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Study on use of Industrial Waste in Preparation of Green Bricks

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Abstract

Background/Objectives:The present generation of fly ash in the country is about 90 million tonnes and quarry dust is about 65 million tonnes. The utilization of fly ash in cement and other related industries is less than 10%. Safe disposal of remaining fly-ash and quarry dust has become a challenging problem. It is therefore necessary to utilize fly-ash and quarry dust in structural elements. 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 and the burning of these fossil fuels liberate green house gases which cause depletion of ozone layer. Also, continuous removal of topsoil, in producing conventional clay bricks, creates environmental problems. **Methods/Statistical Analysis:** A feasibility study was undertaken on Fly ash-Lime-Gypsum (FaL-G) bricks and Quarry dust-Fly ash-Lime-Gypsum (QuFaL-G) bricks to use as a building element. The bricks of size 220 x 100 x 75mm were casted to study the strength and durability characteristics. Results shows that the compressive strength of FaL-G bricks was 8.2 N/mm^2 on the 28th day, which is much higher than the conventional burnt clay bricks (>3.5 N/mm^2). **Findings:**The water absorption property of FaL-G brick is lesser than the water absorption of normal good quality burnt clay bricks (20%). **Applications/Improvements:** In view of the strength and durability characteristics of these bricks, it can be used in place where the fly ash and quarry dust available more in quantity to solve the consequences of pollution and at the same time to build houses economically by utilizing industrial wastes.

Keywords: Fly Ash, FaL-G Bricks, Gypsum, Lime, QuFaL-G Bricks

1. Introduction

In India there is a higher demand for housing. The enormous increase in construction activities have coupled in years and have made housing a great deal in today's world. The most basic building material for construction of houses is the usual burnt clay brick[1]. Enhanced construction activities, shortage of conventional building materials and abundantly available industrial wastes have promoted the development of new building materials. The rapid increase in the capacity of thermal power generation in India has resulted in the production of a huge quantity of fly ash, which is approximately 90 million tons per year. The prevailing disposal methods are not free from environmental pollution and ecological imbalance. Large stretches of scarce land, which can be used for shelter, agriculture or some other productive purposes, are being wasted for disposal of fly-ash[2–6]. Fly ash, lime and gypsum are available in mutual proximity in many regions. An economical alternative to conventional burnt clay bricks will be available, if these materials can be used to make bricks having adequate strength. Lime and gypsum are usually available either from mineral sources or may be procured from industrial wastes. Gypsum 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 alkalis. Approximately 5 million tons of gypsum is

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produced each year in India and causes serious storage and environmental problems[7]. Cementitious binder, FaL-G, finds extensive application in the manufacturing of building component such as bricks. The FaL-G technology enables production of bricks with a simple process of mixing, pressure-free moulding and water curing. Due to such appropriate technology, apart from achieving economy, conservation of energy and pollution control are also achieved. The next major pollution causing agent is the Quarry dust; it is produced as a reject from stone crushers (about 65 million tons per year). By their very nature, quarry operations involve drilling, blasting, handling and movement of significant quantities of often dry material[8]. At almost all stages of extraction and processing, there is a potential to produce and emit dust to the atmosphere. In some situations, this dust can contain harmful substances such as quartz and this clearly requires special attention. Hence to design effective mitigation systems for both potential use and fugitive dust emissions, the quarry dust can be utilised effectively in brick making process. Hence Quarry dust is used as a one of the constituent in the production of FaL-G brick to produce Quarry dust FaL-G (QuFaL-G) brocks.

2. Experimental Programme

2.1 Materials Used

The materials used for the production of FaL-G and QuFaL-G bricks are Fly-ash, Lime, Gypsum and Quarry dust.

2.2 Mix Proportions

The mix proportions of FaL-G and QuFaL-G bricks used in this study are given in Table 1 and Table 2. In the present study for QuFaL-G bricks, Mix proportion M1 was selected from the FaL-G brick and Quarry dust substitution of 15, 25 and 35% in fly ash was adopted.

Table 1. Mix proportions of FaL-G bricks

Symbols	Constituent Materials (%)		
	Fly-ash	Lime	Gypsum
M1	75	15	10
M2	70	20	10
M3	65	25	10
M4	60	30	10

Table 2. Mix proportions of QuFaL-G brick

Symbols	Constituent Materials (%)			
	Fly-ash	Lime	Gypsum	Quarry dust
M5	60	15	10	15
M6	50	15	10	25
M7	40	15	10	35

2.3 Specimen Preparation

2.3.1 Fabrication of Moulds

The moulds for casting the bricks were prepared with wood and fibre plastic material. The internal dimensions of the moulds were 220 x 100 x 75mm[9,10]. The brick moulds were prepared in their commercial size, so as to make easy comparison with the properties of commercial burnt clay bricks available in the markets of Tamil Nadu.

2.3.2 Mixing of Raw Materials

To produce FaL-G bricks, the required quantities of fly ash, lime[11–13] and gypsum were batched by weight and mixed thoroughly in dry state. The gypsum and fly ash were sieved through a 4.75 mm sieve whereas lime was sieved through a 1.18-mm sieve. Water content used was fixed as 45% on the basis of standard normal consistency test. The ingredients were mixed thoroughly by kneading until the mass attained a uniform consistency. The same procedure was followed for the mixing of QuFaL-G bricks, but Quarry dust was added in addition to Fly-ash, lime and Gypsum.

2.3.3 Casting of Bricks

Dry sheet of papers were placed on the floor and the moulds were kept on it. A very thin coat of lubricant (Grease or oil) is applied to the inner sides of the mould before the casting process. The FaL-G slurry mix was placed in moulds in two layers and were properly compacted, then the moulds were removed within 10mins and the raw bricks were left to dry. The same procedure was followed for the preparation of QuFaL-G bricks.

2.3.4 Curing Method Adopted

The bricks taken out from the moulds were left to dry for 48hrs and then the bricks were covered with wet gunny bags for two to three days. After two to three days, when the brick specimens had attained sufficient strength for handling, they were transferred to the water filled curing tanks at 23±2^{0}C until the testing periods.

3. Testing of FaL-G and QuFaL-G Bricks

3.1 Compressive Strength

The compressive strength of FaL-G and QuFaL-G bricks were determined by placing the brick between two 3-ply plywood sheets each of 3mm thickness and carefully centring them between the plates of the compression testing machine[14]. Axial load was applied at a uniform rate till the failure and the maximum load was noted.

3.2 Water Absorption

The water absorption of FaL-G and QuFaL-G Bricks were determined by immersing the bricks completely in clean water at a temperature of 27±2 ^{0}C for 24 hours. The specimens were removed from water, left to dry for 3minutes and were weighed after wiping out the traces of water with a damp cloth. The difference in weight of the brick before and after immersion, expressed as percentage of initial dry brick weight was considered to be the water absorption of the brick[15].

3.3 Sulphate Intrusion

The durability of FaL-G and QuFaL-G bricks was investigated by curing these bricks in an aggressive sulphate environment and testing their compressive strength. The FaL-G and QuFaL-G bricks were taken out from the moulds and were covered with wet gunny bags for a week. After one week, when the specimens had attained sufficient strength for handling, these bricks were transferred to the Sulphate solution filled curing tanks at 27±2 ^{0}C instead of water. The sulphate solution having a sulphate (SO_4) concentration equal to 10,000 ppm was prepared in the laboratory by mixing 14.79 gm of Na_2SO_4 in 1 litre of water.

4. Experimental Results and Discussions

4.1 Compressive Strength

The compressive strength of various mix proportions of FaL-G and QuFaL-G brick at various curing period are provided in the Table 3 and 4. From the test results, it can be observed that the compressive strength of mix M1 is increasing with an increase in curing period (Figure 1). For the Mix ratio M1 the increase in compressive strength from 7days to 14 days and 14 days to 28 days are 23% and 37% respectively. The same trend was observed in the mix ratios M2, M3, M4, M5, M6 and M7 which is illustrated in Figure 1 and Figure 2.

The results indicate that, the compressive strength of the FaL-G and QuFaL-G bricks for all the mixes used in this study gives higher strength at the age of 7 days itself when compared to normal burnt clay brick (>3.5N/mm^2). The compressive strength of QuFaL-G bricks shows better results (Figure 3.) when compared to FaL-G bricks, as the Quarry dust introduction into the FaL-G mortar has provided a coarser medium in the brick may be the reason for increase in the strength of the QuFaL-G brick.

Table 3. Compressive strength of FaL-G bricks

Symbols	Compressive strength (N/mm^2)		
	7th day	14th day	28th day
M1	5.6	6.9	9.5
M2	4.5	5.8	8.6
M3	4.3	5.5	8.4
M4	4.4	5.5	8.3

Table 4. Compressive strength of QuFaL-G bricks

Symbols	Compressive strength (N/mm^2)		
	7th day	14thday	28th day
M5	5.2	7.1	9.1
M6	5.6	7.6	9.8
M7	5.1	7.1	9.2

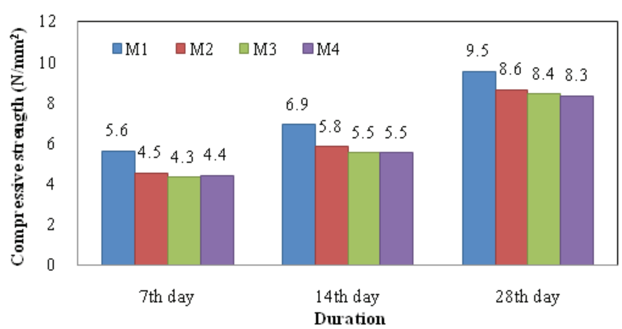

Figure 1. Compressive strength of FaL-G bricks.

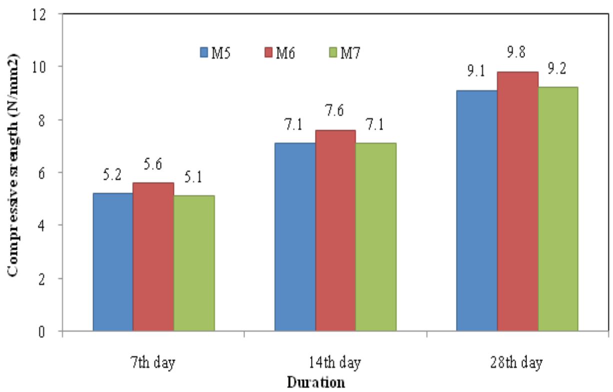

Figure 2. Compressive strength of QuFaL-G bricks.

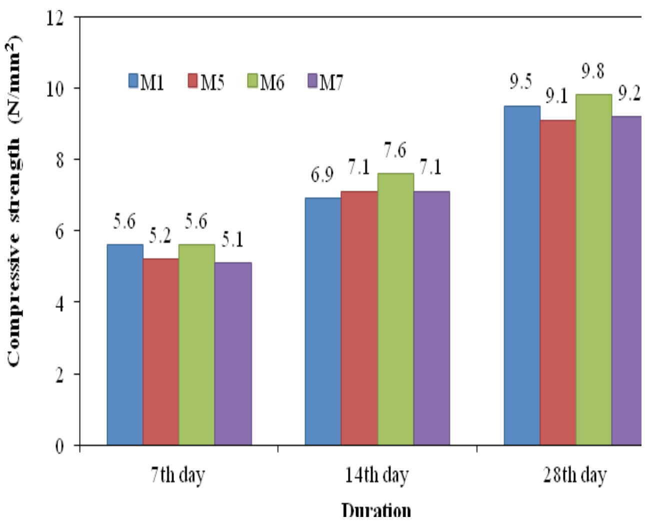

Figure 3. Compressive strength comparison of FaL-G and QuFaL-G bricks.

4.2 Sulphate Intrusion

The effect of sulphate intrusion on on compressive strength of various mix proportions of FaL-G and QuFaL-G brick with respect to aging are provided in the Table 5. The bricks subjected to sulphate intrusion also exhibited the similar trend in the strength increase with respect to its age but their strength magnitudes were lesser when compared to the bricks cured under normal water. The percentage decrease in compressive strength of brick after 28 days sulphate intrusion was 1% for the mix M1, M2; 4% for the mix M3, M5, M6; 8% for the mix M7 and there was no change in the compressive strength of the mix M4. These results are nearly equal to the compressive strength of the brick subjected to normal water curing. On sulphate attack QuFaL-G bricks showed greater resistance (Figure 4.) than FaL-G bricks, as the absorption capacity of QuFaL-G bricks are lesser than FaL-G brick.

Table 5. Compressive strength of FaL-G bricks after sulphate intrusion

Symbols	Compressive strength (N/mm^2)		
	7th day	14th day	28th day
M1	5.4	6.6	9.1
M2	4.3	5.6	8.1
M3	4.2	5.4	8.0
M4	4.2	5.2	7.9
M5	5.2	7.0	8.9
M6	5.4	7.3	9.3
M7	5.0	6.9	8.8

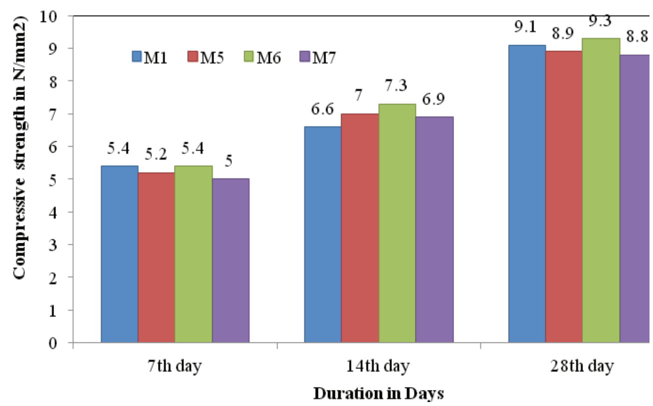

Figure 4. Compressive strength comparison of FaL-G and QuFaL-G Bricks after sulphate intrusion.

In general the reduction in compressive strength due to sulphate intrusion was marginal. The FaL-G bricks showed a decrease of 0–4% and the QuFaL-G bricks showed a decrease of 4–8% when compared to bricks cured under normal water. From the experimental results obtained, it can be observed that the FaL-G brick has higher compressive strength than normal burnt clay brick and the QuFaL-G bricks give higher strength than sulphate intruded FaL-G and normal burnt clay brick.

4.3 Water Absorption

Test results for water absorption of FaL-G and QuFaL-G bricks of various mix proportions and various curing periods are provided in Table 6. The water absorption of FaL-G bricks increases with increase in curing periods, but in QuFaL-G bricks there is no variation in water absorption with the aging. In general, the test results indicates that the maximum water absorption property for the various mix proportions of FaL-G brick is 16% and QuFaL-G brick is 11%, It is less when compared to the permissible water absorption limit of 20% on burnt clay bricks.

The QuFaL-G bricks absorb lesser water than FaL-G brick (Figure 5.) as the pores inside the FaL-G brick are reduced by the substitution of Quarry dust and it is stabilised with the increase in curing period.

Table 6. Water absorption of FaL-G brick

Symbols	Water absorption (%)		
	7th day	14th day	28th day
M1	12	13	15
M2	14	14	16
M3	13	14	16
M4	13	14	16
M5	08	08	08
M6	09	10	10
M7	11	11	11

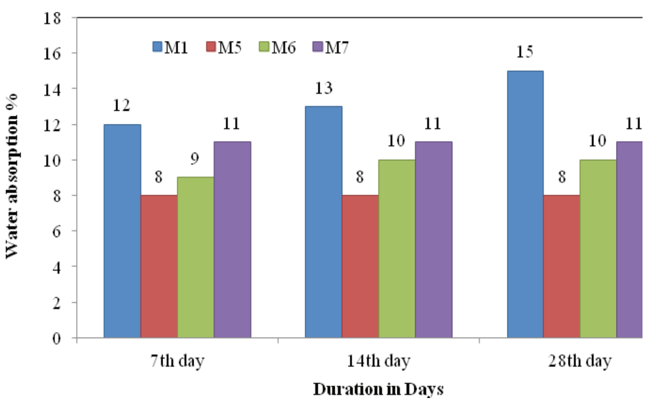

Figure 5. Water absorption comparison of FaL-G and QuFaL-G bricks.

5. Conclusions

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

- The compressive strength of bricks of all mix proportions of FaL-G bricks was above 8.2 N/mm^2 on the 28th day, which is much higher than the compressive strength of conventional burnt clay bricks (>3.5 N/mm^2).
- The FaL-G brick was subjected to sulphate intrusion also shows a compressive strength more than 8.0 N/mm^2, it is also more than the compressive strength of conventional burnt clay bricks.
- The water absorption property of all proportion of FaL-G (<16%) and QuFaL-G brick (<11%) is lesser than the water absorption of normal good quality burnt clay bricks (<20%).
- The compression strength of all mix proportions of the QuFaL-G bricks was above 9.1 N/mm^2. It is more than the compressive strength of FaL-G bricks, hence it is stronger than FaL-G and conventional burnt clay brick. The similar trend was observed in compressive strength of sulphate intrusion bricks also.
- QuFaL-G bricks can be appreciably preferred to FaL-G bricks, in regions where Quarry dust is available in mutual proximity.
- These bricks require no skilled labour and can also be moulded in to any shape and size depending upon the requirements similar to conventional brick. Hence the FaL-G and QuFaL-G brick provides a good alternative and replacement for the burnt clay bricks.

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