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EXPERIMENTAL INVESTIGATION ON INTERLOCKING BLOCKS BY PARTIAL REPLACEMENT OF CEMENT WITH SILICA FUME

[1] Prasanna Jenifer Golda.J, [2] Anitha.P

[1]PG student,[2] Assistant Professor

[1] *Department of Civil Engineering,*

[1] *Sethu Institute Of Technology, Kariapatti, Tamilnadu.*

Abstract: **Bricks are mostly used in construction throughout the world. Traditional bricks are made up of clay which is treated in high temperature kiln firing. The removal of top layer of the soil and clay from the resources cause soil erosion. The conventional technique of masonry bricks production has caused severe environmental pollution due to the massive emissions of greenhouse gases which lead to several climate changes such as haze, fog, air pollution, acid rain and global warming. Consequently, the main objective of this paper is to study the development of eco-friendly interlocking bricks for masonry applications by incorporating silica fume. Interlocking bricks are the enhanced form of conventional clay bricks. Each brick is constructively designed to lock itself to the other bricks around without the use of mortar. The self-locking is achieved using shear-key and lock mechanism. Based on the design, the shape of shear-key will vary and a complimentary lock is provided on the opposite side of brick. Load transfer is achieved by shear transfer and gravity. Silica fume is a by product of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Partial replacement of cement with silica fume in interlocking brick by 5%, 10%, 15%, 20%, 25%, 30% were used in this study. Compressive and Water absorption test, Block density was conducted to find out the characteristic changes.**

Index Terms - **Self locking, shear key, ferrosilicon alloys, pozzolan, block density.**

I. INTRODUCTION

Conventional bricks are the most elementary building materials for houses construction. However, the rapid growth in today's construction industry has obliged the civil engineers in searching for a new building technique that may result in even greater economy, more efficient and durable as an alternative for the conventional brick. Moreover, the high demands for having a speedy and less labor and cost building systems is one of the factor that cause the changes of the masonry conventional systems. These changes have led to improved constructability, performance, and cost as well. Several interlocking bricks has been developed and implemented in building constructions and a number of researches had studied the manufacturing of interlocking brick with the alternative material and its structural behavior as load bearing and non-load bearing element.

II. EXPERIMENTAL PROGRAM

A. *Materials*

Materials used for this research consist of ordinary Portland cement (OPC), Coarse aggregate (6mm Jelly), fine aggregate (M sand dust), fly ash, silica fume. The basic characterization of these materials was carried out in accordance with Indian standard. All materials are available locally in Tamilnadu. OPC conforming to Indian Standard 12269 was used in this research activity. M Sand dust consists of fine grains or particles of mineral and rock fragments with specific gravity of 2.618. Class F fly ash which conforms to the specifications of ASTM C618 and ASTM C311 and having specific gravity of fly ash is 2.76 was used. Silica fume is a by product of the smelting process in the silicon and ferrosilicon industry, having a specific gravity of 2.25 was used.

FIG. 1 Silica fume

B. Dimension of Interlock block

Volume of interlock block=l×b×d

= 0.28 m×0.152 m×0.152 m

= 0.00647 m^3

C. Mix Design

In order to achieve the maximum compression strength of the interlocking bricks, seven different mix designs were derived as shown in Table 1. The mixtures were prepared by varying the percentage of silica fume in material used such as cement, fly ash, M sand dust. In this research, the cementitious (fly ash and silica fume) were used as cement replacement materials, and M sand dust was utilized as filler. Cement and cementitious will be combined with M sand dust and 6mm Jelly to produce the interlocking bricks. The water cement ratio adopted is 0.50.There is no clay and without firing in producing the interlocking bricks. Based on compressive test, the maximum compression strength was achieved by using Mix-5.

TABLE I
QUANTITY OF MATERIALS REQUIRED FOR EACH MIX

MATERIALS (Kg/m^3)	**MIX 1 0% SILICA FUME**	**MIX 2 5% SILICA FUME**	**MIX3 10% SILICA FUME**	**MIX4 15% SILICA FUME**	**MIX5 20% SILICA FUME**	**MIX 6 25% SILICA FUME**	**MIX 7 30% SILICA FUME**
CEMENT	0.842	0.800	0.750	0.702	0.655	0.608	0.562
COARSE AGGREGATE (6MM JELLY)	5.928	5.928	5.928	5.928	5.928	5.928	5.928
FINE AGGREGATE (M SAND DUST)	3.627	3.627	3.627	3.627	3.627	3.627	3.627
FLY ASH	0.080	0.080	0.080	0.080	0.080	0.080	0.080
SILICA FUME	0	0.010	0.020	0.30	0.40	0.50	0.60

D. *Curing*

- Curing for 14 hours is required for good strength of Interlock blocks.
- These results in the Better strength of Interlock blocks.

E. STANDARD TEST METHOD

1) *COMPRESSIVE STRENGTH*: The testing machine shall be equipped with two steel bearing blocks one of which is a spherically seated block that will transmit load to the upper surface of the masonry specimen, and the other a plane rigid block on which the specimen will rest. When the bearing area of the steel blocks is not sufficient to cover the bearing area of the masonry specimen, steel bearing plates shall be placed between the bearing blocks and the capped specimen after the centroid of the masonry bearing surface has been aligned with the centre of thrust of the bearing blocks. Each full size units shall be tested within 72 h after delivery to the laboratory, during which time they shall be stored continuously in normal room air. Units of unusual size, shape, or strength may be sawed into segments, some or all of which shall be tested individually in the same manner as prescribed for full size units. The strength of the full size units shall be considered as that which is calculated from the average measured strength of the segments. For the purpose of acceptance, age of the testing the specimens shall be 28 days. The age shall be reckoned from the time of the addition of water to the dry ingredients.

Fig. 2 Experimental setup of compressive strength test

2) *WATER ABSORPTION*: The test specimens shall be completely immersed in water at room -temperature for 24 h. The specimens shall then be weighed, while suspended by a metal wire and completely submerged in water. They shall be removed from the water and allowed to drain for one minute by placing them on a 10 mm or coarser wire mesh, visible surface water being removed with a damp cloth and immediately weighed. Subsequent to saturation, all specimens shall be dried in a ventilated oven at 100"C to 115°C for not less than 24 h and until two successive weighing at intervals of 2 h show an increment of loss not greater than 0.2 percent of the last previously determined mass of the specimen.

FIG. 3 *WATER ABSORPTION TEST*

3) *BLOCK DENSITY*: Three blocks taken at random from the samples shall be dried to constant mass in a suitable oven heated to 100° C to find the Mass of block, in kg approximately. After cooling the blocks to room temperature, the dimensions of each block shall be measured in centimetres (to the nearest millimetre) and the overall volume computed in cubic centimetres. The block shall then be weighed in kilograms and the density of each block is calculated.

III. Results And Discussions

A. *Compressive Strength*: The compressive strength of interlocking bricks The maximum compressive strength was achieved by Mix-5 . It was clear that the compressive strength of bricks can be influenced by the cementitious material. The enhancement of cementitious up to 20% percentage will increase the compressive strength of interlocking bricks. Based on the test results, the optimum compressive strength attained by Mix-5 was referred for another tests in this research. This value is lower than strength achieved by Mix-1, therefore the interlocking bricks developed in this study can be recommended as alternative brick aside from the conventional one.

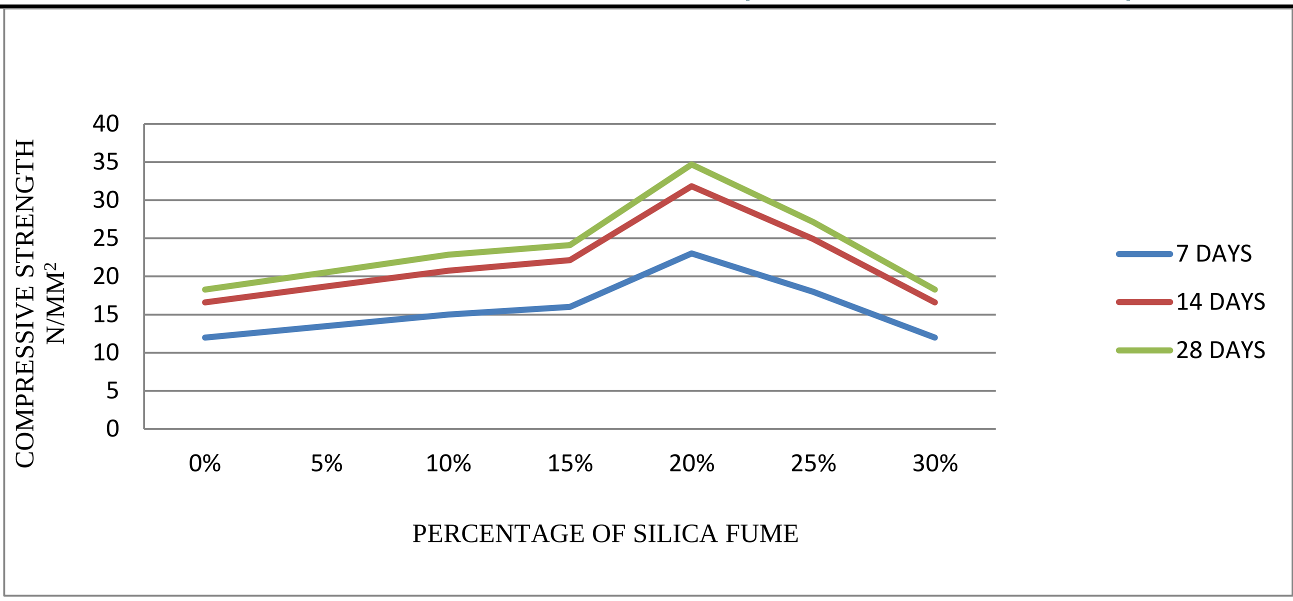

FIG4. COMPRESSIVE STRENGTH OF BLOCK AND OPTIMUM VALUE FIXATION

B. Water Absorption Test: Based on the 24 hour of water absorption test, the results are in accordance with the IS 2185(Part 1) requirements. The two successive weighings at intervals of 2 h show an increment of loss not greater than 0.2 percent of the last previously determined mass of the specimen

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TABLE II
WATER ABSORPTION

Specimen	Dry mass(kg)	Wet mass(kg)
1	12.500	12.620
2	12.600	12.740
3	12.550	12.650

After 28 days continuous curing

Water absorption = ((12.620-12.500)/(12.500))×100
= 0.96 %

Water absorption = ((12.740-12.600)/(12.600))×100
= 1.11 %

Water absorption = ((12.650-12.550)/(12.550))×100
= 0.79 %

Average =0.95%

It should not be more than 10 percent by mass.

It was safe as per code IS 2185 (PART 1): 2005

C. Block density:

TABLE III
BLOCK DENSITY

Specimen	Mass (kg)	
	Before drying	After oven drying
1	12.190	11.960
2	12.230	11.980
3	12.210	11.975

Density of block = (Mass of the block in kg/Volume of specimen in cm^3) $\times 10^6$ Kg/m^3
= (11.960/6469.12) $\times 10^6$Kg/m3
=1848.78 Kg/m^3

Density of block = (11.980/6469.12) $\times 10^6$Kg/m3
=1851.87 Kg/m^3

Density of block = (11.980/6469.12) $\times 10^6$Kg/m3
=1851.10 Kg/m^3

Average =1850.58 Kg/m^3

It was safe as per code IS 2185 (PART 1): 2005

D. Estimation

Traditional clay brick(1m^3)
Size 22.8 cm×10.7 cm ×6.9 cm
For 1m^2 t=0.23
Number of bricks=114
Cost of 114 bricks =114 ×10=Rs 1140
Interlocking brick for (1m^3)
Number of bricks=28
Cost of 28 bricks=28×32=896
Comparison of cost analysis of interlocking block with traditional clay bricks resulted in an economic construction. Rate for 1m3 using traditional clay brick and interlocking block were obtained as Rs 1140 and Rs 896 respectively.

III. Conclusions

Depending upon certain considerations, a suitable interlocking block has been designed. Interlocking blocks were cast successfully as per the code 2185:2005 (part 1).

A. Optimum value of cement by silica fume replacement was found as 20% through trials. Block density and water absorption tests were satisfactory.
B. Compressive strength of interlocking block was found greater than that of ordinary clay block .
C. Because of the pattern of interlock, it provides better matrix strengthening, wall stability, disallows movements and reduces mortar.
D. Therefore, the interlocking block masonry can be adopted as a suitable substitute for traditional masonry. And in conclusion, interlocking masonry can be recommended for housing projects as an alternative method that is cheaper than the conventional.

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