment as pollution of both air and water. Disposal these requires huge area of land. A very small part of it is being utilised in infrastructural activities. Therefore, use of these fly ashes for production of any new building materials shall help the infrastructural development and environmental protection.

2.1.2 General Characteristics of Indian Fly ash
Physical Characteristics:
- Specific Gravity varies from: 2.54 to 2.65 gm/cc
- Bulk Density is about: 1.12 gm/cc
- Fineness varies from: 350 to 450 m³/kg

Chemical Characteristics:
- Silica content varies from: 35% to 59%
- Alumina varies from: 23% to 33%
- Calcium Oxide varies from: 10% to 16%
- Sulphur varies from: 0.5% - 1.5%
- Iron varies from: 0.5% - 2.0%

2.2. Earth for Bricks
For manufacture of the conventional earthen bricks quality of earth plays a major role. But the proposed bricks shall be independent of quality of earth. Normal local earth mixed with required proportion of fly ash and water for manufacture of the brick. Laboratory tests should be conducted for deciding the proportions of materials for mixing to obtain desired compressive strength.

2.3. Manufacturing of Bricks
Earth, after collection is gone under various processes such as weathering, blending by adding desired quantity fly ash, sand etc as per the designed mix. After proper formation of very sticky stuff, this is placed in moulds to form required shape and size. After removal from mould it is allowed to dry in sun for at least 3 days. Traditionally the clay bricks are generally made by hand resulting variable dimensions and other properties. Mechanised moulding of bricks is not practicable when the bricks are produced in small numbers and remote localities.

3. Results
The bricks are moulded in the laboratory utilizing local earth and the fly ash available locally. Mechanical properties of earth and fly ash used have not been tested. Compressive strength of the bricks produced are tested to ensure the suitability of those in the building construction. The variation of compressive strength with different proportion of fly ash has been presented in next section.

3.1. Compressive strength of Bricks
Sample bricks with varying proportion of earth and fly ash manufactured for test purpose. Laboratory tests of the bricks are conducted for ascertaining the compressive strength and results of which are presented in Table 1.
Table 1. Compressive strength of the bricks.

| Sl. No. | Replacement of fly ash% | Sample No | Dimension (mm) | Max Load (KN) | Comp. Strength N/mm² | Avg. Comp. Strength (N/mm²) |
|---------|-------------------------|-----------|----------------|---------------|-----------------------|----------------------------|
| 1       | 0%                      | 1         | 247 x 118      | 32            | 1.09                  | 1.196                      |
|         |                         | 2         | 250 x 119      | 40            | 1.34                  |                            |
|         |                         | 3         | 250 x 117      | 34            | 1.16                  |                            |
| 2       | 10%                     | 1         | 255 x 127      | 54            | 1.66                  | 1.671                      |
|         |                         | 2         | 255 x 125      | 55            | 1.72                  |                            |
|         |                         | 3         | 255 x 125      | 53            | 1.63                  |                            |
| 3       | 20%                     | 1         | 255 x 127      | 84            | 2.59                  | 2.543                      |
|         |                         | 2         | 255 x 125      | 82            | 2.57                  |                            |
|         |                         | 3         | 255 x 125      | 79            | 2.47                  |                            |
| 4       | 30%                     | 1         | 247 x 120      | 125           | 4.21                  | 4.250                      |
|         |                         | 2         | 250 x 119      | 123           | 4.13                  |                            |
|         |                         | 3         | 250 x 117      | 129           | 4.41                  |                            |
| 5       | 40%                     | 1         | 247 x 118      | 146           | 5.01                  | 4.856                      |
|         |                         | 2         | 250 x 119      | 141           | 4.73                  |                            |
|         |                         | 3         | 255 x 117      | 144           | 4.82                  |                            |
| 6       | 50%                     | 1         | 255 x 127      | 136           | 4.19                  | 4.427                      |
|         |                         | 2         | 255 x 125      | 148           | 4.64                  |                            |
|         |                         | 3         | 255 x 125      | 142           | 4.45                  |                            |
| 7       | 60%                     | 1         | 255 x 125      | 81            | 2.54                  | 2.432                      |
|         |                         | 2         | 254 x 125      | 79            | 2.48                  |                            |
|         |                         | 3         | 255 x 127      | 73            | 2.25                  |                            |

The properties of these unburnt bricks thus produced are mostly dependent of quality of the earth. Unlike the burnt bricks which are produced with selected earth can’t be compared with these as far as strength is concerned. It is therefore difficult assign single value of strength. The strength of unburnt brick masonry mostly depends on properties of these materials, wall thickness and the content of water in it.

Figure 2. % of Fly Ash V/s Compressive strength of Brick

It is an established fact that with the increased water content in the masonry the compressive strength gets reduced. Therefore, it is desirable that the masonry be kept dry after its construction. The water content normally remains higher at the time of construction due to use of wet mortar and get stabilized...
afterwards during iuse. Figure 2 shows the difference of compressive strength of brick with the variation of fly ash content in the bricks. It is found that the compressive strength shows an optimum value at substitution of nearly 40% of fly ash for earth. This may vary from place to place and with quality of materials.

![Figure 2. Difference of compressive strength](image)

**Figure 2.** Difference of compressive strength of brick with the variation of fly ash content in the bricks.

3.2. Effect of varying Relative Humidity on compressive strength
The unburnt mud brick absorbs more amount of moisture from the during higher atmospheric humidity, that may affect its compressive strength. Much study has not been reported regarding the effect of relative humidity on the mud brick masonry. Figure 3 shows a typical test results on this issue. It shows that there is not great change in the strength even in the case of relative humidity varying widely from 30% to 97.5%. A case study of long-term monitoring of a structure built using unburnt clay brickwork in Dalguise, U.K., revealed the relative humidity of the structure was varying within 40% and 65% during the entire year, even in the case of continuous use of bathroom and with shower. It was found that in this case of change of relative humidity the strength only varied nearly 12% for the earth masonry having higher clay content, and about 8% in case of the lower content of clay used for the work.

4. Summary
The adaptability of this brick has been justified considering the various advantages, in spite of some major disadvantages. It can be substitution of burnt clay brick, it can be suitable for poor people who can’t afford for standard bricks for their houses.

4.1. Advantages
- **Safety:** The prime concern for dwelling houses, especially, in remote rural areas is safety from wilds and rough weather, and for household valuables, those lack in the twig walled houses present in tribal areas. But use of these bricks adds to the safety at very lower cost.
- **Strength:** The compressive strength of these bricks are lower than the burnt clay bricks and fly ash bricks, it is higher than the ordinary unburnt mud bricks, which is suitable for walls of the sloped roofed houses and can used low-cost housing due to its cost effectiveness.
- **Aesthetics:** The aesthetics of fly-ash enriched mud bricks are very attractive due to their pleasing colour matching cement, uniformity in sizes and smoother finishing. They are free from cracks and bulges making the masonry better.
- **Thermal conductivity:** The thermal conductivity of these bricks varies from 0.9 to 1.05W/m². Less heat absorption keeps buildings cooler even in summer, hence suitable for varying Indian climates.

![Figure 3. Result of Relative humidity V/s Compressive Strength](image)

**Figure 3.** Result of Relative humidity V/s Compressive Strength [9]
• Durability: Though the laboratory tests for durability of these bricks are not available, examples stated in earlier sections showed high durability and less permeable. The lower permeability of these bricks reduces their efflorescence effect. They are less porous which adsorbs less moisture and thus reduces dampness on the wall. These are also resistant to mild acid attack.

• Insulation for Sound: Masonry constructed with fly ash enriched mud bricks provide adequate insulation to sound for the building.

• Resistance to Fire: Obviously masonry constructed with these bricks are fire resistant as other bricks.

• Friendliness to Environment: As simple technology is adopted for manufacturing these bricks, these are eco-friendly. Avoiding the burning process emissions are automatically avoided and there is no discharge of effluents. Consequently, huge felling of trees is avoided protecting environment which otherwise needed for walling purpose.

• Conservation of Energy: Due to very low consumption of energy due to absence of burning process as in case of conventional bricks huge energy is conserved.

• Cost: The same number of fly ash enriched earthen bricks will cover more areas than clay bricks due to use of thicker mortar. Normally mud mortar is used for the masonry. Quality of water also does not play much importance. It requires less labour. The cost of this brick is approximately 70% lower than burnt clay brick.

4.2. Disadvantages

Major disadvantage of this brick is that it can be safely used for single storied buildings and construction of next storey is not advisable. Use of higher quality fly-ash is advisable for preventing negative effects. The defective construction shall result giving lesser strength and may not be suitable for construction. Bricks having poor quality will have negative impact on buildings. These are ideally suitable for arid zone. Mechanical strength being very low, this can be used by mixing other suitable ingredients. Availability and transportation of the fly ash at the brick manufacturing site may be the major constraint.

5 Conclusion

It can be concluded from the study that the proposed fly ash enriched brick can be used safely in the walls of the tribal houses providing safety and security to the habitant. It is quite safe from strength point of view. Local earth can be used and small quantity of bricks can be manufactured by the local labour at much lower cost. As it does not have the sufficient moisture resistance as burnt clay brick, it should be ensured for using in dry condition during and post construction. This brickwork has a lower strength than conventional brick masonry, it is not recommended to use thin-walled earth masonry. In spite of various advantages, the availability and transportation of fly ash for individual user may the major huddles. Governments/ NGOs should come forward to help in this regard for providing safe houses for tribal. Considering the various criteria described in details these bricks can be a utilized in the tribal houses substituting the present mud plastered twig walled houses.

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