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SLAG CEMENT:
PHOSPHOROUS SLAG

SUITABILITY OF PHOSPHORUS SLAG FOR MAKING SLAG CEMENT

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PHOSPHORUS slag is a waste product available in India to the extent of about 0.75 million tonnes per year by the end of Fifth Five-Year Plan. It is obtained during the production of phosphorus by the electric furnace method at temperature of 1200-1400° C as per the following reactions:

$$Ca_3(PO_4)_2 + 3SiO_2 = 3(CaO.SiO_2) + P_2O_5$$
slag

$$P_2O_5 + 5C = 2P + 5\,CO$$

The molten slag is quenched in water and is thus obtained in granulated form. The material is not finding any use so far. Investigations were taken up to study its suitability for making slag cement.

Chemical Composition

A representative sample was obtained from M/s. Star Chemicals, Bombay. Chemical composition of the sample is reported.

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Table—1

Constituents	Percentage
Silica (SiO_2)	40.14
Alumina (Al_2O_3)	4.06
Calcium oxide (CaO)	49.02
Magnesium oxide (MgO)	1.94
Phosphorus pentoxide (P_2O_5)	0.56
Loss on ignition	3.72
Total	99.44

Though the composition does not fall within the range recommended in IS 455:1967 for Portland Blast Furnace Cement, it complies with the following two indices recommended in the above standard

i) $$\frac{CaO + MgO + 1/3\ Al_2O_3}{SiO_2 + 2/3\ Al_2O_3} = 1.22$$

ii) $$\frac{CaO + MgO + Al_2O_3}{SiO_2} = 1.37$$

The material was dried at 110°C. A small sample was ground to pass No. 15 I.S. Sieve, suspended in a refractive index liquid and examined under microscope. It was observed to be all glassy in nature. X-ray powder diffraction also showed it to be completely glassy.

Grindability

Slag cements are manufactured either by intergrinding slag and cement clinker with small amount of gypsum or by separate grinding and blending. The latter method is preferred if the grindability of the two materials is much different. In order to recommend one or the other method, grindability of phosphorus slag was studied vis-a-vis that of one sample of cement clinker and two of commercial granulated blast furnace slag as per bond's grindability test. Work index was calculated from the grindability by the empirical equation.

$$Wi = \frac{(16)}{(G.82)} \sqrt{\frac{Y}{100}}$$

Where Wi = the work index

G = Ball mill grindability

Y = Micron size of the mesh of grind

Since 200 mesh equals 74 microns

$$Wi = \frac{13.76}{(G).82}$$

This work index is defined as the KWH required to grind one tonne of material to 80 per cent passing 100 microns.

Approximate power required to grind the material to fineness of 4000 sq. cm./g (Blains) was calculated from the equation

$$W = \frac{IoWi}{\sqrt{P}} - \frac{1oWi}{\sqrt{F}}$$

Where W is the work in KWH/tonne and Wi is the work index.

P and F are the 80 per cent passing sizes in microns of the product and feed material. Results of study are reported

polymerises the structure thus making it compact and less easier to grind. On the other hand, calcium ions have the property of depolymerizing the structure and hence making it easier to grind. Increase of grindability with decrease of alumina content in slags was also shown by Kolhatker and Cherien.

Grindability of phosphorus slag is almost similar to that of cement clinker and hence intergrinding method can be recommended for producing slag cement.

Preparation of Slag Cement

The following materials were taken:

a) Phosphorus slag (Table 1)

b) A cement clinker (Table 3)

c) Gypsum of purity of 95 per cent

The above materials a) and b) were mixed separately in the proportions of 15:85, 25:75 and 36:65 each with four per cent of gypsum on the total weight of the solids. Each mix was ground separately in ball mill to fineness of about 4000 sq. cm./g (Blains). The three samples of slag cements thus prepared were tested as per IS 4031-1968. Single fraction standard Ennore sand was used for casting mortar cubes for compressive strength. The results (Table 4) were compared with those of Portland cement prepared by grinding cement clinker b) with four per cent of gypsum.

TABLE—2

S. No. Material	Grindability gm/revolution	Work index KWH/Tonne	Power reqd. to grind material to 4000 sq.m./g (Blains) KWH/Tonne
1. Phosphorus slag	0.80	21.4	52.4
2. Cement clinker	0.85	20.4	50.0
3. Blast Furnace Slag A	0.70	23.9	61.0
Slag B	0.74	22.8	56.0

Results of grinding rate and power consumption show that the phosphorus slag is softer to grind than blast furnace slag and this appears to be due to its lower alumina and higher calcium oxide content. Aluminium ion in slag glass has been shown to exist in four fold coordination and on account of its excess negative charge, it

Discussion

Addition of slag more than 15 per cent retards the strength development at early ages of curing. This may be due to its alumina content less than the optimum of 15 to 18 per cent and the presence of phosphate which is considered to be a deleterious constituent. However strength of two mixes (15.85 and 25:75) at 28 days and beyond far exceeds that of Portland cement. Similar results were obtained by Kryzhanovkoya. Since these two mixes comply with IS 455:1967, addition of slag up to 25 per cent may be recommended for the manufacture of slag cement. This cement has been shown to have increased resistance to sulphates.

Recommendation

Addition of upto 25 per cent of phosphorus slag to Portland cement is recommended for the manufacture of slag cement. This will solve the problem of disposal of waste phosphorus slag and will add to the production of cement in the country.

TABLE—3

Chemical composition of cement clinker

Constituents	Percentage
Silica (SiO_2)	24.17
Alumina (Al_2O_3)	3.39
Iron oxide (Fe_2O_3)	3.38
Calcium oxide (CaO)	62.42
Magnesium oxide (MgO)	3.21
Sulphur trioxide (SO_3)	0.49
Loss on ignition ($H_2O + CO_2$)	0.46

TABLE—4

S. No.	Properly	Portland cement	Requirements of IS 455-1967	15:85	25:75	35:65
1.	Fineness sq. cm./g (Blains)	3320	Not less than 2250 sq. cm. per g	4100	4100	4100
2.	Setting time (Minutes)					
	Initial	80	Not less than 30 minutes	115	180	180
	Final	254	Nor more than 600 minutes	276	300	320
3.	Compressive Strength kg/cm²					
	3 days	197	Not less than 160	195	151	85
	7 days	280	220	278	215	128
	28 days	308		430	359	276
	90 days	436		509	456	348
	180 days	450		510	503	444
	360 days	458		520	528	450
4.	Soundness (Lechatelier's expansion) mm	1	10	0.5	0.5	0.5

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