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Stresses in Fly Ash Brick using Different Proportion of Lime, Cement, Gypsum, Sand and Stone Dust

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Abstract*: The dead load of any structure varies depending on the type of bricks and its weight. Due to the increased numbers of high rise buildings, lighter materials than normal clay bricks are preferred. Fly-ash bricks are more popular presently since it weighs 28% less than clay bricks as well as shows higher strength .The strength is higher by 25% than commonly available bricks. Besides strength other characteristics such as absorption capacity, modulus of rupture, initial rate of absorption, durability and bond strength. The values thus obtained from the test shows excellent results as compared to that of brick clay. The latest type of bricks has been given the name fly-ash bricks. The key objective of the paper is to study the strength of fly ash brick using different material proportion and also to improve the compressive stress and also to determine the durability along with stability of the bricks.

Keywords: bricks fly ash, compressive strength, environment, lightweight, infrastructure, water absorption, high performance, economy, durability.

I. INTRODUCTION

The constituents that a fly ash brick consists are fly ash, sand, lime, stone dust and gypsum. The fly ash bricks being lighter and stronger than ordinary burnt clay bricks can be easily used for the purposes of construction. Fly ash is a waste material that gets accumulated in a large volume near the industries which causes environmental pollution. Thus the use of fly ash as raw materials will not only grant a productive disposal of the fly ash but also help to mitigate the pollution to a great extent. Henry et.al (2005) intended to provide a solution to the fly ash disposal problem by utilizing the fly ash produced from different sources. Moreover, the heat cement emits due to its hydration is liable for greater percentage of global warming. Henry Liu et.al (2009) developed bricks made of pure fly ash which do not require high kiln temperature similar to that in the production of clay bricks.

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The long term tests conducted on the fly ash bricks resulted in higher strength due to the process of carbonation which is caused by the absorption of carbon-di-oxide from the atmosphere.
This also results in the reduction of global warming. The cement industry emits a huge amount of CO_2 along with high energy consumption produce cement. To reduce these effects, the pozzolanic materials such as fly ash may be used by replacing lime. In this current work the attempt has made toward find the optimum mix proportions so as to obtain highest compressive strength of latest fly-ash brick. These bricks made with fly-ash are prepared for different ratios of ingredients using hydride lime or slug lime and Gypsum as binder material and 28 days compressive strengths are calculated. Fly ash based bricks are prepared for different ratios of ingredients using cement as binder material and 28 days compressive strengths are calculated. The optimum quantity of fly ash that is needed to be mixed with the soil while to achieve better properties than clay bricks is an important factor that needs to be determined. Krishnamurthy et.al (1994) investigated the optimum quantity of fly-ash that must to be added to soil for the production of high-quality bricks. The strength observed by replacing 50% fly ash ranged from 9.8 N/mm^2 to 11.5 N/mm^2. Though for country brick the strength obtained was only 3.5 N/mm^2 which didn't increase even with the increase in the percentage of fly ash. Obadakayaliet.al (2005) compared the properties of fly ash bricks to the clay bricks. The produced fly-ash bricks were not only 28% lighter than clay bricks although it possess 40MPa or higher compressive strength. The compressive strength of the fly ash bricks is found to be 24% greater than that of any good quality brick. Again the fly ash bricks possess 28% lesser density than the normal clay bricks. Mei-In Chou and Shang Fu Chou (2004) reported that the paving bricks with 20 % volume of fly ash and building bricks containing fly ash upto 40% were produced. Dayal (1995) described that the fly ash has relatively a lesser amount of compressibility and superior shear strength properties and also mentioned about the usage of fly ash in various modes. Fly-ash based bricks are categorised in two types, non-calcinite bricks (fly ash mix with bonding agent) along with calcinite bricks (fly-ash clay brick). Percentage of fly ash mixed varied from 10% to 80% and tested for their suitability and 40% by weight of local silty soil found as the optimum percentage of fly ash. Kute and Deodhar (2003) also found suitable alternative methods of brick manufacturing process to the existing materials.

They tested the properties exhibited by fly ash bricks by addition of different proportions of fly ash and baking them at different temperature. The result of the test showed that the compressive strength along with the water absorption were improved by adding 40% of fly ash (by weight) along with burning at 1000^{o} C. Mandal and Majumdar (2009) studied the outcome of a variety of factors such as ratio of water and fly ash, temperature of curing, concentration of alkali activators and different time period of curing on the compressive strength of mortar such as 3, 7 and 28 days. 48 hours curing at about 60-70^{o}C was optimum for the present scenario. Moinul Islam and Saiful Islam (2010) studied both the parameters such as the optimum replacement volume of cement with fly ash and also the environmental of the cement. The fly ash being cheaply available, when used in high volume replacing cement in any construction work reduces the heat of hydration due to cement thus making the project economical as well as environment friendly.

II. INGREDIENTS OF FLY ASH BRICK

The major ingredients required to produce a fly ash brick are fly ash, gypsum and quarry dust with binding material lime and/or cement. Figure 1 shows the flowchart ingredients.

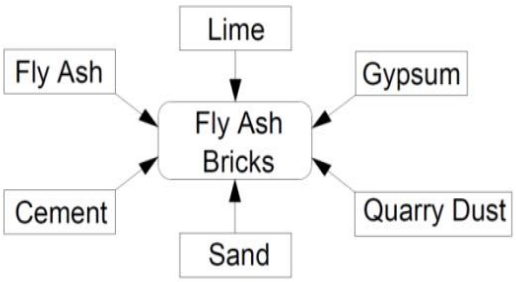

Figure 1: Flowchart representing the composition of Fly Ash brick.

A.Chemical Composition of Fly Ash Brick*:*

The chemical composition of fly ash bricks are provided in the table I.

Table I: Chemical composition of Indian fly ash

Chemical Composition	Percentage %
Silica (SiO_2)	38 - 63
Alumina (Al_2O_3)	27 - 44
Titanium dioxide (TiO_2)	0.4 - 1.8
Iron Oxide (Fe_2O_3)	3.3 – 6.4
Manganese oxide (MnO)	0 – 0.5
Calcium Oxide (CaO)	0.2 - 8
Magnesium Oxide (MgO)	0.01 – 0.5
Sodium Oxide (Na_2O)	0.07 – 0.43
Loss of Ignition (LOI)	0.2 – 3.4

B. Experimental properties of materials:

The materials used to prepare the fly ash bricks of dimensions 200mm x 100mm and 100mmare tested thoroughly to determine their properties. Sieve analysis is carried out to determine the grain size distribution of the sand. The result shows that the sand has 1% gravel along with 15.4% coarse sand, 27.4% medium sand and 53.2% fine sand. The sand also has a small percentage of silt clay, about 3%. Sand has been tested for its bulking properties and it was found that the volume of the sand has increased by 3% after 1 hour as well as 24 hours. Average moisture content of fly ash by oven dry method was 0.3. The consistency was determined using the Vicat apparatus. A mixture of 400 gm cement and 136 ml of water was penetrated to a depth of 6 mm. Similar amount of cement was mixed with 140 ml of water for the determination the initial and final setting time of the cement. The determined outcome showed an initial setting time of 87 min and a final setting time of 3 hours and 5 min. The 14 days strength and 24 days strength of the cement are 15.13 MPa and 19.46 MPa respectively. Table II shows the specific gravity of the materials as determined by Pycnometer test. Different proportions of materials are mixed together to prepare different grades of bricks and their strength is checked. The proportions in which the fly ash, stone dust, lime, gypsum and cement are mixed are provided in table III. This process is carried out to determine the optimum quantity of fly ash that provides the highest strength.

III. EXPERIMENT RESULT

Fly ash bricks are prepared using seven different proportions. Among these seven proportions, four different proportions were prepared without cement content but adding hydride lime and gypsum as shown in table III. Three bricks of each proportion were made and tested to check their compressive strength. Table V shows the peak load and stresses as achieved by testing these bricks made without cement. From the different figures shown below, it is evident that the stress in the bricks increases linearly with the increase in load. From Figure 2 it can be observed that the maximum stress and minimum stress generated are 6 MPa and 5.25 MPa respectively by combination of fly-ash, quarry dust, hydride lime and gypsum in the proportion of 45:40:10:5. The average stress being 5.61 MPa. Figure 3 shows that when the stone dust is decreased to 22.5% and fly ash is increased to 62.5 % without any change in the amount of hydride lime and gypsum, the average stress generated is increased to 6.90 MPa. The graph plotted in Figure 4 shows that if the stone dust and fly ash and gypsum are kept approximately of similar proportion to that in experiment 2, the load carrying capacity might be increased by increasing the amount of Hydride lime upto 15 percent. The maximum stress generated in this case is increased to 9.38MPa. It is found that if the hydride lime in increased (experiment 4), average stress generated is increased to 10.40 MPa (Fig. 5). Unlike the above experiments (No. 1 to 4), the hydride lime and Gypsum is removed in the experiment 5 to 6 and is replaced with cement. It is observed from experiment 5 using Fly ash, stone dust, and cement in the proportion of 47.2:42.5:10, a mean strength of 8.89 MPa is obtained. By increasing a minute amount of fly ash and decreasing the amount of stone dust without any change in cement, the mean strength is increased to 9.15 MPa. If the percentage of fly ash is increased to 60% reducing the percentage of sand/stone dust to 20 % and a small percentage of cement is reduced, the stress carrying capacity of the brick is increased to 11.04 Mpa.

Table II: Specific gravity of fly-ash, cement, sand, hydride lime, gypsum

Materials	Fly-ash	Cement	Stonedust /Sand	Hydride Lime	Gypsum
Specific Gravity	2.125	3.3	2.7	2.427	2.7

Table III: Material ratio for brick test without cement content

Material Name	Ratio of Material (%)			
	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Fly Ash	45	62.5	60	50
Sand/Stone Dust	40	22.5	20	25
Hydride lime	10	10	15	20
Gypsum	5	5	5	5
Cement	0	0	0	0

Table IV: Material ratio for brick test with cement content

Material Name	Ratio of Material (%)		
	Experiment 5	Experiment 6	Experiment 7
Fly Ash	47.5	50	60
Sand/Stone Dust	42.5	40	32
Hydride lime	0	0	0
Gypsum	0	0	0
Cement	10	10	8

Table V: Fly ash brick (without Cement) load test data

	Experiment 1			Experiment 2			Experiment 3			Experiment 4		
	1	2	3	1	2	3	1	2	3	1	2	3
Peak Load (KN)	120	112	105	135	142	137	175	199	189	205	212	207
Stress (N/mm^2)	6	5.6	5.25	6.75	7.1	6.85	8.75	9.95	9.45	10.25	10.60	10.35
Average Stress (N/mm^2)	5.61			6.90			9.38			10.40		

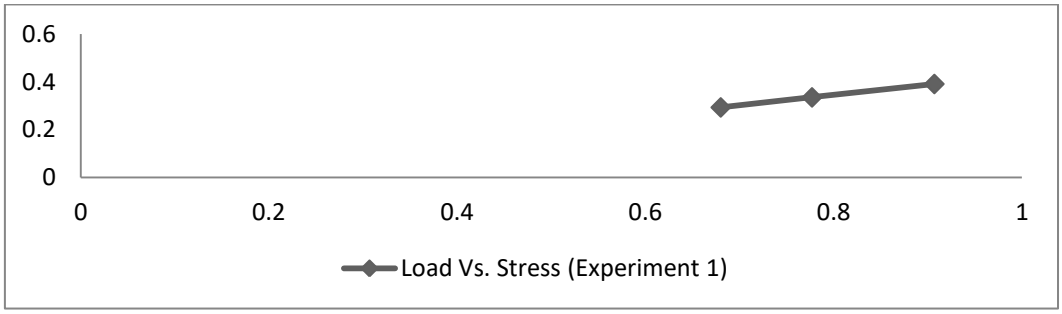

Figure 2: Load Vs Stress graph for experiment 1

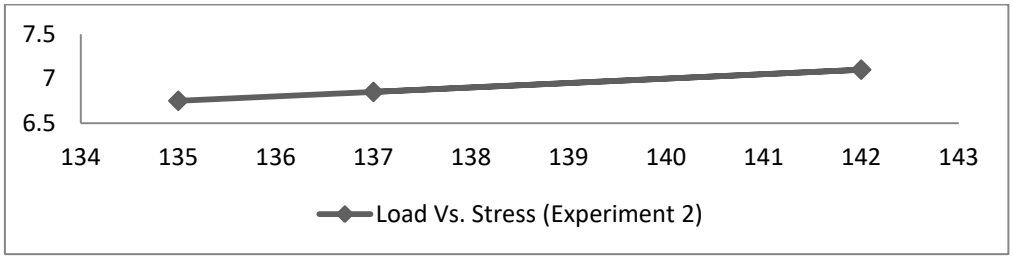

Figure 3: Load Vs Stress graph for experiment 2

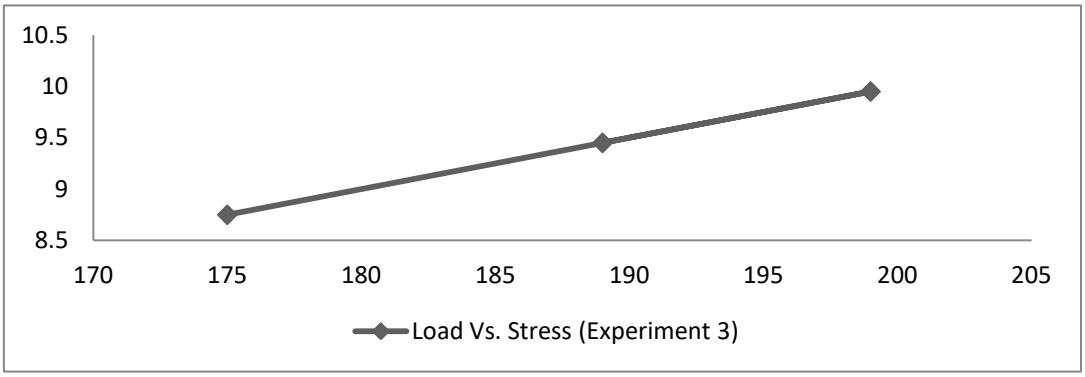

Figure 4: Load Vs Stress graph for experiment 3

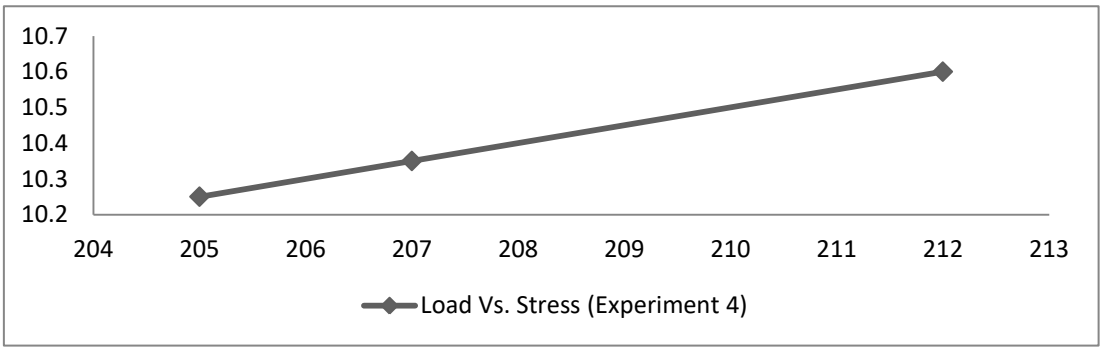

Figure 5: Load Vs Stress graph for experiment

Table VI: Fly ash brick (with Cement) load test data

	Experiment 5			Experiment 6			Experiment 7		
	1	2	3	1	2	3	1	2	3
Peak Load (KN)	186	185.9	162.8	169.2	190.4	189.7	200	213.9	248.6
Stress (N/mm^2)	9.3	9.29	8.1	8.46	9.52	9.49	10	10.69	12.43
Average Stress (N/mm^2)	8.9			9.15			11.04		

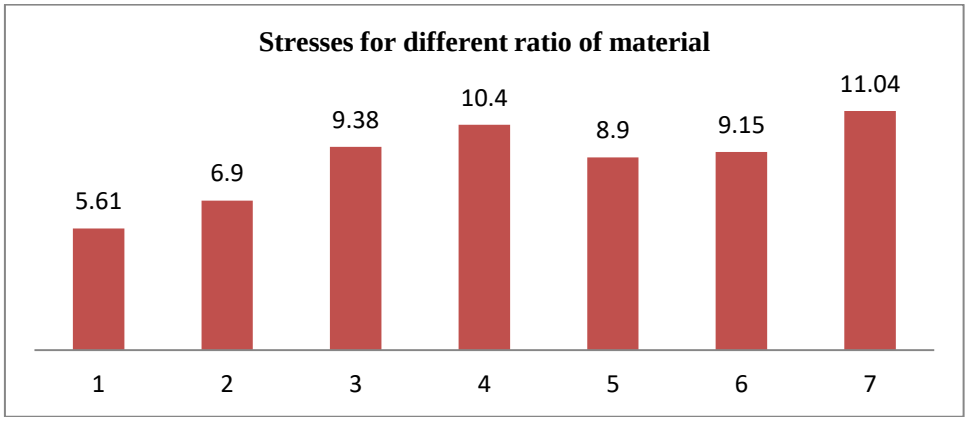

Fig 9: Comparison of mean stresses obtained from load test data

IV. CONCLUSION

Here an attempt has been done to study the behavior of fly ash based bricks using lime and gypsum as binder material. Further studies have been made by the application of cement as a binder material. Based on the results obtained from the experimental study it can be concluded that, Fly ash based brick develop sufficient strength using both the hydride lime and the cement as a binder material.

By different trial ratios it is observed that fly ash based bricks achieve more compressive strength for slug lime (cement) then hydride lime even if using fifty percent of fly ash. Also it can be concluded that with a lesser percent of cement a good strength of fly ash based brick can be prepared. Practically the average weight of standard brick is 3.5 kg whereas the average weight of fly ash brick is found to 2.58 kg which is more or less 26-30% lighter than the standard modular brick. Due to less weight fly ash bricks the self-weight over the structure will be reduced.

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