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GYPSUM: BINDER

Article

A CASE STUDY ON TECHNO-ECONOMIC FEASIBILITY FOR PRODUCTION OF

WATER RESISTANT BINDER

FROM BY - PRODUCT GYPSUM

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Abstract

Phosphogypsum is a useful by-product available from phosphatic fertilizer plants. It contains some soluble and insoluble impurities which need to be processed prior to the production of water-resistant gypsum binder for use in different building materials. The purification methods of phosphogypsum, preparation of plaster of Paris and production of gypsum binder are described. The major equipment specifications for a 50 tpd plant are given. Techno-economic feasibility aspects of the complete process have been worked out for an envisaged plant at an appropriate location. It is concluded that the of production gypsum binder will conserve the depleting sources of high purity natural gypsum and at the same time will introduce a new low-cast water resistant and thermally insulating material. The twin problem of environmental pollution and health hazards will also be mitigated. The economic viability of the process has been presented.

INTRODUCTION

Phosphogypsum is produced as a by-product in the manufacture of phosphoric acid. It contains impurities of phosphates, fluorides, organic matter, free moisture and small quantities of alkalies which adversely affect the setting and hardening of cements and plasters produced out of it. However after beneficiation, the gypsum has been found to be suitable as evident from the work carried out in some advanced countries, such as, Japan, Federal Republic of Germany, Austria, France etc., where the plaster produced has been used for the production of building blocks, partition panels, and as jointing and moulding plasters (1-2).

Presently, about 4.0 million tonnes of by-product phosphogypsum is produced in India annually. It is being used to a small extent in the manufacture of cement, ammonium sulphate fertilizer and soil reclamation in the country. The bulk of it, however, remains unutilized and creates problems of environmental pollution and health hazards. Effective means of utilization of phosphogypsum are, therefore, called for. Detailed investigations have been carried out in CBRI regarding processing and utilization of this by-product (3-4).

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Article

Gypsum plaster and plaster products are soluble in water and get damaged on continuous exposure to wet conditions. A cheap water resistant binder from by product phospho and natural selenite gypsum has been developed at the Central Building Research Institute, Roorkee by using relatively cheaper materials, like flyash, slags and additives with the gypsum plaster (5-6). A staunch need has been felt for the development of materials which can replace the use of portland cement in masonry and plaster works owing to the everincreasing housing activities in the country. The production of phosphogypsum based water resistant binder is a step forward in that direction.

MAJOR INGREDIENTS AND PROPERTIES

The main raw materials required for the production of water resistant binder are phosphogypsum, flyash/granulated slag and ordinary portland cement. Phosphogypsum whether obtained from the Dihydrate or Hemihydrate-Dihydrate process must conform to the requirements laid down in IS: 12679-1989. Care should be taken to keep the level of impurities within the prescribed limits. Similarly flyash, granulated slag and ordinary portland cement should comply to the requirements given in IS: 3812 (Part I) - 1981, IS: 455-1976 and IS: 269-1976, respectively. Loss on ignition in flyash should not exceed 12% and at the same time the specific surface area of flyash shall be more than 3,200 cm²/g (Blaine's). In case of granulated slag, the glass content should be above 90%. The physical properties of gypsum binder tested as per IS: 4031-1968 and IS: 6909-1973 are given in Table - 1.

TABLE - 1

Physical Properties of Gypsum Binder

Density (kg/m³)	1100-1200
Setting Time (Minutes)	
Initial	95.0
Final	150.0
Compressive Strength (N/mm²)	
1 day	13.7
3 days	19.0
7 days	20.0
28 days	22.0
Soundness (Cold Expansion) mm	0.88
Water absorption (%)	Below 10.0

Durability : No leaching (After 28 days immersion in water)

PRODUCTION METHOD

A production plant of capacity 15,000 tonnes of binder

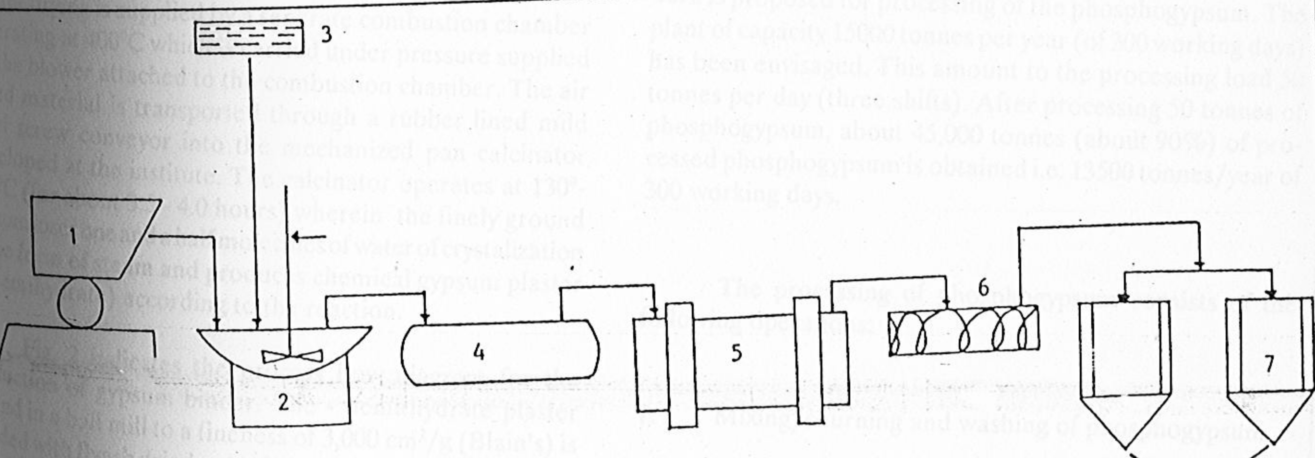

FIG. 1 - PROCESS FLOW DIAGRAM FOR THE BENEFICIATION AND CALCINATION OF PHOSPHOGYPSUM USING MECHANISED PAN CALCINATOR
(1) Trolley (2) Churner (3) Water Reservoir (4) Centrifuge
(5) Rotary Dryer (6) Screw Conveyor (7) Mechanised Pan Calcinator
(8) Storage Bin for β-Hemihydrate Plaster

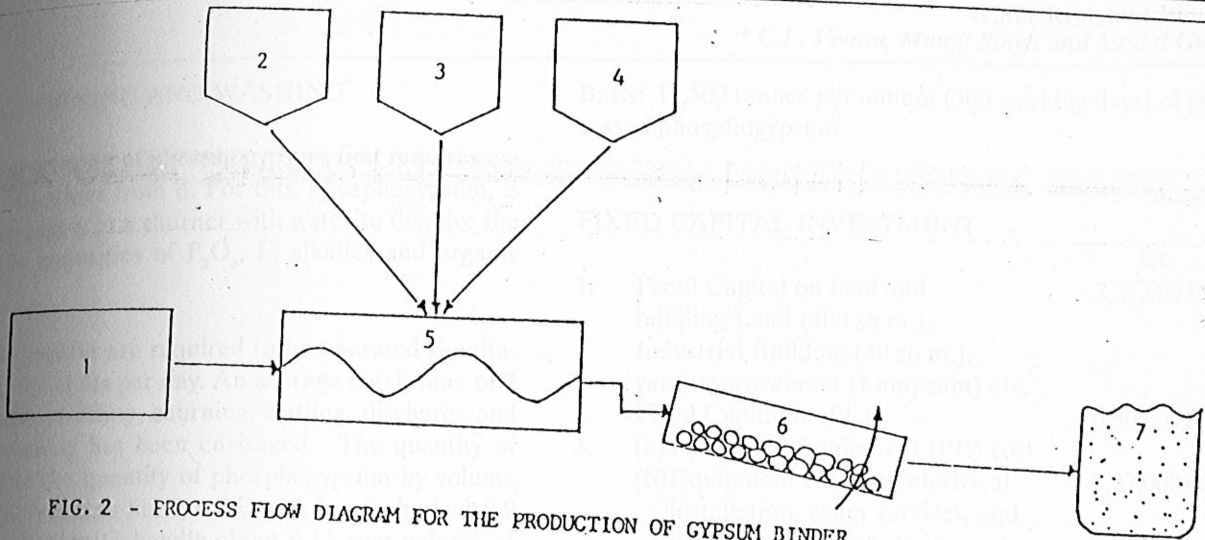

FIG. 2 - PROCESS FLOW DIAGRAM FOR THE PRODUCTION OF GYPSUM BINDER
(1) Storage Bin for β-Hemihydrate (2) Fly Ash (3) Ordinary Portland Cement (4) Retarder (5) Blender (6) Ball Mill (7) Packing

per annum has been envisaged. Fig. 1 depicts the process flow diagram for the beneficiation and calcination of phosphogypsum which is based on the laboratory studies carried out at the Central Building Research Institute, Roorkee. The plant site in the close proximity of the factory producing by-product gypsum is assumed. The processing of phosphogypsum first requires extraction of impurities from it. The raw material is dumped into a water washing unit (churner) through trolleys. Here the phosphogypsum is mixed thoroughly with water soluble impurities of P_2O_5, F, alkalies and organic matter. The slurry is centrifuged and dried in a rotary dryer at 110°C to remove free moisture. Hot air for drying is supplied by a separate combustion chamber operating at 400°C which is carried under pressure supplied by the blower attached to the combustion chamber. The air dried material is transported through a rubber lined mild steel screw conveyor into the mechanized pan calcinator developed at the institute. The calcinator operates at 130°-170°C (for about 3.5 - 4.0 hours) wherein the finely ground gypsum loses one and a half molecules of water of crystalization in the form of steam and produces chemical gypsum plaster (- hemihydrate) according to the reaction.

Fig. 2 indicates the process flow diagram for the production of gypsum binder. The - hemithydrate plaster ground in a ball mill to a fineness of 3,000 cm^2/g (Blain's) is blended with flyash dried at 110°C, ordinary portland cement and retarder in different proportions in a power mixer for a period of one hour followed by grinding the whole mix for a period of half-an-hour to form uniform binder. The binder thus prepared is packaged for marketing

MAJOR PROCESSES AND EQUIPMENT

BENEFICIATION OF PHOSPHOGYPSUM

Based on the data obtained for phosphogypsum sample using simple water washing technique, the following procedure is proposed for processing of the phosphogypsum. The plant of capacity 15000 tonnes per year (of 300 working days) has been envisaged. This amount to the processing load 50 tonnes per day (three shifts). After processing 50 tonnes of phosphogypsum, about 45,000 tonnes (about 90%) of processed phosphogypsum is obtained i.e. 13500 tonnes/year of 300 working days.

The processing of phosphogypsum consists of the following operations:

1. Mixing/churning and washing of phosphogypsum
2. Rotary drying of processed phosphogypsum at 110°C

MIXING/CHURNING AND WASHING

The processing of phosphogypsum first requires extraction of impurities from it. For this, phosphogypsum, is churned thoroughly in a churner with water to dissolve the water soluble impurities of P_2O_5, F, alkalies and organic matter.

Two churners are required to be operated simultaneously in three shifts per day. An average batch time of 3 hours inclusive of filling, churning, settling, discharge and secondary washing has been envisaged. The quantity of water equal to the quantity of phosphogypsum by volume shall be used. A rubber lined, mild steel, hemispherical, 2.9 m diameter churner to handle about 6.15 cum volume of phosphogypsum per batch is required.

DRYING

The washed Phosphogypsum is dried in a rotary drier at 110°C to remove free moisture. Phosphogypsum slurry is treated in hot air supplied by separate combustion chamber which operates at 400°C. The hot air is carried away under the air pressure supplied by the blower attached to the combustion chamber. A rotary dryer operated by parallel in flow with a capacity of 2 tonnes per hour of phosphogypsum is used.

A carbon steel rotary dryer 1.6 m internal diameter and 9.0 m long, is specified. The accessories for the dryer are combustion chamber and blower.

CALCINATION

The mechanised pan clacinator system has two main components, namely, the mechanised mixing system and the furnace. It comprises of a mild steel pan, a vertical power shaft and a number of blades rigidly connected to the vertical power shaft at two levels and a sweeping chain attached at the bottom of the lower set of the mixing lades and a removable lid to cover the pan and allow churning of the gypsum charge without any dust loss; and finally a prime mover alongwith appropriate power transmission mechanisms. The pan has a diameter of 1.25 m and depth 0.7 m. The capacity of each mechanised pan calcinator is about 5 TPD.

CAPITAL OUTLAYS

BENEFICIATION OF PHOSPHOGYPSUM

Basis: 13,500 tonnes per annum (300 working days) of processed phosphogypsum.

FIXED CAPITAL INVESTMENT

		Rs.
1.	Fixed Capital on land and building Land (400 sq.m.), Industrial Building (50 sq.m.), yard improvement (Lumpsum) etc.	2,25,000.00
2.	Fixed Capital on Plant	6,30,000.00
3.	(a) Purchased Equipment (PE) cost	
	(b) Equipment erection, electrical installation, water services, and drainage, instrumentation and control, laboratory and workshop, contingency etc.	3,27,000.00
	Total	9,57,000.00
	Fixed Capital on Plant (1+2)	11,82,000.00

COST OF PROCESSING

1.	Raw materials 15,000 tonnes phosphogypsum	3,00,000.00
2.	Utilities:	
	Power 3,75,948 KWH	3,00,000.00
	Water 14,400 KL	14,000.00
3.	Labour and Supervision (L.S.)	1,32,000.00
4.	Maintenance and repairs (Plant & building)	63,045.00
5.	Depreciation of plant	95,700.00
	Total cost of processing for 13,500 tonnes	9,05,903.00 i.e. Rs.67/tonne

PRODUCTION OF BINDER

Basis: 15,000 tonnes/year (300 working days) of water-resistant gypsum-binder

Capital Investment

A.	Fixed Capital on Building Land (400 sq.m.), Building (50 sq.m.) Shed (300 sq.m.), Yard improvement (Lumpsum) etc.	3,45,000.00
B.	Fixed Capital on Plant	
	(a) Purchased Equipment (PE) Cost	4,90,000.00
	(b) Equipment Erection, Electrical	2,45,000.00

Installation, Instruments & Controls, Water services & Supervision charges etc.	
Fixed Capital on Plant	8,44,500.00
Total Fixed Capital (A+B)	11,89,500.00
C. Working Capital @20% on the Fixed Capital	2,37,900.00
TOTAL CAPITAL INVESTMENT (A+B+C)	14,27,400.00

Cost of Production

1.	Raw Materials	
	(a) Processed Phosphogypsum	8,97,264.00
	(b) Flyash inclusive of transportation charges	1,12,500.00
	(c) Ordinary portland cement	25,50,000.00
	(d) Retarder (Commercial grade)	6,22,500.00
	TOTAL	41,82,264.00
2.	Utilities	12,72, 348.00
	(a) Electrical power 2,68,560 KWH, coal 603 tonnes, packing of bags (L.S.)	
3.	Labour and supervision (L&S)	2,48,100.00
4.	Maintenance and repair (Plant & Building)	79,995.00
5.	Operating supplies	8,000.00
6.	Taxes and insurance	23,790.00
7.	Plant and overheads	32,360.00
8.	Depreciation (Plant & Building)	1,91,725.00
9.	Interest on total capital investment	2,21,247.00

Annual cost of production	=	61,95,679.00
Production per tonne	=	413.04
Administrative & Selling expenses @ 3% of the production cost	=	12.39/tonne
Total cost of production	=	Rs.425.43 say Rs.425/- per tonne

D. Profitability Analysis

(a)	Gross annual income from sales @500/tonne	=	Rs. 75.00 lakhs
(b)	Total annual cost of production	=	Rs.63.75 lakhs
(c)	Gross annual return	=	Rs.11.25 lakhs
(d)	Corporate taxes @55%	=	Rs.6.18 lakhs
(e)	Net annual return (after taxes)	=	Rs.5.07 lakhs

(f) Return on investment (after taxes) = Rs.35.52 %

Break-Even Point

The fractional degree of production (n) required at the break even point is given by the expression.

$$n = F/S-V$$

Where F is the annual fixed cost; S is the total annual sales; V is the annual variable cost.

For the water-resistant gypsum binder, the distribution assumed is :

Fixed cost = 40% of the total cost of production
Variable cost = 60% of the total cost of production
Thus, F = 0.40 x 63.75 = 25.50 lakhs
V = 0.60 x 63.75 = 38.25 lakhs
S = 75 lakhs

$$n = \frac{25.50}{75.00-38.25} = \frac{25.50}{36.75} = 0.69$$

Thus the plant breaks even at 69% of the capacity i.e. 50 x 0.69 = 34.5 tonnes/day of the production.

USES OF GYPSUM BINDER

1) The gypsum binder has been found suitable for making masonry mortar for use in place of portland cement-sand mortar. A mortar consisting of 1 part of gypsum binder and 4 parts of sand (F.M. 1.91 and F.M. 1.25) by weight can be used in place of 1:6 cement sand mortar with additional advantages of high strength (28-30 kg/cm^2), water retention (65-67%) and good bond formation between bricks and mortar (1.75 - 1.80 kg/cm^2). The mortar is suitable for external as well as internal plastering. Cost-wise it is much cheaper than cement-sand mortar.

(2) Gypsum binder is suitable for light weight building blocks (density 1.75 g/cc. compressive strength 4-4.5 N/mm^2) and insulation blocks for use in providing thermal comfort in buildings (Thermal conductivity 0.14 - 0.16 Kcal/m/h/^{0}C) and non-load bearing partition walls.

(3) Gypsum binder is also found suitable for making the composites by reinforcing the glass fibre or sisal fibre to the gypsum binder by hand moulding method. The gypsum binder boards are suitable for commercial applications as they possess much higher transverse load (sisal reinforced :

...icle

...68 kg, glass reinforced : 113-115 kg) than the minimum ...cified value of 34 kg in IS : 8273 - 1984. It could be used ...structural partition in school buildings, office buildings ...l as door panels and dry wall lining material in place of ...ment-sand plaster. The gypsum binder boards have low ...rmal conductivity (glass reinforced 0.09 kcal/m/h/^{0}C, ...l reinforced 0.20 Kcal/m/h/^{0}C) which makes them suit...le for use in false ceiling.

...ONCLUDING REMARKS

The economic estimates as presented in this paper are ...dicative and the same based on a case study of techno...onomic feasibility for a proposed plant envisaged to be ...stalled at a site in close proximity to a thermal power plant ...d by-product phosphogypsum dumping site adjascent to a ...osphoric acid production unit. It would be presumptuous ...one's part to assume that it caters to the full requirements ...f all prospective manufacturers of water resistant gypsum ...nder. This paper is a pragmatic exercise to indicate the ...tential of utilisation of an industrial waste for conversion ...to wealth by producing innovative low cost building mate...ials and at the same time assisting in alleviating the pollution ...f the surface and ground waters on account of the prevailing ...isposal practices. The real returns on investment can be ...orked out after ascertaining the nature and source of the ...nancing body.

...CKNOWLEDGEMENT

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