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Evaluation of Suitability of Phosphogypsum for Use in the Preparation of Different Building Materials

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Phosphogypsum available as a waste from the phosphoric acid industry to the extent of about 0·9 million tonnes per annum contains phosphates, fluorides and organic matter as impurities, which impede its large scale use. A simple method for improving the quality of phosphogypsum by eliminating the coarse fraction rich in these impurities is described. The resulting product is suitable for use as an additive for cement clinker and also for making calcined plaster, set plaster boards and lightweight blocks for partition walls.

PHOSPHOGYPSUM is a waste product of the wet process phosphoric acid industry. For every tonne of P_2O_5 produced as phosphoric acid, 4-5 tonnes of phosphogypsum containing about 20% moisture are obtained. In India, it is available to the extent of about 0·8 million tonnes per annum. Another 1·8 million tonnes would be available annually from the plants slated to go on stream in the near future.

Disposal of phosphogypsum poses a serious problem, because its inland dumping leads to pollution of ground and river waters and dumping in sea involves huge recurring expenditure.

Phosphogypsum contains phosphates, fluorides and organic matter as impurities. These impurities affect the hydration of cement if the material is used as an additive to cement clinker during its grinding. They also inhibit the hydration and strength development of calcined plaster produced from it. Investigations were taken up to improve the quality of phosphogypsum so as to make it suitable for the above applications.

Experimental procedure

A representative sample of phosphogypsum received from Albright, Morarji and Pandit, Bombay was taken. The sample after drying at 42°C analysed: SiO_2, 6·60; Al_2O_3, 5·86; CaO, 27·76; MgO, 0·25; SO_3, 39·65; P_2O_5, 0·92; F, 1·50; H_2O, 17·84; and organic matter, 0·13%.

Microscopic examination showed agglomerated rhombic and lath shaped crystals of gypsum. X-ray powder diffraction indicated the impurity of $CaHPO_4.2H_2O$ in gypsum. The thermogram showed shifting of transition temperature of $CaSO_4(III)$ to $CaSO_4(II)$ at 360°C for mineral gypsum to 470°C for this material, presumably due to the formation of solid solution of the impurity in gypsum crystal[1].

A sample was washed and wet sieved. The fractions obtained were dried at 42°C and weighed. Sieve analysis of the sample is given in Table 1.

The above four fractions were tested for impurities. The results given in Table 2 indicate that the concentration of impurities

Table 1 — Sieve analysis of different fractions

Fraction No.	IS sieve No.	Retained %
1	300	1·2
2	150	10·4
3	90	49·4
4	−90	39·4

is comparatively high in the fractions retained on IS: 300 and 150 μ sieves, constituting 11·6% of the bulk. To reduce the contents of impurities in the bulk sample, the fractions retained on IS: 300 and 150 μ sieves were discarded.

Suitability for making plaster boards

The remaining two fractions which formed the major portion of the bulk were calcined separately in a laboratory oven at 150°C to form hemihydrate. The two calcined plasters were tested as per Australian standard specification SSA Int. 317. The results are given in Table 3.

The minimum strength specified in the above standard is 84 kg/cm². Hence, the two fractions comply with the specifications. Thus, the use of the plaster can be recommended for making plaster boards.

Test specimens of plaster boards of 30×30 cm size (thickness, 12 mm) reinforced with teased sisal fibre were prepared as per the procedure described earlier[2]. These were tested for breaking load as per Australian Standard No. 44-1950 by holding them at a span of 25 cm and applying load in the middle. The results are given in Table 4.

The minimum breaking load specified for 12 mm thick plaster board is 34 kg. The test specimens pass this requirement and hence the plaster is considered suitable for making plaster boards.

Suitability for making lightweight blocks

The plaster produced was tested for its suitability for making lightweight blocks. It was made into slurry and poured into 5 cm cube moulds. The material set in 30 min. The cubes were demoulded, air dried to constant weight and tested for compressive strength.

The results given in Table 5 show that the material is suitable for making lightweight blocks for load bearing and non-load bearing partition walls as per IS: 2849-1964. However, their use in external situations is normally not recommended, except in dry climates.

Table 2 — Impurities in phosphogypsum

Fraction No.	P_2O_5 %	F %	Organic matter %
1	0·698	0·491	0·075
2	0·624	0·438	0·060
3	0·575	0·391	0·045
4	0·453	0·362	0·035

Table 3 — Characteristics of plasters

Fraction	Consistency %	Setting time min	Bulk density kg/m³	Compressive strength kg/cm²
Retained on IS sieve 90 μ	65	20	1200	95·64
Passing IS sieve 90 μ	64	20	1200	97·21

Table 4 — Strength characteristics of different fractions

Fraction	Consistency %	Breaking load kg
Retained on IS sieve 90 μ	80	37·48
Passing IS sieve 90 μ	80	38·52

Table 5 — Characteristics of lightweight blocks

Fraction	Consistency %	Bulk density kg/m³	Compressive strength kg/cm²
−150+90 μ sieve	80	1040	68·99
	90	9437	59·58
−90 μ sieve	80	1080	72·13
	90	9625	68·85

Suitability for use as additive to cement clinker

The above tests show that the plaster and set products produced from the two fractions retained and passing IS sieve 90 μ have more or less similar characteristics. The two fractions of phosphogypsum were, therefore, combined and the suitability of the mix as an additive to cement clinker was investigated. It was interground with a sample of cement clinker of the following composition: Silica,

Table 6 — Physical characteristics of cements

GYPSUM USED	FINENESS OF CEMENT sq cm/g	SETTING TIME, min		COMPRESSIVE STRENGTH*, kg/cm²				
		Initial	Final	1 day	3 days	7 days	28 days	90 days
Natural selenite	3300	79	254	80·5 (100)	196·8 (100)	280·0 (100)	308·0 (100)	436·0 (100)
Phosphogypsum Untreated	3300	290	500	60·2 (74·8)	112·0 (56·8)	175·2 (62·6)	225·5 (73·2)	300·9 (69·0)
Washed	3435	270	480	62·8 (78·0)	115·3 (89·1)	174·6 (62·4)	227·4 (73·8)	318·4 (73·0)
Passing IS 150 μ, washed	3389	210	365	91·7 (113·9)	192·7 (97·9)	270·0 (96·4)	316·0 (102·6)	443·6 (101)

*Values within parentheses are the percentages of the corresponding data with natural gypsum.

24·17; aluminium oxide, 3·39; iron oxide, 3·38; calcium oxide, 62·42; magnesium oxide, 3·21; sulphur trioxide, 0·49; and loss on ignition, 0·46%. The cements produced were tested as per IS: 4031-1968. The results were compared with those for cements produced under identical conditions using selenite gypsum and phosphogypsum as such and after washing. SO_3 in all cements was kept constant at 1·75%.

The results presented in Table 6 show that experimental cement prepared using phosphogypsum passing IS 150 μ sieve and washed several times has characteristics comparable to those of cement obtained using natural selenite gypsum as additive to clinker. This marks improvement over the results reported earlier[3]. Hence, processed phosphogypsum may be taken to be suitable for use as an additive to cement clinker. Its use would be economical in cement plants situated far from the deposits of natural gypsum.

The use of phosphogypsum in the production of calcined plasters and set plaster products and as an additive to cement clinker, besides solving the problem of its disposal, will help conserve the depleting resources of natural high grade gypsum. Phosphogypsum has the advantages of light weight, fire resistance and thermal insulation.

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References

1. BERRY, E. E. & KUNTZE, R. A., *Chemy Ind.*, **23** (38) (1971), 1072.
2. TANEJA, C. A., *Fibrous gypsum plaster boards*, Building Materials Note 11, Central Building Research Institute, India, Nov. 1971.
3. TANEJA, C. A. & MALHOTRA, S. K., *Res. & Ind., New Delhi*, **18** (1973), 24-25.