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EXPERIMENTAL STUDY ON CLASS F FLY ASH CEMENT BRICKS USING PARTIAL REPLACEMENT OF FLY ASH BY METAKAOLIN

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ABSTRACT

Normal fly ash brick and burnt clay brick is an olden building material which is used for housing in urban area as well as rural part of India. The bricks are manufactured from natural clay, which is obtained from agricultural land. Excess usage of agricultural land for this clay results in loss of good fertile quality of soil and diversion of agricultural land for brick manufacturing. The modified 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 understood these bricks can be used for construction of low cost houses. This paper is an attempt to study the durability and strength aspect of bricks prepared using class F fly ash, Cement, metakaolin and quarry dust. The experiment work also investigated the effectmetakaolin content in class F fly ash cement brick based on trial and error mix proportion methods. The experiment are conducted in two phases to observe the properties i.e. compressive strength and water absorption of fly ash cement brick. In both phase the cement (10%) and quarry dust (35%, 30%) are kept constant and class f fly ash (55% to 35%, 60% to 40 %) is replaced with white metakaolin up to 20 percentage. The fly ash based cement bricks are tested after 7 days, 14 days and 28 days curing in advanced concrete research laboratory of the institute. The test results showed that, the maximum optimized compressive strength is obtained for optimal mix proportion percentage of class F fly ash 40%, cement 10%, quarry dust 35% and metakaolin 15%. In both phases of experiment observed that there is a decrease (Inadequate value) in water absorption ratio of fly ash brick while using metakaolin powder.

Keywords: Cement, Compressive strength, Metakaolin, Quarry dust, Water absorption.

INTRODUCTION

Fire causes thousands of deaths and loss of property loss every year. The need to understand the manner in which cement based material such as brick behave at higher

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temperature is cardinal need for public safety. There are two fundamentally different approaches exist to make brick and other building products. The first is to make bricks in the same way fired clay bricks are made except for the use of fly ash to substitute for a portion of the clay or the entire amount of clay used in making bricks. This approach requires the newly shaped bricks to be heated in kilns fired to over 2000^0F, which consumes much energy, pollutes air and contributes to global warming. The second method is to make bricks with the help of fly ash (Class F) that contain large amount of silicate, do not need to fire or heat the products in kiln. Instead, the products can be cured in the same way concrete is cured by keeping the products in a wet environment for more than 24 hours until the material sets and harden due to chemical reaction with water or moisture contained in the products. Fly ash is a by-product from coal based thermal power plants. Its large-scale availability in countries like India creates disposal problems and hence need for development of its eco-friendly applications. FA utilisation level at present is only about 60%. Fly ash is generated in thermal power stations. It is fine particulate material precipitated from the stack gases of industrial furnaces. Fly ash is finely divided residue resulting from combustion of powdered coal. Fly ash contains amorphous silica, which is responsible for pozzolanic activity. The predominant constituents in fly ash are inert mineral oxides. Approximately 95 per cent of the ash is made up of silicon, aluminium, iron, and calcium in their oxide forms. Fly ashes are mainly of two types - Class F and Class C.

Even though fly ash brick is generally believed to be an excellent fire proofing material, here study on the effect of metakaolin in class F fly ash bricks and determine whether the brick will be able to maintain its structural integrity. The durability and performance is based on the performance of its constituents cement, class F fly ash, quarry dust, metakaolin, and water used in the bricks.

EXPERIMENTAL

Materials

Cement: Ordinary portland cement (OPC) 53 grade of cement is used for the entire experimental investigation. The physical properties were tested according to standard procedure confirming to IS: 12269 – 1987.

Class F fly ash: Low calcium (Class F) fly ashes characteristically contain a large proportion of silicate glass of high silica content plus crystalline phases of low reactivity, typically mullite, magnetite and quartz. On the equal weight basis high calcium fly ashes (normally from lignite and sub-bituminous coals) gain more early strength than low calcium fly ashes normally from bituminous coal) due to both chemical and physical factors. The chemical composition of the glass in fly ashes varies considerably, affecting its activity. The structure of the glass varies from that of the strongly interlinked network characterizing highly siliceous glass in many class F fly ashes, to a more substituted structure, which contains a larger proportion of network of modifiers in the class C fly ashes. These constituents may include alkaline earth, alkali, and alumino silicate glasses similar to the glassy structures of blast furnace slag. Calcium aluminates glasses are reported to be present. The high silica glass is intrinsically less reactive with water than the other glasses. Therefore, Class F fly ashes require higher glass contents to be as effective in portland cement concrete as class C fly ashes. It is reported in the literature that class F fly ash-based bricks produce higher compressive strength than class C fly ash-based brick. Class F Fly ash is used throughout the work.

Metakaolin: Metakaolin (MK) is a pozzolanic material. It is a dehydroxylated form of the clay mineral kaolinite. It is obtained by calcination of kaolinitic clay at a temperature between 500^{o}C and 800^{o}C. Between 100 and 200^{o}C, clay minerals lose most of their adsorbed water. Between 500 and 800^{o}C kaolinite becomes calcined by losing water through dehydroxilization. The raw material input in the manufacture of metakaolin ($Al_2Si_2O_7$) is kaolin clay. Kaolin is a fine, white, clay mineral that has been traditionally used in the manufacture of porcelain. Kaolinite is the mineralogical term that is applicable to kaolin clays. The dehydroxilization of kaolin to metakaolin is an endothermic process due to the large amount of energy required to remove the chemically bonded hydroxyl ions. Above this temperature range, kaolinite becomes metakaolin, with a two dimensional order in crystal structure.Like other pozzolans (such as fly ash and silica fume), metakaolin reacts with the calcium hydroxide (lime) by-products produced during cement hydration. Calcium hydroxide accounts for up to 25% of the hydrated Portland cement, and calcium hydroxide does not contribute to the concrete’s strength or durability.

Quarry dust: It is residue taken from granite quarry. Due to excessive cost of transportation from natural sources locally available river sand is expensive. Also creates environmental problems of large-scale depletion of these sources. The properties of the quarry dust are in conformation with IS 2386:1963. Quarry dust was tested was various properties like specific gravity, sieve analysis and are conforming to IS standards. The specific gravity of the quarry dust was found to be 2.56 and the sieve analysis of quarry dust was found to be zone II.

Water: Ordinary clean portable water free from suspended particles was used both for mixing and curing the brick specimen. And also there is no IS provision for taking water amount. So here water amount is took (means, trial and error method) based on which amount of the water is suitable for casting and note that value.

Mix proportion

Different mix proportions of the class F fly ash cement bricks in percentage are shown in Table 1.

Table 1: Mix proportions of fly ash cement bricks for Phase I and II

S. No.	Mix designation		Quantity of materials in percentage							
			Phase-I				Phase- II			
	Phase I	Phase II	Class F fly ash	Quarry dust	Cement	Metakaolin	Class F fly ash	Quarry dust	Cement	Metakaolin
1	S-I-1	S-II-1	55	35	10	0	60	30	10	0
2	S-I-2	S-II-2	50	35	10	05	55	30	10	05
3	S-I-3	S-II-3	45	35	10	10	50	30	10	10
4	S-I-4	S-II-4	40	35	10	15	45	30	10	15
5	S-I-5	S-II-5	35	35	10	20	40	30	10	20

Experimental methodology

Mould preparation

Total 15 number of mould was prepared with a non-water absorbing material like steel plate of size of 190 mm length, 90 mm wide and 90 mm deep. The shorter sides of mould are slightly projecting to serve as handled.

Mixing of raw materials

After all the ingredients were ready, the mixing was done. In this project, mixing was done with the help of the pan mixer in CACR (Centre for Advanced Concrete Research) Lab. The weighed quantity of quarry dust, cement, class F fly ash and metakaolin was thoroughly mixed in dry state in a pan mixer with the help of trowel. The mixture in dry state is mixed till it attain a uniform colour. When the mixture is attains uniform colour weighed quantity of water is added in the mixture of quarry dust, cement, class F fly ash and metakaolin. And to calculate the quantity of water to be added in the mixer.

Moulding the fly ash cement bricks

After mixing, it should be placed in the mould before 30 minutes. So, 15 moulds were used at a time to make the process very fast. In this project, the fly ash bricks were moulded with the help of vibrating table. A total of 180 fly ash bricks are made, in which 150 fly ash bricks used for compression and water absorption test and rest of 30 fly ash bricks used for hardness test, soundness test, structure test and efflorescence test (presence of soluble salts) etc.

Method of curing

The bricks were taken out from the moulds after 24 hours. After removal from the moulds the brick were kept for air drying for half day. After that brick were transferred to water filled curing tank.

RESULTS AND DISCUSSION

Compressive strength test

It is the main and important test. This test only decides the strength of the brick. This test was carried out by a compression testing machine. This test was carried out on the 7th, 14th, 28th days from the date of casting of brick. When the brick failed at higher load at the structure was not fully collapsed. Only the outer faces cracked and peeled out. So the bricks are having elastic behaviour and little brittleness. Table 2 shows compressive strength and water content of fly ash cement bricks in Phase I and Phase II.

Table 2: Results of compressive strength test and quantity of water added in each mix proportions

S. No.	Mix designation		Average compressive strength in N/mm^2							
			Phase-I				Phase–II			
	Phase I	Phase II	7 Days	14 Days	28 Days	Water content (g)	7 Days	14 Days	28 Days	Water content (g)
1	S-I-1	S-II-1	4.614	7.132	9.416	8000	2.752	5.692	7.232	7800
2	S-I-2	S-II-2	7.310	9.571	13.372	7600	5.731	7.033	7.486	7800
3	S-I-3	S-II-3	7.115	9.669	14.854	8700	6.277	8.636	12.339	7600
4	S-I-4	S-II-4	10.370	13.119	18.830	7800	9.064	11.345	16.354	8000
5	S-I-5	S-II-5	6.413	8.600	10.390	9200	6.043	7.466	9.669	8300

Water absorption test

Water absorption test is used to find out the water absorption ratio. Because the fly ash cement brick, which are absorbing more water cannot be used in water logging area or exterior walls which is open to sky. The fly ash cement bricks from all the proportions were tested. Then the water absorption ratio was calculated by the formula,

$$\text{Water absorption ratio} = [(W_2 - W_1)/W_1] \times 100$$

First all the fly ash cement bricks were weighed in an electronic weighing machine and this weight was noted as W_1. After 24 hrs the bricks were taken out and wiped with cloth. Then the fly ash cement brick was weighed and this weight was noted as W_2. The Table 3 shows water absorption of fly ash cement bricks in Phase I and Phase II.

Table 3: Results of water absorption

S. No.	Mix designation		Average water absorption in percentage					
			Phase-I			Phase-II		
	Phase-I	Phase-II	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
1	S-I-1	S-II-1	0.801	2.090	3.030	0.741	1.606	1.058
2	S-I-2	S-II-2	1.065	2.795	1.036	1.006	1.818	1.742
3	S-I-3	S-II-3	2.556	2.905	1.840	1.158	0.880	1.094
4	S-I-4	S-II-4	1.925	1.996	0.766	0.459	1.378	1.139
5	S-I-5	S-II-5	0.662	0.871	0.777	0.271	0.665	1.298

CONCLUSION

The following conclusions have been drawn based on the experimental investigations carried on the performance of class F fly ash cement bricks in metakaolin powder.

(i) Replacement of class F fly ash by 15% of metakaolin shows increase in compression strength is 18.830 N/mm^2

(ii) In the phase one, the optimum dose of class F fly ash and metakaolin in combination is found to be 10% and 15% (by weigh) respectively at 28 day compressive strength.

(iii) In phase two, the optimum dose of class F fly ash and metakaolin in combination is found to be 10% and 15% (by weigh), respectively at 7 day compressive strength.

(iv) The result show that the metakaolin based fly ash cement bricks have more compressive strength and very less water absorption in comparison to conventional clay bricks.

(v) The minimum standard required compressive strength of bricks is 7.5 N/mm^2. But when 5% of metakaolin (in phase one) was added by weigh in the supplementary cementations material. Then it gave the compressive strength of 13.372 N/mm^2, again while increasing the percentage of metakaolin as 10%, 15% by weigh the compressive strength of fly ash cement brick also increases 14.854 N/mm^2 and 18.830 N/mm^2, respectively.

(vi) Experimentally found that metakaolin based fly ash cement bricks are less porous compared clay bricks and no need of plastering in normal cases.

(vii) The water absorption characteristics of fly ash cement bricks become poor (every values less than 3.2%), when the fly ash is replaced by metakaolin; however it gets improved when the white metakaolin powder is added in mix.

(viii) All the results are indicative of the satisfactory performance of fly ash cement bricks as load bearing elements. Therefore, provide a large venue for the disposal of fly ash in a very efficient, useful and profitable ways. From the research we hope that this metakaolin based fly ash cement brick will be act as an eco-friendly bricks for present construction field.

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