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511
SLAG LIME BRICK

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Investigations on the prospects for development of slag-lime bricks

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The ever increasing demand for burnt clay bricks has necessiated the development of alternative walling units based on various industrial wastes as raw materials with a view to reducing the pressure on agricultural land. Preliminary investigations were carried out to explore the possibility for making sand-lime type of bricks, using granulated blast furnace slag, a by-product obtained during the manufacture of iron and steel. Laboratory results revealed that good quality bricks can be produced at sufficiently low pressure of 5 Mpa and the manufacturing process of these bricks does not require firing or autoclaving for strength development. Sufficient strength was obtained even by moist curing. Techno-economic feasibility for the manufacture of slag-lime bricks is envisaged in the vicinity of steel plants.

Clay bricks are being widely employed in construction activities since times immemorial. The quality of these bricks depends on the type of soil used. In many parts of the country, good quality bricks cannot be produced due to non availability of suitable soils. With the increasing demand of bricks, the reserves of agricultural soils are also depleting day by day. The estimated annual demand of bricks in the country is of the order of 70,000 million units, whereas the current level of production is about 55,000 million units. In view of the huge demand along with non-availability of suitable soils, the need to explore some alternate raw materials and technologies for making bricks has been identified.

Calcium silicate brick popularly known as sand-lime brick is a futuristic building material[1,2]. These bricks are made from sand/siliceous material and lime. The mixture is pressed at a high pressure of 15-20 Mpa and then autoclaved to achieve the desired strength. Sand lime bricks are known to have certain properties superior to clay bricks. They possess good crushing strength, no efflorescence, better fire resistance, no need of plastering and can be manufactured in all seasons. Although the prospects of sand lime bricks as walling material are promising, yet large scale production of these bricks require huge capital investment on plant and machinery, enormous quantity of particular type of sand and considerable amount of energy for autoclaving.

The manufacture of bricks using different types of mining/industrial wastes has been envisaged to develop energy conservative methods which do not require heavy and expensive plant and machinery. Amongst the various industrial wastes, granulated blast furnace slag is the one which is obtained as a by-product during the manufacture of iron and steel. This slag can be used beneficially in the manufacture of good quality bricks. The bricks can be produced by mixing and pressing a mixture of coarse and ground slag with small quantity of suitable activator such as lime or portland cement. The production of such bricks will help in saving energy and also spare pressure on land for agriculture and housing. This paper describes the preliminary investigations carried out for manufacturing slag-lime bricks and its techno-economic feasibility.

Raw Materials

The raw materials used for slag-lime bricks are granulated blast furnace slag and hydrated lime (or portland cement).

Granulated blast furnace slag

A commercial sample of granulated slag was taken for the study. The granulated slag[3] is obtained in granular form by quenching molten slag in large excess of water. It is a glassy material and possesses latent hydraulic property. The hydraulic property of the slag depends on the presence of glass content as well as on its chemical composition. The hydraulic property of the slag can be increased by increasing surface area and also by adding a suitable activator. Formation of hydraulic constituents depends upon the hydraulic index of the slag used. This was calculated by the formula:

$$(CaO + MgO + Al_2O_3) / SiO_2$$

and found to be 1.06. This is well within the specified limits prescribed in the Indian Standard IS: 455-1989[4].

The significant chemical and physical properties of the slag used determine the final properties of the product. The same were determined and are reported in Tables 1 and 2. The analyses were carried out as per the existing standard methods.

Lime

The quality of lime used is very important for making bricks. The hydrated lime should be of good quality conforming to class "C" as per IS:712-1984[5]. A commercial sample of hydrated lime collected from a high calcium lime source was used. Its physical and chemical properties are reported in Tables 3 and 4, respectively.

Portland cement

Commercial portland cement was procured and used in this study. The physical properties of the cement were determined and the same are reported in Table 5. The cement passes the Indian Standard Specifications[6] as per IS:269-1989.

Preparation of slag-lime briquettes

Stipulated proportion of coarse and fine slag in the ratio of 1:1 by weight were mixed thoroughly with different percentages of dry hydrated lime or portland cement. About 5-10 per cent of the activator was observed to be sufficient to achieve maximum strength. Calculated amount of water is then added to have a semi-dry mixture. The briquettes of size 10×5×3 cm were pressed by a hydraulic machine at 5 Mpa. After demoulding, these briquettes were cured at 95 per cent relative humidity and a temperature of 27±1°C till the time of testing.

Cured briquettes were tested for compressive strength after 28 days in saturated condition and the results are reported in Table 6. The strength increases with the increase of lime or portland cement content from 5 to 10 per cent. The binder consisting of 5 per cent of lime and 5 per cent of portland cement yields optimal results.

The conversion factor for converting briquette strength to full size brick strength[7] is 0.8. Therefore, the compressive strength of full size bricks were calculated and the same are reported in Table 6. It is observed that full size bricks of strength exceeding 14 Mpa can be manufactured even by using 5 per cent lime or portland cement. The slag lime bricks of density 2,000 kg per cubic metre possess 16-18 per cent water of absorption.

Mechanism of strength development

In slag-lime bricks, the strength development takes place in three different ways:

(i) When slag is brought in contact with water[8,9], initially it reacts very fast and the reaction ceases because of the formation of thin layer of silica rich gel over the surface. By adding alkaline activator, however, the structure of gel is broken and the cementitious products are formed. Formation of these products depends upon the hydraulic index of

Table 1—Physical properties of granulated slag

Shape	granular
Specific gravity	2.89
Bulk density	1075 kg/cu.m.
Glass content	95 per cent
Size	less than 2.5 mm
Fineness modulus	2.4

Table 2—Chemical analysis of granulated slag

Constituent	Percentage
Silica	36.75
Alumina	17.00
Calcium oxide	39.00
Magnesium oxide	5.20
Iron oxide	0.60
Manganese oxide	0.50

Table 3—Physical properties of lime

Property	esults
Workability (bumps)	50
Volume yield (ml/gm)	1.89
Popping and pitting	Nil
Plasticity	240

Table 4—Chemical analysis of hydrated lime

Constituent	Percentage
Silica + Insoluble	0.26
Alumina + Iron	0.58
Calcium oxide	97.00
Magnesium oxide	0.54
Available lime	96.00

Table 5—Properties of portland cement

Property	Results	Specifications (IS:269-1989)
Fineness (m^2/kg)	340	Not less than 225
Setting time (minutes)		
Initial	135	Not less than 30
Final	205	Not more than 600
Compressive strength (Mpa)		
72±1 hr	24.5	Not less than 16
168±2 hr	34.6	Not less than 22
672±4 hr	44.0	Not less than 33
Soundness (mm)		
Le-Chatelier's expansion	1.2	Not more than 10

Table 6—Compressive strength of slag-lime/cement briquettes and bricks

Mix No.	Slag	Lime	Portland Cement	Compressive strength (Mpa) Briquettes	Bricks (Estimated)
1.	95	5	—	25.2	20.16
2.	90	10	—	27.0	21.60
3.	95	—	5	18.0	14.40
4.	90	—	10	25.8	20.64
5.	90	5	5	28.0	22.40

granulated slag and are responsible for the strength development.

(ii) Another important factor for strength development depends upon the grading of the granulated slag used. In the case of sand lime bricks, maximum strength of the bricks is obtained by taking well graded sand. Similarly in slag lime bricks a mixture of coarse and ground slag give optimal results.

(iii) The mixture of coarse and ground slag with lime or portland cement is subjected to a pressure of 5 Mpa. Besides providing a dense mass, this pressure helps in providing closer interaction of slag and lime particles i.e. a solid to solid reaction takes place between lime and slag, and this results in strength development in the slag-lime bricks.

Techno-economic feasibility

The economics of production of slag-lime bricks was calculated and the major aspects are reported in appendix-I.

Conclusions

(i) Good quality bricks can be produced by utilizing approximately 90-95 per cent of granulated slag—an industrial by-product.

(ii) Production of bricks from slag without using clay will reduce the excessive pressure on agricultural land.

(iii) Production of slag-lime bricks does not require firing or autoclaving. Therefore, the energy consumption will be less compared to conventional burnt clay and sand lime bricks.

(iv) Production of slag-lime bricks requires less moulding pressure compared to that for the sand-lime bricks.

(v) The cost of production of slag-lime bricks are comparable to those of burnt clay and sand lime bricks.

The process of manufacturing slag lime bricks is simple and does not require any sophisticated plant and machinery, firing or autoclaving. Slag lime bricks can be used after 28 days of moist curing. Thus, the slag lime bricks with maximum utilization of granulated slag can be manufactured beneficially in the vicinity of iron and steel industry.

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Appendix I—Techno economic feasibility

Capacity—10,000 bricks per day (3,000,000 bricks per year of 300 working days)

			Rs. in lakh
A Total Capital Investment			
(i) Land, Building & Shed			6.50
(ii) Plant and Machinery			3.50
Fixed Capital			10.00
(iii) Working Capital			1.00
Total Capital Investment			11.00
B Cost of Raw Materials			
(i) Unground granulated slag, @ Rs. 100/T		4500 T	4.50
(ii) Ground granulated slag, @ Rs. 160/T		4050 T	6.48
(iii) Hydrated Lime @ Rs. 1500 T		450 T	6.75
			17.73
C Cost of labour, power, water, maintenance etc.			6.70
D Total annual cost of production			24.43
E Cost per thousand of slag lime bricks Rs.			814.00