Experimentation on the usage of Fly Ash in Brick Formation

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Abstract

In every year, there are millions of tonnes of fly ash produced from the thermal power plant. These fly ashes are already utilized to make economical Fly Ash bricks. But, these bricks are rarely used in house wall due to lower compressive strength as compare to burnt clay bricks. Also, the bonding strength in between mortar and fly ash bricks is not that strong enough to make it durable. Due to these reasons, it lowers the priority to choose a fly ash bricks. A feasibility study was undertaken to production of fly ash-based bricks with clay, wood ash, lime, gypsum and to increase the compressive strength of the bricks as well as bonding strength in between the bricks and mortar. The mortar composition was modified to make it more efficient. The compressive strength of the bricks, shear in between the bricks and mortar was carried out. It is expected that the compressive strength of the bricks will increase and the bonding strength in between the bricks and mortar will improve. Thus, their property will be modified.

Introduction

Fly Ash: An overview

In the thermal power plant, coal is used to produce energy. So, during production these energies, one new exhaust materials formed. This is fly ash. It is obtained as by-product from burning crumbled coal. The fly ash is in the form of fine powder. Mostly, the fly ashes are captured by an electrostatic precipitator or other filtration equipment, before flue gases move out from the chimneys. Depending upon the source and form of the coal being burned, fly ash contains different component. But all fly ash contains some amount of SiO_2(Silicon Dioxide), Al_2O_3(Aluminium Oxide) and CaO (Calcium Oxide). [w3, w4]

Fig 1: Fly Ash Powder [F1]

Fly ash has one unique property, it is pozzolanic property. This means when these mixed with lime and water, it forms a Portland cement like compound. As fly ashes are waste material from the thermal power plant, so it is free of cost. But there are toxic materials present in the fly ash particle, which are harmful for human health as well as environment. To solve these issues, fly ashes are used in different application so that waste materials can be used in some productive field due to its pozzolanic property. [w5, w6]

Properties of Fly ash

Fly ash is used for wide range of application such as manufacture of bricks, manufacture of cement, manufacture of blocks, tiles etc. The pozzolanic property of fly ash help to implement concrete or bricks when lime and water are added to it. [w5, w7]

Fineness: Fly ash contain very small particle mostly made up of some clear glass spheres. Thus, whenever a product is made from this, it will be highly dense. Thus, the strength will be increase. [w8]

Pozzolan Property: The pozzolan property means when water and lime is added to the fly ash, it reacts and forms a cementitious product. With increase in time, the fly ash gain strength. The compressive strength of fly ash is less, but it can be increase by adding some materials like lime, gypsum etc. [w8]

Geo-technical property: It makes fly ash a good substitute of soil as well as the presence of desired Silica, Alumina, iron oxide etc make it suitable for different sintered application. [w8]

The following tables will provide the different properties of fly ash as well as different chemical composition of the fly ash.

Physical Properties:

Parameters	Fly Ash
Bulk Density(gm/cc)	0.9-1.3
Specific Gravity	1.6-2.6
Plasticity	Lower or non-plastic
Shrinkage limit (volume stability)	Higher
Grain size	Major fine sand/silt and small percent of clay size particles
Clay(Percent)	Negligible
Free Swell Index	Very low
Classification(texture)	Sandy Silt to Silty loam
Water holding capacity(WHC)(Percent)	40-60
Porosity(Percent)	30-65
Surface area(m2/kg)	500-5000
Lime reactivity (MPa)	1-8

Chemical Composition:

Compounds	% Amount
SiO_2	38-63
Al_2O_3	27-44
TiO_2	0.4-1.8
Fe_2O_3	3.3-6.4
MgO	0.01-0.5
CaO	0.2-8
K_2O	0.04-0.9
Na_2O	0.07-0.43
pH	6-8

The chemical composition and properties may be vary depending upon the type of fly ash. [w8]

Mortar: An overview

To combine building blocks together, mortar is used. Mortar acts as a binder in between two. These building blocks can be bricks, stones or concrete masonry unit. The mortar doesn't only bind them together, but also fill as well as seal the gaps between these two. Now a day it is also use as a decorative colour in the wall. [w15, w16]

In generally, mortar is a mixture of sand, water and a binder. The binder can be different according to the type of use. In mostly, the binder is cement. But sometimes, different

Fig 2: Cement Mortar [F4]

binders like lime, recycled aggregate, etc are used. For house wall bricks, the ratio of the proportion of cement, sand and lime are 1:5:2. Water is added as desired. The ratio of the proportion is varied according to the use of the mortar. [w15, w16]

Objective of the Proposed Study of Fly Ash in Brick

The fly ash particles have pozzolan property. So, it will be a great job if we use these materials to make an effective product. The objectives of this study are:

- To make a fly ash brick with optimum composition to obtain high compressive strength.
- To obtain strong bond in between mortar and bricks by changing the composition of the mortar.
- To make a cost effective durable fly ash bricks.

- To make the bricks with high shear and tensile strength.
- To make a light weight fly ash brick, so that the total weight of bricks in a building is minimised.

Materials, Equipment's and Experimental Setup

Material for bricks

The study to find the materials to increase the strength of the fly ash bricks has been done. The materials required for making the bricks are Fly Ash, Wood Ash, Clay Powder, Lime, Gypsum. There are total 5 compositions of these material is decided to make bricks and do the testing. These compositions are:

Number/Name	Fly Ash	Wood Ash	Clay Powder	Lime	Gypsum
1	50%	10%	15%	10%	15%
2	55%	10%	15%	15%	5%
3	50%	20%	15%	5%	10%
4	50%	5%	10%	20%	15%
5	65%	0	0	25%	10%

Material for mortar

The bonding strength of mortar with fly ash brick is not that good. Due to this, breakage in the wall, or many such type of issues developed. Thus, it is important to increase the bonding strength between mortar and the fly ash brick. So, the composition of the mortar has been redefined as follows:

Number/Name	Cement[Ratio]	Sand[Ratio]	Lime[Ratio]
M-1	1	5	0
M-2	1	5	2

Experimental Setup

Parameters

The dimensions of the bricks are: 230mm × 110mm × 70mm. The weight of one bricks is 2.6 KG. For one composition 6 bricks prepared. We have 5 compositions, so total 30 bricks. 3 bricks from each composition were kept dried for 14 days (curing time) and others 3 were kept for 28 days (curing time).

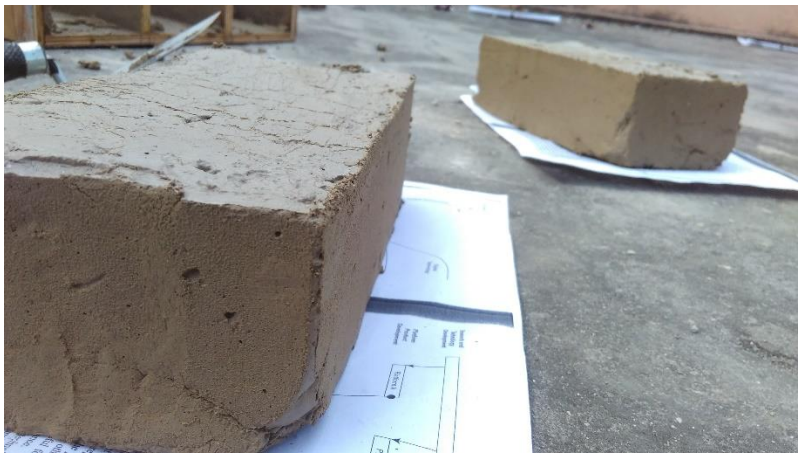

Fig 19: Bricks during preparing

After 2 days of moulding, the bricks are taken out from the mould and it looks like this as shown in the fig. These bricks are kept for dry as desired curing time for particular days.

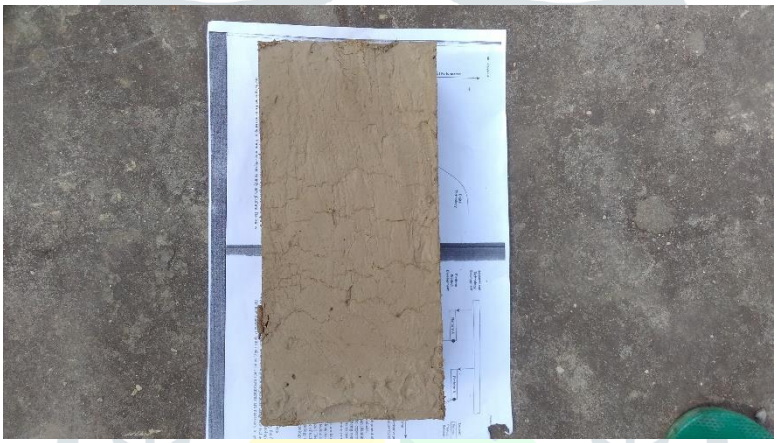

Fig 20: Wet Brick

Result and Discussion

Compression Test

The compressive strength of the fly ash bricks was carried out on compression testing machine in the civil laboratory. This test indicates how much the particles of the fly ash bricks hold together to make one sample. Normally, the conventional bricks have compressive strength about 11-15 N/mm2. Total 10 sample of fly ash bricks was used to check the compressive strength. 2 bricks from each composition with different curing time was used. Rest 20 samples were used to check the shear strength in the UTM.

The result of the compressive test was as follows:

Composition	Curing Time	Peak Load(KN)	Area(mm2)	Strength(N/mm2)
C-1	14 days	101.5	230×110=25300	4.01
	28 days	125.7	230×110=25300	4.94
C-2	14 days	81.7	230×110=25300	3.22

	28 days	99.3	230×110=25300	3.92
C-3	14 days	90.1	230×110=25300	3.56
	28 days	111.3	230×110=25300	4.39
C-4	14 days	133.9	230×110=25300	5.29
	28 days	151.7	230×110=25300	5.99
C-5	14 days	78.9	230×110=25300	3.11
	28 days	95.3	230×110=25300	3.76

It is important to mention that when the curing time increases, the compressive strength of the brick increases. Thus, the compressive strength from the result showed same behaviour. The line graph for the result of compressive strength has shown below. C-1, C-2, so on indicate the composition number from 1 to 5 as mentioned earlier. Area is that surface where the loads was applied. Thus, compressive strength was calculated by dividing the peak loads by surface area of the brick.

When only fly ash with lime and gypsum was used, the compressive strength was least(C-5). The results are as follows:

- When the curing time increases, the compressive strength of the bricks increases. This is because of fly ash. It has ability to increase its strength over time. Thus, if curing time increased to 48 days or higher time, the strength will be way higher than earlier.
- The C-4 has highest compressive strength as compared to others. So, it can be confirmed that when amount of binders e.g. lime and gypsum increase to the composition and amount of fly ash decreases, then the materials has stronger bonds leads to high compressive strength.
- In C-2, the compressive strength was less because of high fly ash and less gypsum. In C-3, the amount of binders (lime and gypsum) were less, so compressive strength was less. In C-5, the compressive strength is the least because of high amount of fly ash and no amount of clay and wood ash on it.

Shear Test

Composition	Curing Time	Mortar Composition	Force Applied(kg-f)	Loads(KN)
C-1	14 days	M-1	495	4.85
	28 days	M-1	503	4.92
C-2	14 days	M-1	488	4.78
	28 days	M-1	492	4.8
C-3	14 days	M-1	497	4.87
	28 days	M-2	536	5.25
C-4	14 days	M-2	528	5.17
	28 days	M-2	540	5.29

C-5	14 days	M-2	517	5.06
	28 days	M-2	529	5.18

The shear test was carried out in the Universal Testing Machine(UTM). There were 10 samples for doing the shear test. In the 5 samples, mortar composition with M-1 was used, and in other 5 mortar composition M-2 was used. In the M-2, lime was used with cement and sand. Thus lime increases the bonding strength in between the bricks. That's why M-2 has high strength as compared to M-1 mortar composition. In the above table, the values were written after obtaining those in the lab.

When other binding material lime is added to it, the strength increases. The curing time for mortar was taken as 5 days only. As there was no fly ash, so the testing of different samples with different curing time was not considered. The results are as follows:

- The bricks composition normally doesn't matter the strength of the mortar. But still there is a slight different in the strength values. The different is not that huge. It was found that the bricks with 28 days curing time has little bit higher binding strength as compared to 14 days curing ones.
- When the mortar composition was changed with M-2, the binding strength was increased. This is due to the addition of lime, which acts as a binder to bond the brick together. The binding strength may increase a lot if other binding materials add to it.

  There are some good materials, which can increase the strength of bricks and mortar e.g. Glass Fibre, Carbon fibre etc. But, it will increase the cost. So, if the cost per brick will be high, it will no longer cost-effective product. That's why these materials were didn't considered.

Conclusion

It is finalized that the waste material: Fly ash can be used to make a high strength, low cost and light weight bricks. Though the strength of the fly ash bricks is usually lower than the conventional bricks, but by adding some binders, it can be improved.

The bonding strength in between fly ash bricks and the mortar is not that good. Due to which cracking of wall appears. It is finalized that the bonding strength can be improved by using binding materials in the mortar.

The final conclusions are listed below:

- When 50% Fly ash, 5% Wood ash and 10% clay were used with 20% lime and 15% gypsum, the compressive strength of the brick was found as highest. The lime and gypsum work as a binder. Thus, it creates a strong bond in between the particles. That's why this particular composition has highest compressive strength.
- When the addition of fly ash increases, we have found that the compressive strength of the bricks decreases. To increase the compressive strength, other admixture was used.

- Curing time has direct impact on compressive strength. When the curing time increases, the compressive strength of the bricks containing fly ash increases. This is because of fly ash. It has ability to gain strength over time.
- More wood ash, more compressive strength. Clay helps to gain strength shortly. The binders lime and gypsum helps to bind every particle strongly to make high strength bricks.
- When lime is added to mortar composition, the binding strength increases. But, the cost of the mortar will increase a little bit.

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