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Durability of cementing binders based on fly ash and other wastes

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Abstract

The paper deals with the cementitious binders produced by blending 60–70% fly ash with fluorogypsum, hydrated lime sludge, with and without Portland cement and chemical activator in different proportions. Data show that strength development of cementitious binders takes place through formation of ettringite, C–S–H and wollastonite compounds. The durability of these binder has been studied by its performance in water and by accelerated aging i.e. alternate wetting and drying as well as by heating and cooling cycles at temperatures in the range 27–50 °C. The results indicate Lawrence of strength of binder with the increasing cyclic studies at different temperatures. The maximum fall in compressive strength was noticed at 50 °C.

Keywords: Fly ash; Durability; Cementitious binders; Fluorogypsum

1. Introduction

Over 100 million tones of fly ash is available as waste from thermal power plants in India. Not more than 20% is being utilized at present in spite of incentives provided by the Government of India. Lack of control over quality of fly ash may be responsible for its limited use. Improvement in the quality of fly ash is essential for its maximum application in wider perspective. Upgrading of fly ashes for use are in mortar and concrete is the subject of several investigations in recent years. Mechanical treatment of fly ashes by grinding is one of the known methods, however, few specific studies, on their influence on ground fly ash–cement mortar have been reported [1,2]. Dhir et al. [3,4] studied a wide spectrum of fly ashes showing fineness as thoroughly most significant physical parameter characterizing water reducing ability of fly ashes in concrete [5–8].

Among different ways of fly ash activation [9], the addition of gypsum was found suitable for fly ash–cement blends. The use of fly ash in concrete increases sulphate resistance due to interaction between sulphate and fly ash to form denser structure of ettringite and monosulpho aluminate hydrate that fill pores in the paste [10–14]. Besides fly ash, fluorogypsum and lime sludges are known industrial wastes generated by hydrofluoric acid plants and sugar paper and acetylene, soda ash manufacturing units in India [15,16], considerable work has been done in China and other places [17–19] to improve water-resistance of binders based on fly ash, fluorogypsum/phosphogypsum and cement for use in construction.

To reduce pollution and disposal of these industrial wastes, there is an urgent need to develop useful cementitious binders from these waste materials. With this in view, investigations were under taken to work out the possibility of using a much higher fly ash content (up to 70%) in combination with fluorogypsum, lime sludge and Portland cement to enhance the physico-chemical properties of cementitious binder. The durability of such binders has been studied by alternate wetting and drying and heating and cooling cycles at 27–50 °C already devised by authors [19] as well as by its performance under water are reported and discussed.

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2. Experimental

2.1. Raw materials

The chemical composition and physical properties of fly ash, fluorogypsum, lime sludge and ordinary Portland cement used as raw materials for formulating the cementitious binders are listed in Tables 1 and 2 respectively. The lime sludge was calcined at 1000 °C for a period of 4 h to form lime which was used after complete hydration.

Table 1
Chemical composition of fly ash, fluorogypssum, lime sludge and Portland cement

Constituents	Fly ash	Fluorogypsum	Lime sludge	Portland cement
P_2O_5	–	–	3.60	–
F	–	1.20	1.00	–
Organic matter	–	–	–	–
Cl	–	–	0.10	–
$Na_2O + K_2O$	0.76	–		
SiO_2	62.90	0.67	3.10	22.50
R_2O_3 ($Al_2O_3 + Fe_2O_3$)	28.35	0.61	0.50	9.60
CaO	1.50	40.44	52.00	61.50
MgO	0.80	Tr.	0.31	2.65
SO_3	0.20	56.00	0.16	1.75
LOI	1.50	0.62	41.00	2.00

(Basis: oven dried).

The physical properties of fly ash, fluorogypsum, calcined lime sludge and the Portland cement listed in Table 2 complied with the requirements of IS: 3812 (Part I)-2003, Specification for pulverized fuel ash, Part I-For use as pozzolana in cement, cement mortar and concrete, IS: 2547 (Part-I)-1976, Specification for gypsum building plaster, IS: 712-1984, Specification for building limes (class E) and IS: 8112-1989, Specification for 43 Grade Ordinary Portland Cement respectively.

2.2. Preparation and testing of cementitious binders

The cementitious binders were prepared by intimately blending the ground fly ash ($\simeq$400 m^2/kg, Blaine) with fluorogypsum, hydrated lime sludge, Portland cement and a suitable chemical activator in different proportions followed by inter-grinding in a ball mill to the fineness of a specific surface area of 410 m^2/kg (Blaine) (Table 3). The cementitious binders were tested and evaluated for their physical properties as per methods specified in IS:4031-1976 [20] and IS:2542 (Part I)-1981 [21]. The hydration of cementitious binder was studied by differential thermal analysis (Stanton Red Croft. UK).

The cementitious binders were cast into 25 mm cubes at normal consistency for compressive strength and durability test. The cubes were cured under high humidity (>90%) at 27 ± 2 °C for a period of 28 days and tested for strength and bulk density values. The durability of cementitious

Table 2
Physical properties of fly ash, fluorogypssum, lime sludge and Portland cement

S.no.	Property	Fly ash	Fluorogypsum	Lime sludge	Portland cement
1	Fineness (m^2/kg Blaine)	320	310	380	330
2	Lime reactivity (N/mm^2)	4.8	–	–	–
3	Setting time (min)				
	Initial		95	125	96
	Final		240	1800	240
4	Compressive strength (MPa)				
	3-day	–	8.5	–	25.0
	7-day	–	18.5	–	39.6
	14-day	–	27.5	1.10	–
	28-day (90% of compresive strength of corresponding OPC (1:3 mortar)		30.6	1.78	50.5
5	Transverse strength (N/mm^2)	–	–	0.7	–
6	Soundness, Lechatlier expansion (mm)	–	0.08	3.0	1.5

Table 3
Mix composition of cementitious binder based on fly ash, fluoroogypsum, lime sludge and Portland cement

Mix designation	Mix composition (wt%)				
	Fly ash (1)	Fluorogypsum (2)	Portland cement (3)	Lime sludge (4)	Activator (5)
F1	70	15	–	15	–
F2	65	15	–	20	–
F3	60	20	–	20	–
F4	50	30	–	20	–
F5	70	15	5	10	1.0
F6	65	10	10	15	1.0
F7	60	10	15	15	1.0
F8	50	20	15	15	1.5