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Fly Ash - Lime and Gypsum Hollow Blocks

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ABSTRACT

FaL-G is the product name given to a cementitious mixture composed of Fly ash (Fa), Lime (L) and Gypsum (G). It is low-cost and environmental-friendly material very useful even in rural housing industry. FaL-G in certain proportions, as a building material is an outcome of innovation to promote large-scale utilization of fly ash. It gains strength like any other hydraulic cement in the presence of water and it is water resistant when hardened. This paper addresses the technology of making FaL-G mortar compressed hollow blocks with low-calcium (Class F) dry fly ash as the base material. The FaL-G masonry hollow blocks were prepared without the use of conventional cement. Quarry dust and sand were used as fine aggregates as sustainable materials. The properties and compressive strength of FaL-G masonry hollow blocks were tested with different parameters. The experimental results reveal that the FaL-G hollow blocks are suitable to be used for the construction of masonry structures.
Keywords : Fly Ash, Lime, Gypsum, Quarry Dust, Sand, Mortar, Compressive Strength.

I. INTRODUCTION

Nowadays the emission of carbon dioxide into the atmosphere is being increased gradually day by day. Considerable amount of fossil fuel, coal and oil are burnt for different reasons. This weakens the heat–trapping blanket that surrounds the planet causing global warming. Various alternatives can be considered to protect the planet. The rapid increase in the capacity of thermal power generation has resulted in the production of a huge quantity of fly ash. The prevailing disposal methods are not free from environmental pollution and ecological imbalance. On the other hand, the production of each ton of cement releases equal amount of carbon dioxide to the atmosphere. The usage of cement can be reduced by using the other possible cementing materials without compromising the strength and durability.

The most basic building material for construction of houses is the usual burnt clay brick. A significant quantity of fuel is utilized in making these bricks. Also, continuous removal of topsoil, in producing conventional bricks creates environmental problems. There is strong need to adopt cost effective sustainable technology using local materials and appropriate/intermediate technologies using materials with efficient and effective technology inputs. Different methods are adopted to produce the building blocks using cement, lime-fly ash, lime-slag bindings etc. There is a need to develop simple and highly effective technologies for producing the building blocks. The imperative need to produce more building materials for various elements of construction and the role of alternative options would be in sharp focus. This is in considering the short supply, increasing cost, energy and environment considerations for traditional and conventional materials. The possibility of using innovative building materials and technologies, using waste material like fly ash has been considered.

There is a strong need to adopt cost-effective and environmentally appropriate technologies by upgrading of traditional technology, as also using local materials as well as appropriate and intermediate technologies employing modern construction materials with efficient, effective technology inputs. Building materials is an area where enormous amount of innovation for cost reduction can be achieved. It is cost effective and environmental-friendly material very useful even in rural housing industry. FaL-G in certain proportions, as a building material, is an outcome of innovation to promote large-scale utilization of fly ash by Bhanumathidas and Kalidas [1]. It gains strength like any other hydraulic cement, in the presence of water, and is water resistant when hardened.

Large amounts of gypsum and fly ash are available at phosphoric acid manufacturing plants and thermal power plants, respectively. These materials can be used to source sulphate and silica alumina. Gypsum contains impurities of phosphate, fluoride, organic matter and alkalies which prevent its direct use as building material. It is one of the calcium sulphate's rich residues. Phosphogypsum is an important by-product of phosphoric acid fertilizer industry. It consists of $CaSO_4.2H_2O$ and contains some impurities such as phosphate, fluoride, organic matter and alkalies. Approximately 5 million tons of phosphogypsum is produced each year in India [2]. Cementitious binder, FaL-G, finds extensive application in the manufacturing of building components and materials such as bricks, ,solid blocks,hollow blocks and lean concrete. FaL-G technology enables production of hollow blocks with a simple process of mixing and water curing. Due to such appropriate technology apart from economy, conservation of energy and pollution control are also achieved [3].

It has been reported that FaL-G mortar can be used in making the masonry hollow block units by different combinations of fly ash, lime and gypsum [4] .FaL-G technology contributes to the conservation of energy and reduces environmental degradation [5]. Since it is manufactured using industrial wastes and by-products, the environmental impacts are mitigated. FaL-G plants have the advantage of continuous year-wide operation and hence provide year-long employment opportunity to skilled artisans.[6] It creates self-help livelihood opportunities for the people. In certain cases, where by-product lime is not available in adequate quantity, ordinary Portland cement is used as the source of lime, producing the same quality of bricks and blocks [7,8].

SCOPE OF THE RESEARCH

FaL-G is relatively economical material derived from base materials like fly ash, lime and gypsum. The research reported till date speaks about the random use of the material without any rational approach. The report on proportioning, strength development in FaL-G is very less. Also there is large scope for the development of FaL-G compressed blocks/bricks made from mortar. In this research, FaL-G mortar hollow blocks were prepared and various properties were studied.

MATERIALS AND METHODS

A Class F fly ash was procured from Raichur thermal power plant. Locally available lime was slaked and sieved through 1.18 mm sieve and stored in air tight container. Dry calcinated phosphogypsum was procured from a fertilizer industry. The weighed quantity of fly ash and gypsum were mixed in dry condition. Lime was added to the mixture to obtain a uniform mix. This mix was termed as FaL-G binder.

TABLE 1: MIX PROPORTIONS OF FAL-G BRICKS

Mix designation	FaL-G Binder proportion			Fine aggregate	FaL-G Binder : Fine aggregate Ratio
	Fly ash	Lime	Gypsum		
H1	50	40	10	Stone dust	1:1
H2	50	40	10	Stone dust	1:1.5
H3	55	35	10	Stone dust	1:1
H4	55	35	10	Stone dust	1:1.5
H5	60	30	10	Stone dust	1:1
H6	60	30	10	Stone dust	1:1.5
H7	65	25	10	Stone dust	1:1
H8	65	25	10	Stone dust	1:1.5
H9	50	40	10	Sand	1:1
H10	50	40	10	Sand	1:1.5
H11	55	35	10	Sand	1:1
H12	55	35	10	Sand	1:1.5
H13	60	30	10	Sand	1:1
H14	60	30	10	Sand	1:1.5
H15	50	40	10	Sand	1:1
H16	50	40	10	Sand	1:1.5

FaL-G mortar was prepared using FaL-G as binder and Quarry dust, sand and pond ash as fine aggregates. The procedure adopted was same as that of cement mortar. Tap water was used to mix the ingredients. The ingredients were mixed thoroughly by kneading until the mass attained uniform consistency. FaL-G mortar is a dry frictional material at water/binder ratio of 0.2. FaL-G compressed hollow blocks were prepared using FaL-G mortar at various binder-fine aggregate ratios. The details of mix used for preparing FaL-G hollow blocks are shown in **Table 1**. The hollow blocks were designated as B1 – B24 for convenience.

Moulds of internal dimension 400 mm x150 mm x 200 mm were used for casting the compressed hollow blocks. The FaL-G mortar mix was placed in the moulds in two layers. Each layer was compacted and compressed using a vibrating table. The compressed brick was then de moulded and stored on the platform. They were cured in wet gunny bags for a day or two. Later they were cured by sprinkling water till the age of 28 days or date of testing whichever was earlier. The properties of FaL-G hollow blocks were studied i.e., dry density, Initial rate of absorption, water absorption, Compressive strength of block and stress- strain characteristics.

RESULTS AND DISCUSSION

The properties of the FaL-G bricks are indicated in **Table 2** for all the series considered. It was found that the density of FaL-G hollow blocks was in the range of 1.465 to1.654 g/cc for all the series. This density was marginally less compared to the conventional concrete hollow block available in the market. The initial rate of water absorption of the bricks varied from 3.92 to 4.4 kg/m^2/min which is considered as less as per ASTM C-67 [9]. The percentage of water absorption was found to be less than 17.56% for all the series against the maximum limit of 20% as per IS 3495-1976[10].

TABLE 2: **PROPERTIES OF HOLLOW BLOCKS OF SIZE 400MM X150MM X 200MM**

Mix designation	Average Dry density in g/cc	Average Initial rate of absorption of brick in kg/m^2/min	Average water absorption of brick in %
H1	1.635	3.960	15.786

Mix designation	Average Dry density in g/cc	Average Initial rate of absorption of brick in kg/m²/min	Average water absorption of brick in %
H2	1.654	3.928	15.712
H3	1.622	3.981	15.924
H4	1.637	3.944	15.804
H5	1.597	4.040	16.159
H6	1.619	3.986	16.052
H7	1.585	4.072	16.287
H8	1.612	4.003	16.147
H9	1.535	4.197	16.788
H10	1.568	4.113	16.617
H11	1.507	4.273	17.089
H12	1.534	4.202	16.919
H13	1.492	4.348	17.262
H14	1.507	4.274	17.094
H15	1.465	4.408	17.564
H16	1.481	4.346	17.410

Parameters:

- Age: 7, 14, 28, 56, 72 and 90 days
- Binder-to-aggregate ratio: 1:1 and 1:1.5
- Quantity of fly ash : 50, 55, 60 and 65%
- Quantity of lime : 25, 30, 35 and 40%

Figure 1, 2 and 3 show the variation of compressive strength of the FaL-G hollow blocks with age for quarry dust, and sand respectively. It is quite obvious that the strength increases with age in all the cases. It is due to continues reaction between the FaL-G binder and water as discussed in the introduction. The compressive strength was around 4 MPa at the age of 28days and around 5.5 MPa at the age of 90 days. The minimum strength at the age of 28 days is more than 3MPa in most of the cases. This strength would be sufficient to use them as masonry units as per IS 3495-1976 [10].

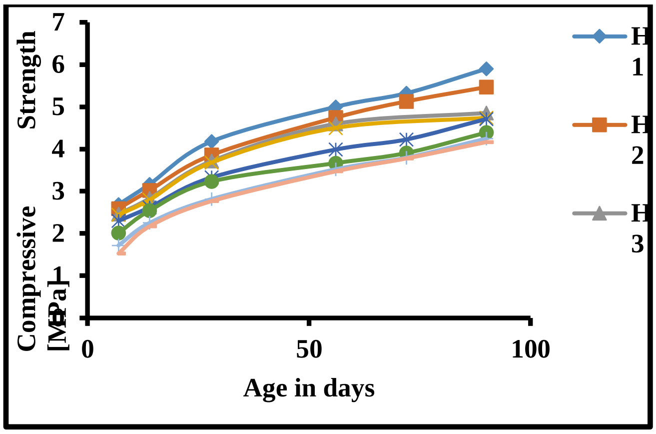

Fig. 1. Variation of Compressive Strength with age with Stone Dust as fine aggregate.

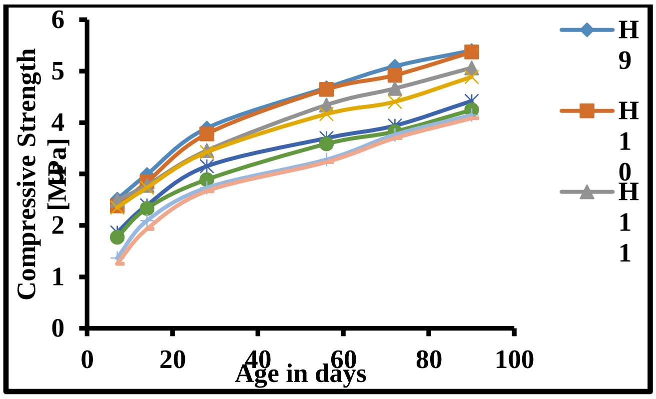

Fig. 2. Variation of Compressive Strength with age with Sand as fine aggregate

Figure 3 indicates the compressive strength of FaL-G bricks at the age of **7, 14, 28, 56, 72 and 90** days in order. The column indicates the strength of the brick having binder-to-aggregate ratio of **1:1** and with ratio of **1:1.5**for different series **H1to H8**with quarry dust as fine aggregate. Similarly **Figure 4** indicates for different series **H9 to H16** with natural sand as fine aggregate. It can be observed that as the ratio of binder-to-aggregate increases the strength decreases in all the cases. It is due to less binder availability in the mortar.

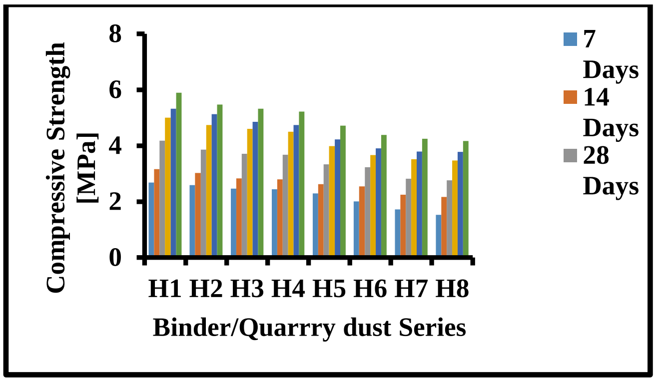

Fig. 3. Compressive Strength of H1 to H8 of Binder/Quarry dust Series for various ages

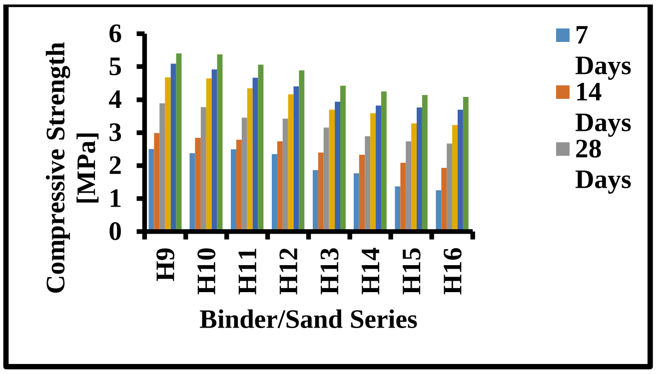

Fig. 4. Compressive Strength of H9 to H16 of Binder/Sand Series for various ages

The series considered for the variation of fly ash with H1 to H8 [binder/quarry dust series] and H9 to H16 [binder/Sand series] with 50, 55, 60 and 65% of fly ash respectively. For convenience, the age of the blocks are considered up to 90 days with quarry dust and sand as fine aggregate. **Figure 5** indicates the variation of compressive strength with the percentage of fly ash. It was found that the compressive strength decreases with the increase in fly ash content, the optimum being 50%. Same observation was found in the research reported by Radhakrishnan [4]. The series considered for the variation of lime from H1 to H16 series with 40 35, 30 and 25% of lime respectively. The variation of compressive strength with the lime content is shown in **Figure 6**.

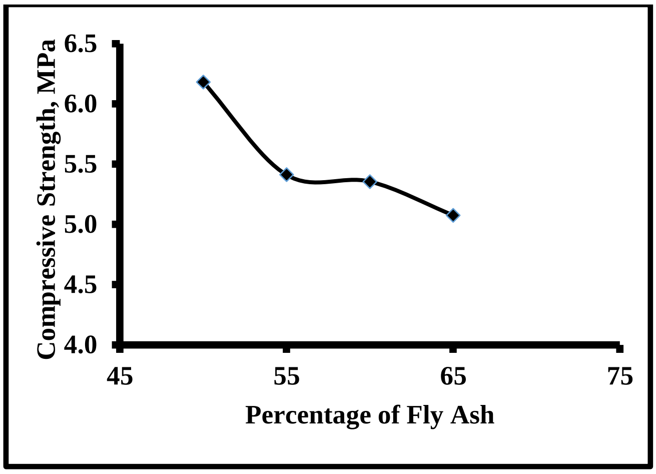

Fig. 5. Variation of Compressive Strength with fly ash content

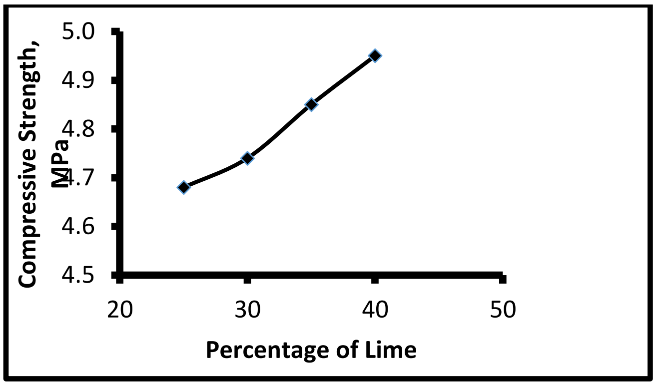

Fig. 6. Variation of Compressive Strength with lime content

It can be noticed that the increase in lime content increases the strength. In FaL-G, as the fly ash content increases the lime content should decrease as the gypsum is maintained at 10%. Modulus of elasticity of hollow block were tested at 28 days for the series H1[50:40:10],H3[55:35:10] with quarry dust as fine aggregate, H9[50:40:10],H11[55:35:10] with natural sand as fine aggregate. The modulus of elasticity was found to be 1768 MPa, 1666 MPa,1876 MPa and 1527 MPa at the age of 28 days respectively. **Figures 7, 8 9and 10** represents the stress-strain behaviour for different series of the hollow blocks. This range of modulus of elasticity is quite satisfactory to use these bricks as masonry units.

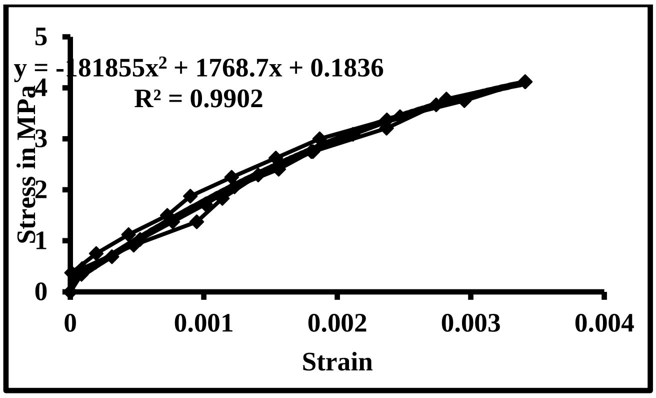

Fig. 7. Variation of Modulus of elasticity at 28 days of series H1[50:40:10][QD]

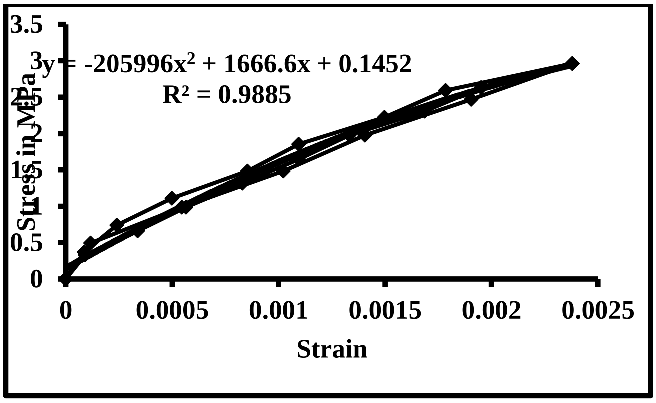

Fig. 8. Variation of Modulus of elasticity at 28 days of series H3[55:35:10][QD]

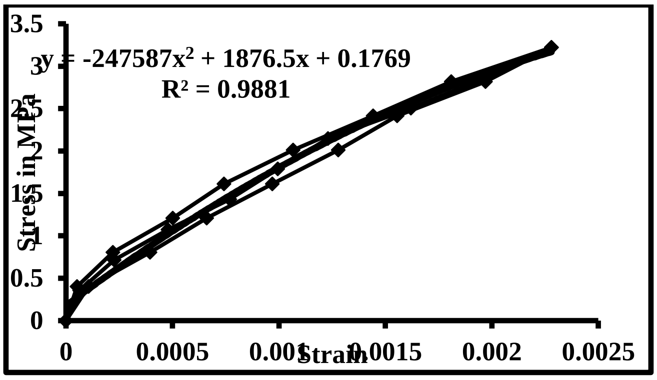

Fig. 9. Variation Modulus of elasticity at 28 days of series H9[50:40:10][Sand]

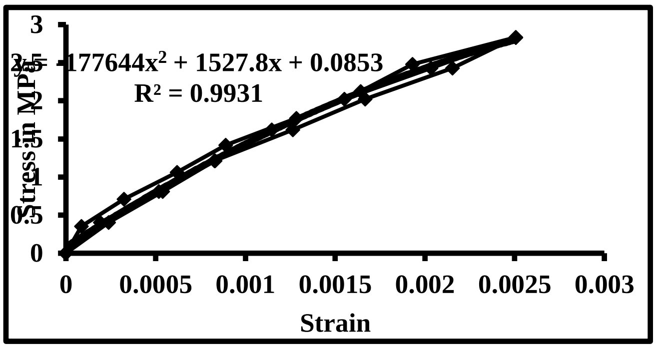

Fig. 10. Variation Modulus of elasticity at 28 days of series H11[55:35:10][Sand]

CONCLUDING REMARKS

- FaL-G compressed masonry hollow blocks can be prepared economically by using industrial wastes like fly ash, lime, gypsum, stone dust and Sand.
- It was found that the dry density, IRA and water absorption of FaL-G compressed bricks were in the range of 1.465 to1.654 g/cc., 3.92 to 4.4 kg/m²/min and less than 17.56 % respectively.
- The hollow blocks attained considerable strength around 4MPa at the age of 28 days to use them as masonry units with adequate modulus of elasticity.
- In view of the above, it can be concluded that FaL-G masonry units can effectively replace conventional masonry units.

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