EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF FLY ASH, CEMENT, LIME AND GYPSUM BRICKS

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Abstract: Manufacturing of fly-ash bricks are the very useful alternatives of conventional burnt clay bricks. Manufacturing of clay bricks cause top soil removal, environmental pollution and health problems. To avoid all this environmental threats an attempt is made to manufacture of bricks using fly-ash, gypsum, sand and cement. Mainly fly-ash bricks are made by applying compressive load on the mold. In this research, the effect of brick forming load on the crushing load, water absorption and unit volume weight were studied. For this purpose bricks were prepared for different fly-ash (50% to 65% at 5% increments), gypsum (12% to 3% at 3% decrements), sand (28% to 22% at 2% decrements) and 10% cement. All ingredients were thoroughly mixed and then poured them to a mold of 9.5cm x 4.5cm x 2.75cm. Bricks were made by different forming load and mechanical properties were noted. This research suggested that it was possible to make good quality bricks using fly-ash, gypsum, Lime, sand and cement.

Keywords: Bricks; Fly ash; Lime; Gypsum; Cement; Sand

1. INTRODUCTION

Burnt clay bricks are being used extensively almost throughout India and are perhaps the most important building construction material. But the unlimited use of clay is harmful to society as all the bricks kilns in India depend on good quality clay available from agricultural fields and presuming a weight of 3 kg per brick. The total clay taken out from the agricultural fields per day was over 300 million tonnes for 10,000 Crore bricks. Moreover, clay bricks available in certain regions are poor in quality and costly which have forced engineers to look for better material capable of reducing the cost of construction. At present, India has production capabilities of over 10,000 Crore bricks through around 45,000 local kilns (bhattas), in the unorganized sector. So the use of industrial waste products such as fly ash, for making bricks is ecologically and economically advantageous since apart from saving precious top agricultural soil, it meets the social objective of disposing industrial waste i.e. fly ash which otherwise is a pollutant and a nuisance.

The ever increasing volume of fly ash quantities in the world has not been remotely matched by its utilization. Australia is an example where such utilization has been minimal. The most important and popular use of fly ash in Australia has been in the partial replacement of portland cement. The use of fly ash

in concrete is to the extent of maximum of 25% replacement of Portland cement. This conservatism can be understood in the context of concrete where the ash is mixed raw, and the effects of high volume replacement are still subject to research. It is however not quite justifiable that the brick industry should take similar conservative attitude. Environmental concerns have been raised in some parts of the world where coal is the main power generating resource and where bricks are also the main building material. Such concerns have resulted in legislation to oblige the brick industry to incorporate at least 25% by weight of fly ash and or bottom or pond ash in the brick making mixture if the industry is within 50 km from a coal power generation plant. Some successful ventures have been reported where fly ash was incorporated in the mixture at the rate of 20% to 50%. The engineers now believe that fly ash on its own can be an excellent raw material for brick making. This has now been proven and a patent is taken for the manufacture of bricks from fly ash. The response of the ash to firing temperature at 1000 ºC and beyond can be accurately controlled even in small factories. The potential savings with this approach are many. Savings in production and transportation costs and producing bricks of superior qualities to those of standard clay bricks are in addition to the environmental solution that such venture may bring about.

2. EXPERIMENTAL PROGRAMME

2.1 Material Used

Important physical and chemical properties of materials used in bricks and fly ash are measured in the laboratory. Their characteristics are given in Chapter of Results and Discussions. The objective of determination of these parameters is to identify and classify the fly ash used. These are commonly used parameters to characterize fly ash.

The chemical composition of clay decides its feasibility for manufacturing of bricks. According to Rangwala (2006) (a) if alumina is in excess bricks will shrink and warp, (b) bricks will become brittle if silica is in excess, (c) if lime is in excess the brick will lose its shape and will result in splitting of bricks, (d) excess of iron oxide will change the colour of bricks from dark blue or blackish or yellowish and (e) excess of magnesia will lead to decay of bricks. Presence of alkalis will cause bricks to twist and warp and will absorbs moisture from the atmosphere.

2.1.1 Cement

Ordinary Portland Cement (OPC) of 43 Grade is used for this experimental work. The cement was available in the local market of Bhopal and kept in dry location. Table 4.1 shows the physical properties of OPC which were evaluated from the experimental work.

2.1.2 Fly Ash

Fly ash, otherwise called a flue- ash, is one of the residual substances that is produced during combustion and comprises of the fine particles that are produced by the flue gases. In an industrial context, fly ash generally refers to ash produced during the combustion of coal. Fly ash is generally collected by

electrostatic precipitators or other particulate filtration equipment before the flue gases reach to the chimney of coal-fired power plants and together with bottom ash removed from the base of the furnace is all things considered known as coal ash for this situation.

2.1.3 Sand

Locally available sand was used in this study. The specific gravity of sand was 2.78 and fineness modulus was 2.34.

2.1.4 Gypsum

Hydrated calcium sulphates are called gypsum ($CaSO_4.2H_2O$). Basically, gypsum doesn't create any adverse effect to the environment, human beings, animals, and plants. It is moderately water soluble. Gypsum blocks are used like concrete blocks in building construction. Gypsum was also collected from work site to do the research.

2.1.4 Water

Locally available water has been used in brick manufacturing.

3. MIXING OF RAW MATERIALS

For the present study, blends of fly ash, cement, lime and gypsum are used. Mr Satish Nannavre a brick manufacturer from "SS Bricks" has helped in the present work. His moulds and kilns were used. The weight of sand, fly ash, cement and gypsum required for various blends is determined as: follows. One moulded fresh brick is taken. It is oven dried. Weight of dry brick is determined, which is equivalent of the sand required to prepare one brick. Then various proportions of fly ash, cement, lime and gypsum are used.

Raw materials including fly ash, gypsum, and cement were prepared for mixing to make bricks in certain proportion of weight. For each proportion, the required materials were calculated correctly and the materials were weighted properly. The percentages of materials required for fly-ash bricks and weight of the materials are given in table no 1 according to brick size = 190 x 90 x 90 mm

Table 1: Mixing proportion of raw materials and brick sample no in % for fly ash-gypsum proportion

Brick sample no.	Fly ash (%)	Cement (%)	Sand (%)	Gypsum (%)
1	50	10	28	12
2	55	10	26	9
3	60	10	24	6
4	65	10	22	3

Table 2: Mixing proportion of raw materials and brick sample no in gm for fly ash-gypsum proportion

Brick sample no.	Fly ash (gm)	Cement (gm)	Sand (gm)	Gypsum (gm)
1	119	35	88	31
2	131	35	82	24
3	143	35	76	16
4	155	35	70	8

Table 3: Mixing proportion of raw materials and brick sample in (%) for fly ash- Lime proportion

Brick sample no.	Fly ash (%)	Lime (%)	Sand (%)	Gypsum (%)
1	50	10	28	12
2	55	10	26	9
3	60	10	24	6
4	65	10	22	3

4. RESULTS AND DISCUSSIONS

Based upon the methodology described for brick manufacturing and their laboratory testing, the various properties of the bricks with various proportions are determined. They are presented here. The interpretation based upon these results is also presented.

4.1 Compressive Strength Testing Of Bricks

It is observed that there is increase in the compressive strength of bricks with addition of fly ash from 50% to 65%. There after sand 15%, fly ash 55%, cement 10% and gypsum 4% trend shows somewhat decreasing. Therefore, it is clear that fly ash addition up to 55% by weight of sand may be taken as optimum proportion to enhance the dry compressive strength of brick. Addition of more fly ash has detrimental effect on the strength. This is attributed to the fact that small proportion of fly ash fills the void in clay matrix; but at higher proportion it reduces the strength since ash acts as a non-reactive component in the matrix. Similar results are obtained for dry as well as wet compressive strength of the bricks.

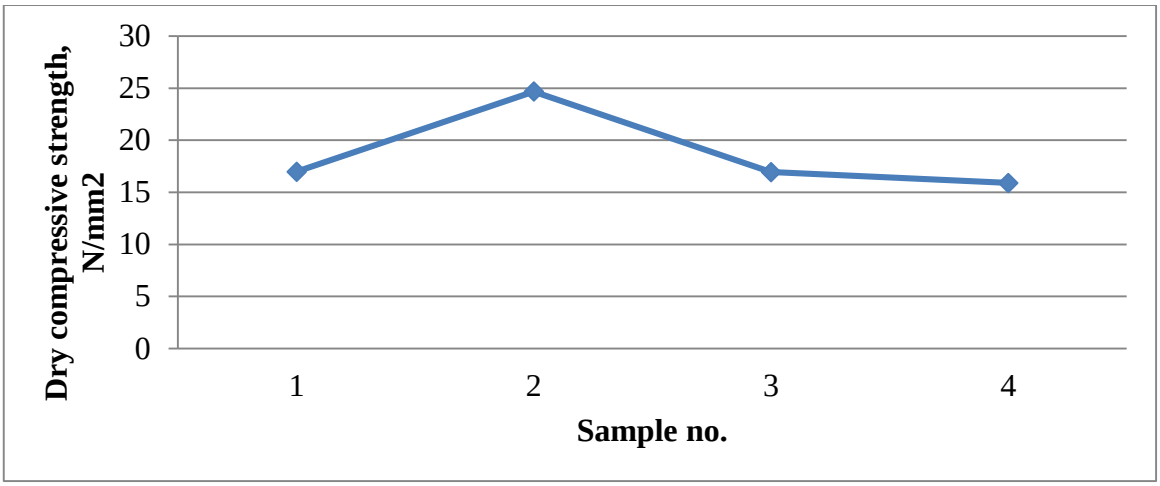

Fig. 1: Dry compressive strengths of fly ash- gypsum bricks

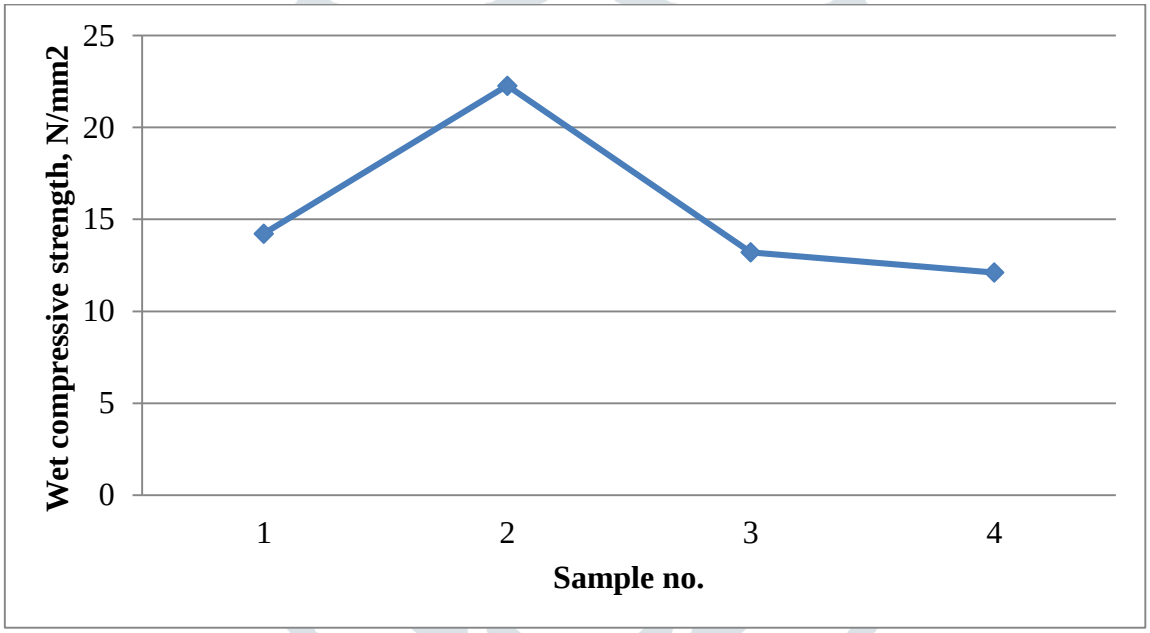

Fig. 2: Wet compressive strengths of fly ash- gypsum bricks

Comparing dry and wet bricks compressive strength values show that dry compressive strength is more. Suggesting that bricks with 55% fly ash can be used under dry and wet conditions since the values are more than the minimum required. The effect may be attributed to the reason that addition of fly ash fills the micro pores of clay matrix and makes it stronger.

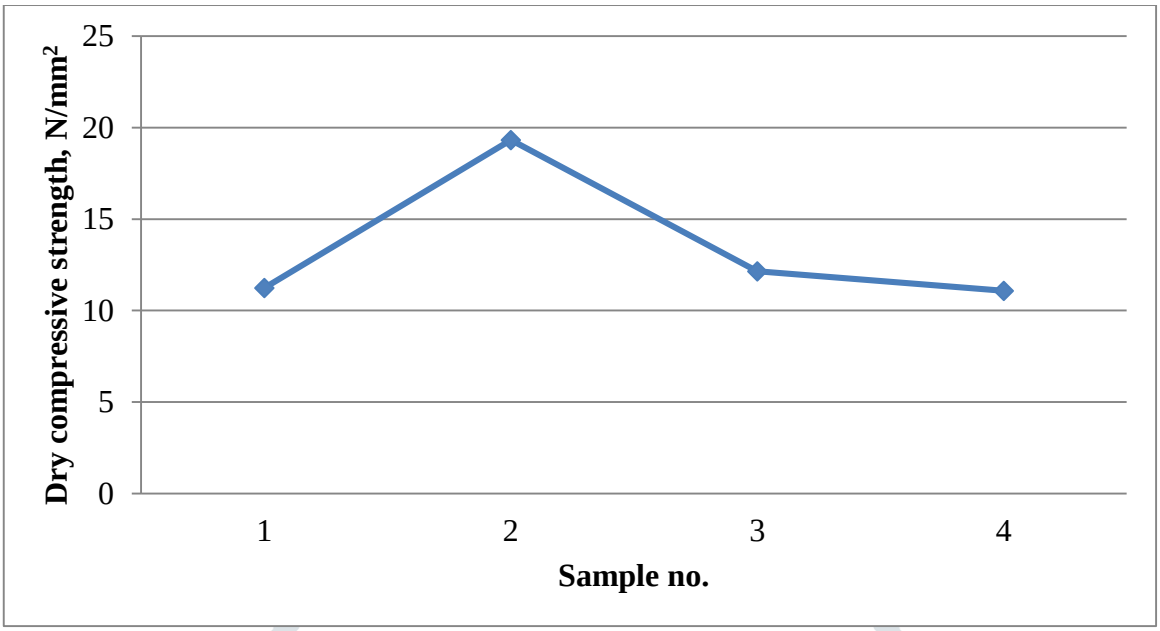

Fig. 3: Dry compressive strengths of fly ash- lime bricks

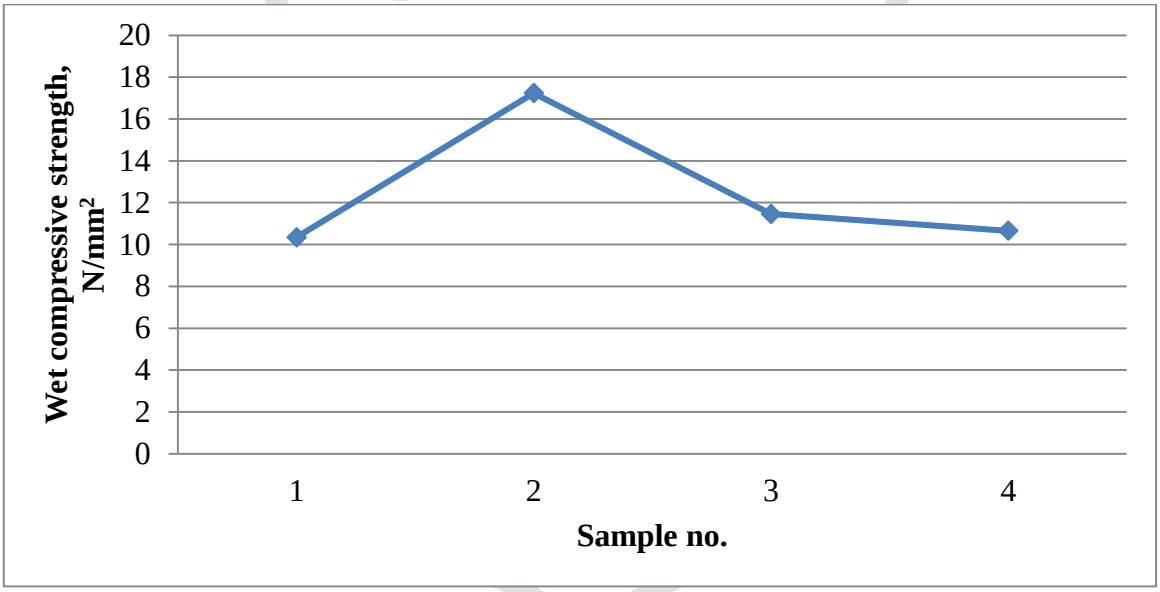

Fig. 4: Wet compressive strengths of fly ash- lime bricks

Results show that addition of fly ash and lime up in any proportion has a detrimental effect on the compressive strength of brick in dry as well as in wet conditions. None of the proportion (blend) has maximum compressive strength than fly ash- gypsum bricks.

4.2 *Water Absorption Testing Of Bricks*

Addition of fly ash with lime has no way benefitted to reduce the water absorption. Rather it has enhanced the water absorption. It might be due to the fact that addition of lime leads to micro-crack development in clay bricks (Rangwala, 2006). This fact may be attributed to the reduced compressive strength and increased water absorption of bricks. Results show that higher proportions of fly ash have increased the water

absorption obviously due to poor binding. Addition of fly ash with lime has no way benefitted to reduce the water absorption. Rather it has enhanced the water absorption. It might be due to the fact that addition of lime leads to micro-crack development in clay bricks (Rangwala, 2006). This fact may be attributed to the reduced compressive strength and increased water absorption of lime bricks.

4.3 Finishing Of Bricks

In case of clay bricks, finishing in terms of well-defined edges, smooth surfaces and texture are important. Especially when the bricks are to be used for exterior parts of the building without plastering for some special architectural purpose. The finishing may get disturbed during burning in kilns which may be due to the chemical interaction of constituents of the bricks. This aspect is not important for lime-sand bricks which hardened by the chemical reaction of hydration. Thus the finishing of bricks using various blends has been observed and is recorded here in table 4 and 5 respectively.

Table 4: General appearance of fly ash- gypsum bricks

Sample	Size	Texture	Edges
1	19 x 9 x 9 cm	Smooth	Sharp and regular
2	19 x 9 x 9 cm	Smooth	Sharp and regular
3	19 x 9 x 9 cm	Slightly rough	Slightly irregular
4	19 x 9 x 9 cm	Slightly rough	Slightly irregular

It is evident that addition of fly ash has not affected the finishing of bricks. Addition of small proportion of gypsum has also not affected finishing upto 7.5% lime, but higher proportion of fly ash has adversely affected the finishing of bricks and witnessed development of white patches on surface and has affected the color with more than 4% gypsum. The smoothness and sharpness of edge is also disturbed due to content of gypsum because of non-binding of material. It is a well-known phenomenon that excesses of lime damages the finishing of bricks (Rangwala, 2006).

Table 5: General appearance of fly ash- lime bricks

Sample	Size	Texture	Edges
1	19 x 9 x 9 cm	Smooth	Sharp and regular

2	19 x 9 x 9 cm	Smooth	Sharp and regular
3	19 x 9 x 9 cm	Slightly rough	Slightly irregular
4	19 x 9 x 9 cm	Slightly rough	Slightly irregular

It is evident that addition of fly ash has not affected the finishing of bricks. Addition of small proportion of lime has also not affected finishing upto 55% lime, but higher proportion of fly ash has adversely affected the finishing of bricks and witnessed development of white patches on surface and has affected the color with more than % lime. The smoothness and sharpness of edge is also disturbed due to content of lime because of non-binding of material. It is a well-known phenomenon that excesses of lime damages the finishing of bricks (Rangwala, 2006).

4.4 Efflorescence in Bricks

Efflorescence refers to the white spot appearance on brick surfaces due to excess of free lime in the bricks. This has detrimental effect on the appearance and makes the bricks unsuitable for use in exterior surfaces. The efflorescence is measured for clay-fly ash and clay-fly ash-lime bricks and is presented in table 6 and 7 respectively.

Table 6: Efflorescence in fly ash- gypsum bricks

Brick sample no.	Fly ash (%)	Cement (%)	Sand (%)	Gypsum (%)	Efflorescence
1	50	10	15	2	Nil
2	55	10	20	4	Nil
3	60	10	25	6	Slight
4	65	10	30	8	Slight

Table 7: Efflorescence in fly ash- lime bricks

Brick sample no.	Fly ash (%)	Lime (%)	Sand (%)	Gypsum (%)	Efflorescence
1	50	10	15	2	Nil
2	55	10	20	4	Slight
3	60	10	25	6	Moderate

4	65	10	30	8	Heavy

The Efflorescence test of flyash –gypsum and fly ash-lime bricks were compared. In this test, for all blends of gypsum-fly ash bricks, it shows negligible degree of efflorescence. With addition of lime the efflorescence appears. It has increased with increase in proportion of lime. This is due to the presence of free salts (especially lime) in the brick. Efflorescence is an undesirable property for bricks. Due to this the external surface appearance becomes spoiled. It makes plastering difficult and after due course of time peeling of plaster takes place (Rangwala, 2006).

4.5 Soundness Test

In this test, we have checked the bricks to check its soundness in case of the sudden impact. The two bricks are taken and made struck with each other. Brick of good quality should not break and produce a ringing sound. Ringing sound of brick goes on decreasing with increase in the amount of lime content. Ringing sound is excellent for sample (fly ash- gypsum) brick two. Ringing sound for brick sample (fly ash- lime) two found least. This is due to increased porosity of the bricks.

4.6 Hardness Test

Scratch is made on the brick surface with the help of finger nail. If no impression on the surface, the brick is sufficiently hard. First two samples show good results and last two samples do not show good results in case of fly ash – gypsum and fly ash- lime bricks.

4.7 Economic Analysis

After all the tests over the ricks, we did analysis to the cost of the bricks. The analysis for the cost of the brick is done on the basis of the four factors.

1. Price of sand
2. Price of lime
3. Price of fly ash
4. Price of gypsum
5. Price of cement
6. Labour cost

According to the mix design calculation we achieved the weight of water, gypsum, lime, cement, sand and fly ash for bricks. As the water is largely available in India, its costs can therefore be neglected. Current study shows that at fly ash 55%, 10% lime, 20% sand and gypsum 4% can be used for making fly ash-gypsum bricks.

As can be seen from cost analysis, the cost of fly ash – lime brick becomes cheaper by 8.5 % than fly ash – gypsum brick.

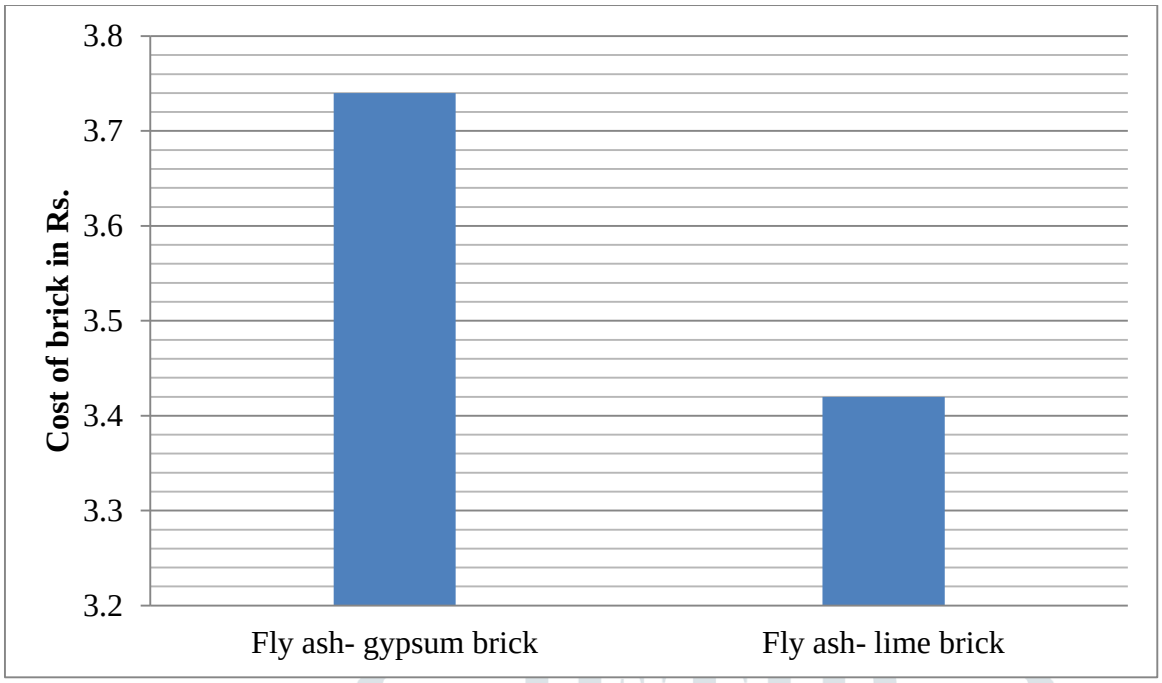

Fig. 5: Cost analysis

5. CONCLUSION

The disposing of fly ash has become a major global environmental concern as its production rate is rapidly increasing. Scientists are exploring various aspects of reuse and disposal of fly ash. In India, off late, demand for energy that too financially viable in an era of economic crisis, has increased the number of Thermal Power Generation Plants.

The present work has proposed to re-use the fly ash for brick manufacturing. The optimum proportion of fly ash to enhance the brick properties has been determined. The cost of fly ash-gypsum blended bricks is estimated and is compared with the same of fly ash- lime bricks. The conclusions are highlighted as below:

1. It is observed that addition of fly ash, cement, gypsum and sand up to certain proportion (Fly ash- 55%, lime- 10%, sand- 20% and gypsum-4%) enhances the dry and wet compressive strength of bricks. Further addition leads to the reduction in strength.
2. It is observed that addition of fly ash, lime, gypsum and sand up to certain proportion (Fly ash- 55%, lime- 10%, sand- 20% and gypsum-4%) enhances the dry and wet compressive strength of bricks. Further addition leads to the reduction in strength.
3. Fly ash- gypsum bricks have higher strength as compared to the fly ash- lime bricks.
4. It can be seen that fly ash addition of fly ash in bricks has resulted into slight reduction in water absorption. This may be attributed to the better filling of pore openings due to fly ash. However higher proportions of fly ash has increased the water absorption obviously due to poor binding. Addition of fly ash with lime has no way benefitted to reduce the water absorption. Rather it has enhanced the water absorption.

5. It might be due to the fact that addition of lime leads to micro-crack development in clay bricks. This fact may be attributed to the reduced compressive strength and increased water absorption of bricks.
6. Results show that higher proportions of fly ash have increased the water absorption obviously due to poor binding. Addition of fly ash with lime has no way benefitted to reduce the water absorption. Rather it has enhanced the water absorption.
7. The workmanship of bricks (edges, surface texture and colour of the bricks) is not badly affected due to the addition of gypsum.
8. The workmanship of bricks is badly affected due to the addition of lime.
9. The fly ash has not caused any efflorescence in the bricks.
10. The lime has resulted into severe efflorescence in the bricks.
11. The manufacturing cost of bricks is estimated. It is observed that fly ash blended bricks are economical as compared to the plain clay bricks.

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