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Strength and Durability of Fly Ash, Cement and Gypsum Bricks

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Abstract:
Burnt clay brick is an age old building material which is used for housing in urban area as well as rural part of India. These bricks are manufactured from good plastic clay, which is obtained from agricultural land. Excess use of agricultural land for this clay results in loss of good fertile soil and diversion of agricultural land for brick manufacturing. Manufacturing of bricks involved burning of bricks using coal. Burning of bricks using coal produces green house gases leading to environmental pollution. Fly Ash bricks are an alternative for the conventional bricks which can be used effectively to replace the conventional bricks. Various properties of these bricks were studied by different researchers and they found that these bricks can be used for construction of low cost houses in the area in the vicinity of thermal power plant. This paper is an attempt to study the strength and durability aspect of bricks prepared using Fly Ash, Cement and Phosphogypsum

Key Words: *Bricks, Fly Ash, Cement, Gypsum, Durability, Sulphate resistance.*

I. INTRODUCTION

In our country we are using ordinary burnt clay bricks. These bricks are having numerous disadvantages such as environmental pollution i.e. air pollution and land pollution. Air pollution takes place due to burning of bricks using coal as a fuel for burning. Burning of coal produces green house gases leading to environmental pollution. For manufacturing of these bricks huge amount of clay is required. This clay is obtained from agricultural land. Thus it causes land pollution through loss of good fertile soil. The manufacturing of bricks in our country is over 60 billion clay bricks annually (1) causing a strong impact on soil erosion and unprocessed emissions. For production of these bricks about 160 million tones of top soil is required which converts about 7500 acres of fertile land in to barren land (1). Manufacturing of conventional bricks is also associated with various social issues related to labours. To overcome these issues and problems now a day various attempts was done by various researchers to study various properties of bricks prepared using various by products and waste materials such as fly ash, lime and gypsum. Through their study they found that these bricks can be used as replacement or an alternative material to burnt clay bricks (2) (3) (4). Such bricks can be manufactured at lower cost and having good compressive strength. In case of lime is not available in the vicinity, OPC can be used as a source of lime.

This paper discusses the durability and strength aspect of the bricks prepared using fly ash, cement and phosphogypsum.

II. MATERIAL USED

For the present study fly ash used is obtained from thermal power plant located at Eklehara, Nasik. A good quality of lime is not available in the vicinity hence OPC is used as a source of lime. Phosphogypsum ($CaSO_4$. 2 H_2O) is obtained from a local agricultural products manufacturing company.

III. MIX PROPORTIONS

In the first part of this study various mix proportions of fly ash, cement and Phosphogypsum were studied for their compressive strength and it was found that bricks prepared with fly ash, cement and Phosphogypsum give sufficient compressive strength. Water absorption of these bricks was found to be on higher side as compared to the conventional burnt clay bricks. The object of this study is to discuss the durability and strength of these bricks, hence both the durability and strength aspect is discussed in this paper.

Table No.1 shows various mix proportions used for the present study.

Table 1: ix proportions

Sr. No.	Mix Proportions	Constituents (%)		
		Fly ash	Cement	Phosphogypsum
01	M-1	25	50	25
02	M-2	30	40	30
03	M-3	35	30	35
04	M-4	40	20	40
05	M-5	45	10	45

IV. METHODOLOGY

a) Mixing of Raw Material: The weighed quantity of Phosphogypsum, Cement and fly ash was thoroughly mixed in dry state in a pan with the help of a trowel. The mixture in dry state is mixed till it attains a uniform colour. When the mixture attains uniform colour weighed quantity of water is added in the mixture of fly ash, cement and phosphogypsum. After addition of the required quantity of water the mixture is thoroughly mixed with the help of trowel in a pan. After mixing the mix initially with the trowel the mixture is again mixed thoroughly by kneading until the mass attained a uniform consistency. To calculate the quantity of water to be added Standard normal consistency test was performed and the water content for the normal consistency was determined. The water content used in the mix for strength tests was 90% of that required to produce the standard normal consistency (4).

b) Preparation of mortar blocks: Standard cement mortar cube moulds of size 70.7mm x70.7mm x 70.7mm were used for preparation of blocks. The mixed binder was placed in the cube mould and was compacted properly by rod. Excess paste was hand finished. The mould was filled in three layers and each layer was compacted properly.

b) Method of Curing: The blocks were taken out from the moulds after 24 hours. After removal from the moulds the blocks were kept for air drying for 2 days. After sufficient strength was gained these blocks were transferred to water filled curing tanks. The durability of blocks was investigated by curing these blocks in the aggressive environments of sulfate solution. The sulfate solution having sulfate concentration equal to 10,000 ppm was prepared in the laboratory by mixing 14.79 g of $Na_2 SO_4$ in one liter of water.

V. EXPERIMENTAL WORK

Number of cubes was prepared using the mix proportions mentioned in Table 1 above and tested for their compressive strength and water absorption, after testing cubes it was found that M-5 can be used for bricks and hence bricks were prepared using M-5 proportions and tested for their compressive strength and water absorption. Since this paper discusses the durability and strength aspect only the results of compressive strength and water absorption test conducted on bricks are given in Table 3 while table 2 shows the results of tests conducted on cubes.

Table 2: Compressive strength and water absorption of cubes

Mix Designation	Compressive Strength in MPa			Water Absorption (%)
	7 days	14 days	28 days	
M-1	12.93	17.80	23.56	29.29
M-2	10.00	17.00	20.67	30.37
M-3	9.88	14.26	18.23	24.91
M-4	5.63	9.96	17.46	20.25
M-5	3.16	7.96	12.00	28.22

Table 3: Compressive strength and water absorption of bricks for M-5 mix proportion

Mix Designation	Compressive Strength in MPa			Water Absorption (%) after 28 days
	7 days	14 days	28 days	
M-5	2.254	6.360	9.420	28.44

After performing compressive strength test and water absorption test on bricks prepared using M-5 mix proportion it was found that mix M-5 is suitable to be used as brick material instead of clay.

To check the durability aspect of the mix i.e. fly ash, cement and phosphogypsum durability test was conducted on all the five mix proportions. For durability test Sulphate solution of concentration 10000 ppm is prepared in the laboratory by mixing 14.79 g of Sodium Sulphate in one litre of water. Three cubes from each type of mix are immersed in Sulphate solution. These cubes will be tested for their compressive strength after 28 days (3). Table 4 shows test results of durability test on fly ash, cement and phosphogypsum cubes.

Table 4: Compressive strength of cubes after curing in Sulphate solution

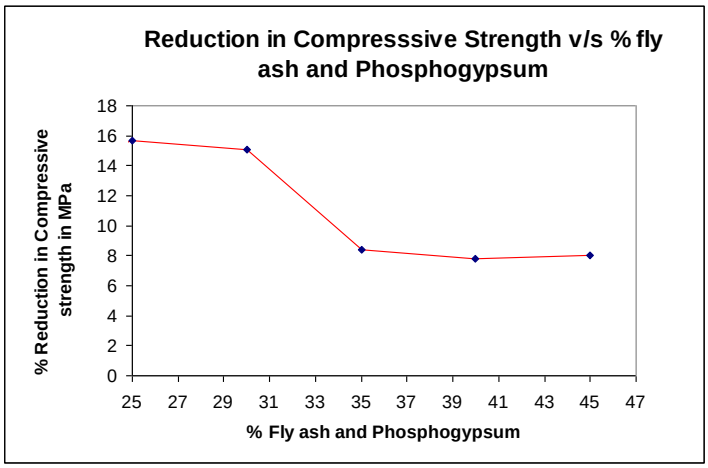
Mix Designation	Compressive Strength in MPa
	28 days
M-1	19.86
M-2	17.56
M-3	16.60
M-4	16.10
M-5	11.036

After testing the cubes for sulphate attack it was found that their strength decreases due to exposure to sulphate solution. Table 5 shows summary of all tests i.e. compressive strength of cubes with curing in potable water, compressive strength after curing in sulphate solution and water absorption test of cubes.

Table 5: Summary of results

Mix Designation	Compressive Strength in MPa		% loss of compressive strength due to sulphate attack.	Water Absorption (%)
	28 days curing in water	28 days curing in sulphate solution		
M-1	23.56	19.86	15.70	29.29
M-2	20.67	17.56	15.04	30.37
M-3	18.23	16.60	8.94	24.91
M-4	17.46	16.10	7.78	20.25
M-5	12.00	11.036	8.033	28.22

Graph 1 shows reduction in compressive strength due to sulphate attack v/s % of fly ash and phosphogypsum



Graph 1 Reduction in compressive strength v/s percentage of fly ash and phosphogypsum

VI. TEST RESULTS AND DISCUSSION

The results of compressive strength on cubes of fly ash, cement and phosphogypsum when cured in potable water are shown in table 2 along with results of water absorption of the cubes. While the results of compressive strength of cubes cured in sulphate solution are presented in table 4. Table 3 shows results of compressive strength and water absorption of bricks prepare with mix M-5. Summary of results for all the tests performed on the fly ash, cement and phosphogypsum binder is shown in table 5. Graph 1 shows effect of curing of the cubes in sulphate solution on compressive strength.

Table 2 shows compressive strength of fly ash, cement and phosphogypsum cubes for different mix proportions. From the table it is clear that the said binder gives good compressive strength though the water absorption is slightly on higher side of the I.S. requirements. When bricks are prepared with mix M-5 and tested for compressive strength and water absorption, it has been found that the bricks are having good compressive strength of 6.360MPa at the age of 14 days and 9.420 MPa at the age of 28 days, which is well above the I.S. requirement of 3.5 MPa. The water absorption of the bricks is found to be 28.44 % after submergence in water for 28 days which is above the I.S. requirement. The results are shown in table 3.

Table 4 shows compressive strength of cubes of all mix proportions when exposed to sulphate solution for 28 days. If it is compared with compressive strength of cubes given in table 2, it can be observed that curing in sulphate solution has resulted in reduction in compressive strength. Graph 1 shows the reduction in compressive strength against the percentage of fly ash and phosphogypsum. The graph shows that for higher percentage of fly ash and phosphogypsum the percentage reduction in compressive strength isles, thus if the percentage of fly ash and phosphogypsum increases durability of the mix increases. Thus the bricks prepared from fly ash, cement and phosphogypsum can offer good resistance to sulphate attack. For higher percentage of cement in the mix the percentage reduction in compressive strength is very high i.e. up to 16%. Due to action of fly ash with sulphate solution and due to increased percentage of phosphogypsum resistance of the mix against sulphate attack increases. From the above results and discussion following conclusions can be drawn.

VII. CONCLUSIONS.

Based on the experimental investigation reported in this study, following conclusions are drawn:

1. Unique possibility exists for the bulk utilization of fly ash in producing bricks in the proximity of thermal power plants, phosphoric acid and fertilizer industries.
2. The test cubes are having sufficient strength and have potential as a replacement for conventional burnt clay bricks.
3. Cementitious binder with fly ash and phosphogypsum content equal to 90% gives better compressive strength and 28.22 % water absorption and thus suitable for use in construction industry.
4. Being lighter in weight, it will reduce the dead weight and material handling cost in multi storied constructions.
5. When subjected to higher Sulphate concentration, the cementitious binders which gave low water absorption exhibited a very low strength loss.
6. From the testing of bricks for compression and water absorption it can be concluded that such bricks are having sufficient strength to be used as a replacement for traditional bricks. The water absorption of fly ash, cement and phosphogypsum bricks is found more than 20%, but such bricks can be used at places where water absorption is not a problem. i.e. for curtain walls.

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