CEMENTITIOUS BINDERS FROM FLYASH AND OTHER WASTES

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ABSTRACT

- Over 300 million tonnes of industrial solid wastes are produced by various chemical and agricultural processes in india.
- The paramount wastes like fly ash, phosphogypsum, fluorogyp-sum, mine tailings, lime sludges, etc. pose serious problems of disposal and health hazards.
- Fly ash is a major industrial pollutant and its disposal is an international issue.
- So far fly ash has been used in making portland pozzolana cement, cellular concrete, bricks (clay/sand-lime fly ash), building components, etc.
- Researches have been carried out to produce cementitious binders by blending 40-60% fly ash with other wastes like phosphogypsum, fluorogypsum, lime sludges, clay pozzolana and chemical activator.
- The hydration (DTA, XRD, SEM) data generated and application of cementitious binder are reported and discussed in the paper.

METHOD

- The raw materials like fly ash, fluorogypsum, lime sludge and clay were analyzed chemically (Table 1).
- The clay (Mondavi, Gujarat) sample was calcined at 700^0C for 1.5 hr. to produce reactive pozzolana conforming to IS:1344-1981.
- The lime sludge (RCF, Ltd. Mumbai) was heated at 1000^0C for 4.0 hr. to form lime, which was hydrated for use in binder.
- The cementitious binders were produced by blending the ground fly ash (450-490 m^2/kg., Blaine), with the calcined clay pozzolana, fluorogypsum, OPC, hydrated lime sludge ($Ca(OH)_2$) and the chemical activator in different proportions followed by grinding to a fineness of 510-530 m^2/kg (Blaine). The cementitious binders were tested and evaluated as per IS: 4031-1999.
- Suitability of the binder was examined for masonry mortars and concrete (As a replacement to cement). The results are presented.

OBSERVATIONS

PROPERTIES OF CEMENTITIOUS BINDERS

- The properties of cementitious binders are reported in Tables 2, 3 and 4.
- The cementitious binder 'B' show higher compressive strength and water retentivity than the binder'A3' probably due to more alkaline conditions in latter than former.
- The high strength development in cementitious binder can be attributed to the formation of CSH, ettringite (C3A.3CaSO4.32H2O) and C4AH13 compounds due to combination of amorphous SiO2, Al2O3 contributed by fly ash and the clay pozzolana with the hydrated lime.
- The strength development in cementitious binder has been supplemented by DTA, XRD and SEM studies.

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- DTA shows endotherms at 120-1300C, 150-1600C, 2000C, 530-5400C and 700-9000C due to formation of ettringite, Ca(OH) 2,and CaCO3 respectively in both the binders 'A3' and 'B' confirming higher strength in 'A3' than 'B' (Fig. 1).
- XRD Data shows similar trend of results as of DTA.
- SEM of cementitious binder 'B' show formation of anhedral to euhedral agglomerated stellate, needle and prismatic crystals whereas binder 'A3' show appearance of prismatic & nodular hydraulic products (Figs. 2,3)

PROPERTIES OF MORTARS AND CONCRETE

Properties of Masonry Mortars

Sl.No.	Proportion of mortars (By mass) Cementitious binder	Sand	Compressive strength (MPa) 7 day	28 day	Water Retentivity (%)
1.	(F.M. 1.26)				
	1	3	2.8	6.3	60.0
	1	4	2.5	5.4	58.9
	1	5	1.1	4.5	57.6
	(F.M. 1.82)				
2.	1	3	3.5	5.6	63.0
	1	4	2.8	5.3	66.5
	1	5	1.7	4.5	60.8
	(Standard Sand)				
3.	1	3	7.3	14.5	21.5
	IS : 3466 - 1989 Limits		Min. 2.5	Min.5.0	Min.60

COMPRESSIVE STRENGTH OF CONCRETE

Sl. No.	Mix proportions (Mass %) Portland Cement	cementitious - binder 'A3'	Sand	Agg.	Compressive strength, (MPa) 7-day	28 day
1	85	15 (1)	2	4	16.8	26.9
	75	25 (1)	2	4	12.0	25.2
2	85	15 (1)	3	6	8.6	12.8
	75	25 (1)	3	6	5.8	11.3
3	1	--	2	4	19.0	30.7
	1	--	3	6	8.7	13.6

MARKETABLE COST OF CEMENTITIOUS BINDER

Bulk cost of binder A3	Rs. 940
Packing	120
Profit	200
	1260
Excise	100
Transport	400
Sales tax	160
Dealer	100
Total	2020 or Rs.100/bag

ADVANTAGES

- Economical
- Better surface finish
- Does not require top coat of Niru
- Low heat of hydration, better Durability.
- In ready mix concrete, up to 25% binder can replace OPC, overall cost reduction up to 10%.
- 30-50% saving in energy per tonne of cementitious binder as compared to OPC.
- 50-60% saving in OPC if binder used in masonry & plastering of buildings.
- Carbon credit (< 50% materials being calcined only)

CONCLUSIONS

- The cementitious binder suitable for use in masonry mortars and concrete can be produced by mixing fly ash with the phosphogypsum plaster, fluorogypsum, hydrated lime sludge, OPC, calcined clay pozzolana and the chemical activator as per IS: 3466-1989.

- Ettringite, C-S-H and C_4AH_{13} have been identified as the major cementing compounds responsible for strength development in these binders.
- The cementitious binder also complies with the properties of BS: 6610-1991, specification for pozzolanic fuel ash cement and Fal-G binder.

- Exemption of excise duty on the use of higher amount of fly ash (40 to 60%) in masonry / blended cement is recommended.
- A patent has been claimed (NF 310/02) for the cementitious binder for greater application of fly ash.

Table 1 Chemical Composition of Fly ash, OPC, Fluorogypsum, Phosphogypsum, Lime Sludge and Calcined Clay

Constituents (%)	Fly ash	OPC	Fluorog-ypsum	Phosphogy psum	Lime sludge	Calcin-ed clay
P_2O_5	---	---	---	1.40	3.6	---
F	---	---	1.2	0.51	1.0	---
Organic matter	---	---	---	0.30	---	---
Cl	---	---	---	0.10	0.10	---
Na_2O+ K_2O	0.76	---	---	-.70	0.16	---
SiO_2	62.90	22.50	0.67	1.25	3.10	53.9
R_2O_3	32.10	9.60	0.61	0.70	0.50	46.01
CaO	1.50	61.50	40.44	32.20	52.0	0.29
MgO	0.80	2.65	Tr.	Tr.	0.31	0.60
SO_3	0.20	1.75	56.0	44.0	0.16	---
LOI	1.50	2.00	0.62	19.48	41.00	---
$CaSO_4$. $2H_2O$	---	---	---	94.60	---	---
pH	---	---	2.5	5.0	11.0	---

Table 2 Properties of Cementitious Binders

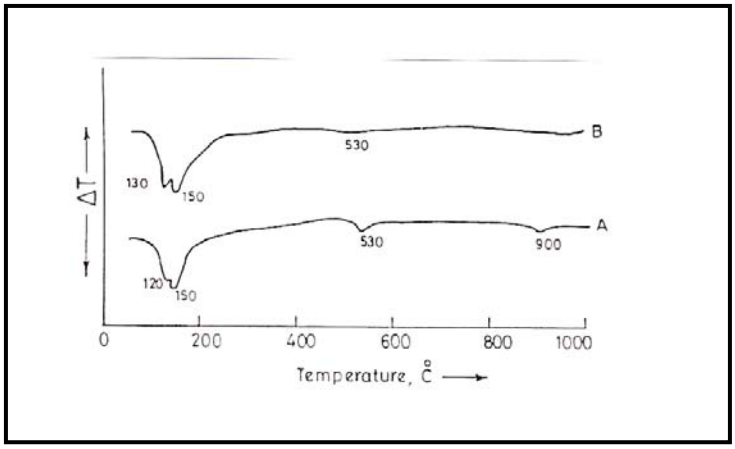
Cement Design.	Consiste-ncy (%)	Setting time, (Hours) Initial	Final	Compressive Strength, (MPa) 1d	3d	7d	28d	Water Retentivity (%)
A	35.6	1.30	4.25	6.9	9.7	13.6	32.8	65.5
B	37.5	1.34	5.30	8.0	18.6	23.7	36.9	66.6
Portland Cement	40.0	1.30	4.0	--	---	---	--	20.0

Table 3 Composition of Cementitious Binders

Cement design	Bind-er A2 (%)	Fly ash (%)	Calcine. clay (%)	Calcin. phosp-hogypsu m (%)	Lime Sludge (%)	OPC (%)	Fluorog ypsum (%)	$CaCl_2.2$ H_2O (%)	$Na_2SO_4.$ $10H_2O$ (%)
A1	---	60	25	---	---	15	---	2.0	---
A2	---	45	25	10	20	---	---	---	---
A3	---	40	25	---	20	---	15	---	1.0
A4	90	---	---	---	10	---	---	---	---

Table 4 Properties of Cementitious Binder

Cement Design.	Consistency. (%)	Setting time (Hours) Initial	Final	Compressive strength, (MPa) 1 d	3 d	7 d	28d	Water Retentivity (%)
A1	32.57	---	---	0.6	0.6	0.6	1.2	45.0
A2	37.0	2.21	5.10	11.1	19.1	21.9	27.2	55.4
A3	34.0	1.32	4.25	12.2	21.9	32.9	36.7	65.6
A4	38.3	---	---	9.8	17.6	21.9	24.0	58.2



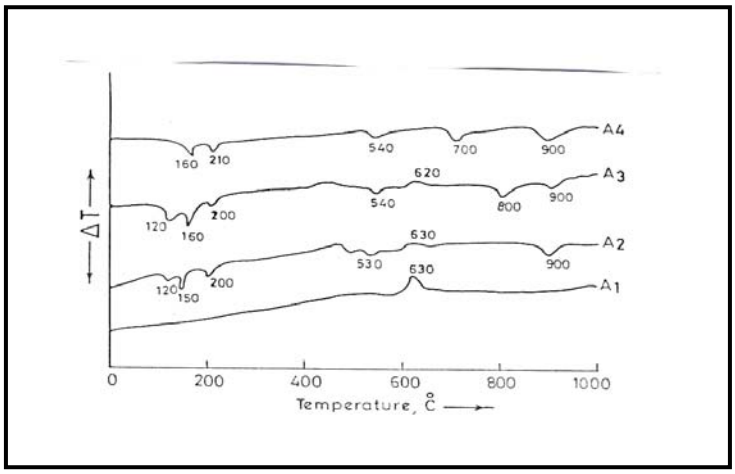


Fig. 1 DTA of Cementitious Binders hydrated for 28 days

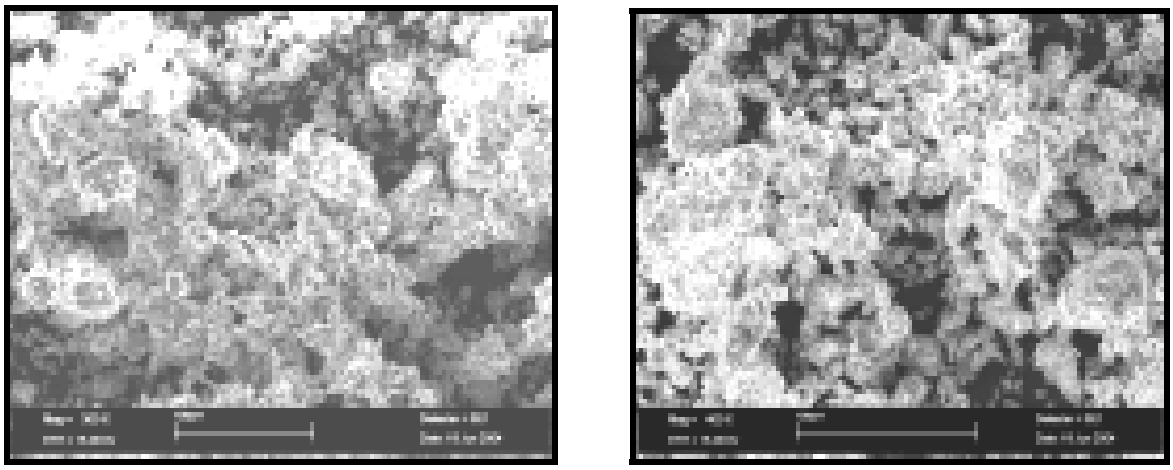


Fig. 2 SEM of Cementitious Binder 'B' Hydrated for (a) 7days and (b) 28 days

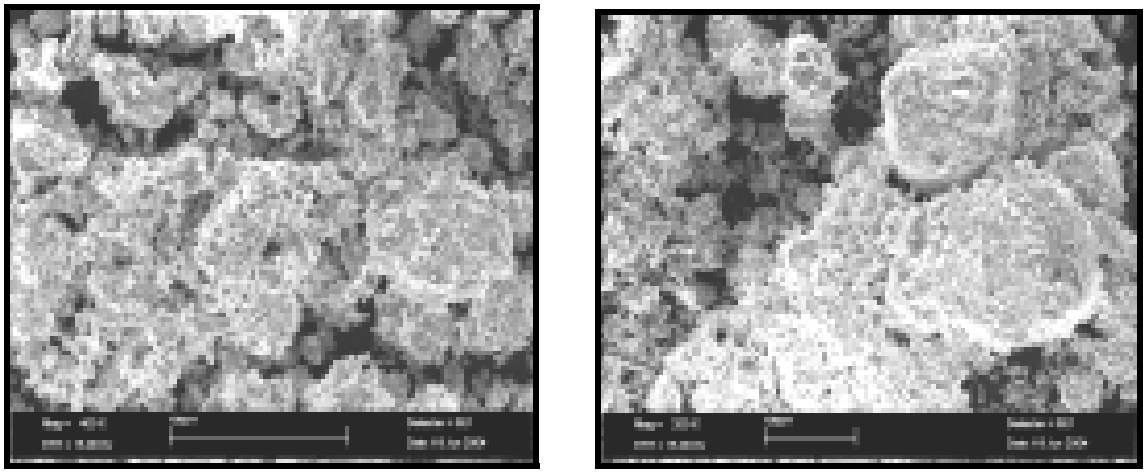


Fig. 3 SEM of Cementitious Binder 'A3' hydrated for (a) 7 days and (b) 28 days