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Rice husk ash, hitherto a waste, has been found to be a good source of pozzolana. The activation of lime and rice husk ash with the help of physico-chemical process developed by CBRI has resulted in a cementitious binder with appreciably good properties. This binder does not employ any scarce material and possesses properties like that of cement. The mortar with this binder:sand (1:3) is found to be about 24% cheaper as compared to 1:6 cement:sand mortar. The capital investment for setting up a small 5 tpd production unit is about Rs 2.6 lakhs.

There is a continuous demand for the cementitious binders in view of acute shortage of portland cement in the country. Lime and pozzolana based binders have a promise to meet this shortage. The traditional method of using lime and pozzolanic materials fails to give early setting, hardening and higher strength properties.

Rice husk ash is obtained in a number of industries where husk is used as fuel. Till recently this ash has been regarded as a waste. Recent studies on development of a process for activation of lime-pozzolana reactions carried out at this Institute[1-3] and elsewhere have revealed that it can be converted to a useful pozzolana for cementitious binders. The pozzolanic properties and other uses of the husk ash have been studied by a number of workers but the main emphasis has been on its use for cement and concrete[4-11] or to make use of rice husk as fuel with other materials and then processing the burnt product along with ash in it[12-13]. This type of exercise involves number of operations and the crushing strength of the ultimate binders is not of high order. In another process[14] where husk ash has been utilised directly for the binder, the strength properties have been found to be low, and also the additive used is a scarce material.

This paper describes the salient features of the process for activated cementitious binder, its uses for some construction operations and also gives an idea about the cost of a small production unit. The economics of the mortar vis-a-vis cement mortar has also been discussed.

Experimental Procedure

Materials used—Rice husk ash in this case was obtained from the boilers used by a chemical industry. It was light grey in colour. Lime reactivity of the ash was determined according to IS:1727-1967 which was found to be equal to 51.04 kg/cm^2. It was also analysed for chemical constituents and these are given in Table 1.

Lime for this purpose was obtained from Dehradun and was analysed for chemical

Table 1—Chemical Composition of Rice Husk Ash & Lime

Sl No.	Constituents	R.H.A.	Lime
1	L.O.I	6.28%	3.50%
2	SiO_2	88.10%	0.51%
3	R_2O_3	1.43%	0.43%
4	CaO	1.34%	94.70%
5	MgO	1.37%	0.34%
6	Available Lime	—	90.40%

constituents according to IS:6932-1973. Results are given in Table 1. Available lime content in the lime was determined according to IS:1514-1959 and was found to be 90.40%. This lime confirms to Class C of IS:712-1973.

Preparation of binder—It was prepared by adopting an approach of physico-chemical activation which is attained by selective addition of lime to rice husk ash alongwith additives and intergrinding all the ingredients to a superfine state in a ball mill.

Properties—Properties of this cementitious binder were determined in accordance with the Indian Standard Methods of physical tests for hydraulic cement (IS:4031-1968). These are summarised in Table 2.

Cubes from the binder after curing for various periods were crushed and the samples so collected were dried in vacuum (30 cm Hg) and ground to pass through IS-15 sieve and stored in airtight containers. These samples were analysed by DTA, TGA and X-ray techniques.

The rice husk ash was examined under petrographic Panphot microscope having magnification (×200).

Table 2—Properties of Rice Husk Ash Based Lime Cement

	Properties	Results	Specifications*
1	Free Moisture	0.46%	—
2	Residue on IS.9 Sieve	1.3%	10% (max.)
3	Le Chatelier Expansion	2 mm	10 mm (max.)
4	Setting Time(Minutes)		
	a. Initial	65	Min. 30 minutes
	b. Final	235	Max. 600 minutes
5	Compressive strength (kg/cm^2)		
	3 days	115.7	115.0 (Min)
	7 days	193.8	175.0 (Min)
	28 days	209.3	—
	300 days	398.0	—
6	Water Retention	71%	—

*I.S. - 269 - 1967

Discussion

Rice husk ash consists mainly of silica. The X-ray and petrographic studies have shown that it consists of both amorphous and crystalline forms. Unburnt carbon is the main impurity.

Rice husk ash as such shows poor pozzolanic properties having a lime reactivity value of 9.5 kg/cm^2, but the ash when ground fine and passed completely through 90 μ sieve has enhanced reactivity of 51.04 kg/cm^2. The pozzolana can be made more reactive by fine state of subdivision which may create a disturbed state in the crystalline form and develop internal stresses in the lattice structure.

Reaction of lime with ash may be regarded as a reaction of a base with acidic oxide. The reaction proceeds with intimate contact in presence of water. Specific surface plays an important part in the physico-chemical activation of the solids involved in the reaction as well as influencing the rate of reaction. The method of activation in the process under discussion is a manifestation of this concept. The lime and pozzolana in presence of other additives are processed in such a manner that a stage is attained when the CaO and the acidic oxide (SiO_2) are so intimately in contact that as soon as favourable conditions are attained the reaction proceeds immediately in presence of water with quick fixation of lime. The reaction proceeds as in the system $CaO-SiO_2-H_2O$. Therefore, this binder is more reactive as compared to conventional lime-pozzolana reactions where the reaction proceeds very slowly.

DTA curves of 7, 28 and 300 days water-cured samples of this cementitious binder clearly indicate the nature of hardened mass[2] similar to the products in lime-silica-water system reported by earlier workers[15-17]. The main and dominant hydration product is C-S-H (I). DTG and X-ray data also confirm this observation. It is also clear from this, that in the 7 days cured sample the CSH (I) is formed which is poorly crystallised but on ageing as is evident in the 28 and 300 days cured samples the hydration products acquire better crystalline form imparting better strength properties.

Field applications—The cementitious binder so developed was tried for various applications in different building operations. This binder was used for mortar, plaster and preparation of stone masonry blocks.

This binder for mortar and plaster work was mixed with sand (fineness modulus 1.26) in the proportion of 1:3 by volume, and water was added to make it workable as required by masons. The flow of this mortar was determined by flow table which was found to be 105%. Mortar cubes of 5 cm size were also moulded with the same mortar and moist cured (90% RH) for seven days. After which the 7 days compressive strength was determined on three cubes and the rest were dipped under water for further curing. The 7 days and 28 days compressive strength values were respectively 23.76 and 27.75 kg/cm^2.

A wallet was constructed with burnt clay bricks using this binder for mortar and plaster work. Periodic examinations did not reveal any defects whatsoever during the four years. Slight crazing on surface was however observed after 90 days which was similar in appearance as in the case of cement-sand and other conventional plastering materials. But the bond with the wall was intact.

Stone masonry blocks [18] of nominal size of 30 × 20 × 15 cm were also prepared using the above binder. Moulds of appropriate size were taken and large stone pieces up to 10 cm sizes were filled into the mould. Concrete mix prepared with this binder having mix proportion 1:2:4 [binder:sand (FM = 0.9): Coarse aggregate (Nominal size 10 mm)] was filled around the stone pieces and into the space left in the mould with gentle tapping along with some more pieces of stone. The moulded stone and concrete body in the moulds was compacted with the help of a trowel. The mould was removed after half an hour leaving the block on the platform. The blocks were moist cured for a period of 28 days. Crushing strength of these blocks was determined and found to be 51.0 kg/cm^2. The weight of these blocks was about 18 kg. These blocks can be used as building units with advantage as blocks with other pozzolanic materials[19].

Economics of mortar—Predesign cost estimates given in this paper have indicated that this binder can be prepared at a competitive cost and it may be made available to the consumer at reasonable

Table 3—Economics of Mortars

Binder	Proportions by vol: Binder	Sand	Material constants for 1 M^3 (mortar flow 110±5%): Binder	Sand	Cost of one M^3 of mortar	% saving w.r.t. cement mortar
Cementitious binder	1	3	0.34 9.79 bags	1.02	Rs 127.50	24.64
-do-	1	4	0.27 7.77 bags	1.08	Rs 109.35	35.37
Cement	1	6	0.265 4.65 bags	0.99	Rs 169.20	—

Rates (at site): Cementitious binder @ Rs 300 per tonne (30 bags in a tonne)
Cement @ Rs 600 per tonne (20 bags in a tonne)
Sand (F.M. = 1.26) @ Rs 30 per cubic meter.

price. This is a lighter material (bulk density being around 950 kg/m^3) in comparison to portland cement (B.D. 1440 kg/m^3). So the mix proportion for this binder with sand (1:3) compares well in strength with (1:6) of cement:sand mortar both having the same consistency. A saving of the order of 24 percent has been worked out in such mortars as given in Table 3.

Economics of production—Predesign cost estimates to manufacture the binder—capacity of the plant: 5 tonnes per 8 hour shift (as in most places the availability of raw materials may warrant a small plant only) are given in Table 4. This may be treated as guideline only.

Table 4—Predesign Cost Estimates

Total Capital Investment

(A) Fixed Capital on building

	Rs
Cost of 200 sq.m. of land @ Rs 25/- per sq.m.	5,000.00
Yard improvement	1,000.00
Shed 150 sq.m. @ Rs 250/-sq.m.	37,500.00
Building 16 sq.m. @ Rs 350/- sq.m.	5,600.00
Total	49,100.00

(B) Fixed Capital on Plant

The ball mill of 1 tonne per hour capacity to produce a material of about 200 mesh and a vibrating screen for sieving the ground material to match the capacity of the ball mill are to be used. Weighing and sewing machine for stitching the bags may also be needed.

	Rs
Purchased equipment as mentioned above	70,000.00
Equipment erection	7,000.00
Laboratory	3,500.00
Electrical installation	7,000.00
Consultancy	5,000.00
Contingency (lump sum)	10,000.00
Total	1,02,500.00

(C) Working Capital

	Rs
It may be taken 25% of annual sales	1,05,000.00
Total capital investment (A + B + C)	2,56,600.00

Cost of Production (300 working days)

Raw Materials—These are lime, pozzolana and additives. The percentage of these materials will depend upon the quality and class of lime and rice husk ash.

Cost of raw materials	1,80,000.00
Cost of paking (using gunny bags)	58,000.00
Electricity 40 hp @ Rs 0.30/kwh	25,000.00
Labour and supervision (6 labourers, one mechanic and one supervisor-cum-Chemist)	
6 labourers @ Rs 6.00/day	10,800.00
1 Mechanic @ Rs 400/month	4,800.00
1 supervisor @ Rs 500/month	6,000.00
	21,600.00
Maintenance & repairs of plant and building	
Plant 6% of B	6,150.00
Building 2% of A	982.00
	7,132.00
Taxes and insurance 2% of A + B	3,032.00
Depreciation	
Plant @ 10% of B	10,250.00
Building @ 2.5% of A	1,228.00
	11,478.00
Administrative and distribution and selling expenses 5% of annual sales	21,000.00
Interest on total capital investment (A+B+C) @ 13% per annum	33,358.00
Total cost of production	3,60,600.00
Selling cost @ Rs 280/T	4,20,000.00
Annual return	59,400.00

Return on total capital investment $= \frac{59400}{2,56,600} \times 100 = 23.11\%$

Conclusions

(1) The rice husk ash can be used to manufacture cementitious binder in combination with lime and additives by physico-chemical activation.

(2) The properties of the binder are comparable to ordinary portland cement.

(3) The cementitious binder can be used in all situations where OPC is used (except the RCC

work) because of the nature of the hydration products, being tobermorite like gel CSH (I) with gelatinous silica. Its use for RCC work needs further exploration which is being studied.

(4) The strength of the binder shows an increasing trend with the period of curing.

(5) The lime reactivity of the rice husk ash from every source shall be determined and similarly the quality of lime available in the area shall have to be determined. The composition of the various ingredients, rice husk ash, lime and additives has to be accordingly adjusted to obtain proper properties in the binder.

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References

1 *Annu Rep*, 1974, *Cent Build Res Inst*, Roorkee.
2 Masood I & Mehrotra S P, *Masalah Bangunan*, 23(2) (1978) 6.
3 Dave N G & Mehrotra S P, *Consultation; Lime-Pozzolana*, Papers & Proceedings, NBO, New Delhi, 8-9 Dec 1977, 71-76.
4 Ahsanullah A K M, Ahmad M & Chotani A H, *Pak J Sci Ind Res*, 1 (1959) 53.
5 Mehta P K & Polivka M, *Chem Abstr*, 85(1976) 165647j.
6 Abdeltalif A D, *Fr Addn*, 2,070,383; 1971, *Chem Abstr*, 76 (1972) 157799j.
7 Chvatal T, *Aust Pat*, 302,149; 1972, *Chem Abstr*, 78(1973), 75477e.
8 Tut Sek A & Bartha P, *Ger Offen*, 2,416,291; 1975, *Chem Abstr*, 84 (1976) 78899d.
9 *Regional Research Laboratory*, Jorhat; cited in F A O, *Agric Serv Bull*, 33 (1978).
10 Cody P D & Groney P R, *Chem Technol*, 7 (6) (1976) 215.
11 Mohanty T K, *Cement*, 8 (1974) 1.
12 Dass A & Malhotra S K, *Res Ind*, 22 (3) (1977) 149.
13 Dutta R K & Dass K, Seminar on Rice Modernisation, East India Rice Mills Association, Calcutta, 22 Sept. 1974.
14 Report, *Hidustan Times*, 30 Nov, 1974.
15 Kalousek G L, *et al*, *J Amer Ceram Soc*, 30 (1954) 7-13.
16 Taylor H F W, *J Chem Soc*, London (1950) 3682.
17 Gaze R, *et al*, *Mag Concr Res*, 8 (22) (1956) 7.
18 Technical Note No 66, *Stone Masonry Blocks*, Cent Build Res Inst, Roorkee.
19 Dave N G & Mehrotra S P, *ISI Bull*, 31 (5) (1979) 159.