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Influence of blended gypsum on the properties of Portland cement and Portland slag cement

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Abstract

The paper deals with studies on the effect of unprocessed phospho-(PG) and fluorogypsum (FG) added independently and in combination with natural gypsum (NG) on various properties of portland and portland slag cement (PSC). The results showed that the adverse effect of P_2O_5 and F impurities in PG and those of FG could be offset by blending NG. An increase in compressive strength and decrease in setting time of the cements was observed on using the blended gypsum. A mix of 40:60, PG/FG by weight gave maximum compressive strength. The properties of portland cement and PSC with blended gypsum conformed to the requirements of cement produced with NG. As compared to PG and FG, the power consumption for grinding cements was reduced on using the blended gypsum.

Keywords: Grinding; Calcium silicate hydrate (C-S-H); Compressive strength; Portland cement

1. Introduction

Large quantities of by-product gypsum are produced by the chemical industry that are currently being disposed of by dumping into rivers, pond or waste land. Due to increasing concerns about environmental pollution, it is essential to utilize these wastes as building material. Attempts have been made by several workers [1–3] to use phospho-(PG) and fluorogypsum (FG) in the manufacture of cement. PG and FG are produced as a by-product by the phosphoric acid and hydrofluoric acid industries. The impurities of P_2O_5, F, organic matter, alkalis present in the gypsum adversely affect the setting and hardening of cement [4]. The effect of unprocessed PG and FG was studied on the properties of portland cement and portland slag cement (PSC) with and without natural gypsum (NG). The NG was blended with by-product gypsum to reduce the adverse effect of impurities of P_2O_5 and F present in this type of gypsum. The role of blended gypsum vis-a-vis by-product gypsum on the grindability properties of cements was examined. The results of these findings are discussed in the paper.

2. Experimental

2.1. Raw materials

The PG, FG, NG, cement clinker and granulated blast furnace slag of chemical composition (Table 1) were used to prepare the ordinary portland cement (OPC) and PSC, respectively. Data shows that PG and FG contain impurities of P_2O_5, F, organic matter and alkalis. The impurities of P_2O_5 and F exist on the surface of gypsum crystals as $Ca(H_2PO_4)$ H_2O and H_3PO_4 as $CaHPO_4$ built in gypsum crystals in place of SO_4 2-ions forming solid solutions or in insoluble form as $Ca_3(PO_4)_2$ and CaF_2 compounds. Fluoride is sometimes also present as NaF and Na_2SiF_6.

2.2. Preparation and testing of cement

The OPC was produced by intergrinding cement clinker with unprocessed phosphogypsum (UPPG) and FG with and without NG at 2.0% SO_3 content to a fineness of 3172 to 3300 cm^2/g (Blaine).

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Table 1
Chemical composition of raw materials

Constituents	Percent				
	PG	FG	NG	Cement clinker	Granulated slag
P_2O_5	0.47	–	–	–	–
F	0.86	1.2	–	–	–
Organic matter	0.59	–	–	–	–
Na_2O	0.27	–	–	–	–
SiO_2+insoluble in HCl	0.98	0.55	8.80	24.19	35.85
Al_2O_3+Fe_2O_3	1.29	1.50	0.66	7.9	19.12
CaO	32.04	40.70	30.25	64.40	39.62
MgO	0.54	0.50	0.10	3.34	4.09
SO_3	43.21	55.60	39.60	0.31	0.13
MnO	–	–	–	–	0.63
LOI	19.40	–	20.00	0.70	0.54

Table 2
Physical properties of OPC in the presence of blended gypsum

Sl. no.	Type of gypsum	Fineness (cm^2/g) (Blaine)	Consistency (%)	Setting time (min)	
				Initial	Final
1	NG	3172	26.1	186	262
2					
a	UPPG	3200	26.0	325	409
b	UPPG+NG				
	40 60	3230	26.3	188	270
	50 50	3200	26.1	190	280
	60 40	3300	26.4	191	286
3					
a	FG	3200	24.5	155	226
b	FG+NG				
	40 60	3200	26.9	132	198
	50 50	3180	27.2	140	202
	60 40	3260	26.8	150	220

The PSC was produced by intergrinding the granulated blast furnace slag and cement clinker with 5% blended gypsum to a fineness of 4160 to 4206 cm^2/g (Blaine). The cements produced were tested for consistency, setting time and compressive strength as per IS: 4031-1985 [5]. The grindability of the

Table 3
Physical properties of PSC in presence of blended gypsum

Sl. no.	Type of gypsum	Fineness (cm^2/g) (Blaine)	Consistency (%)	Setting time (min)	
				Initial	Final
1	NG	4160	22.8	238	305
2					
a	UPPG	4208	23.7	270	380
b	UPPG+NG				
	40 60	4000	23.0	201	275
	50 50	4180	22.8	208	290
	60 40	4180	23.0	222	299
3					
a	FG	4170	22.2	190	226
b	FG+NG				
	40 60	4208	22.6	188	230
	50 50	4200	23.0	200	240
	60 40	4160	23.0	202	250

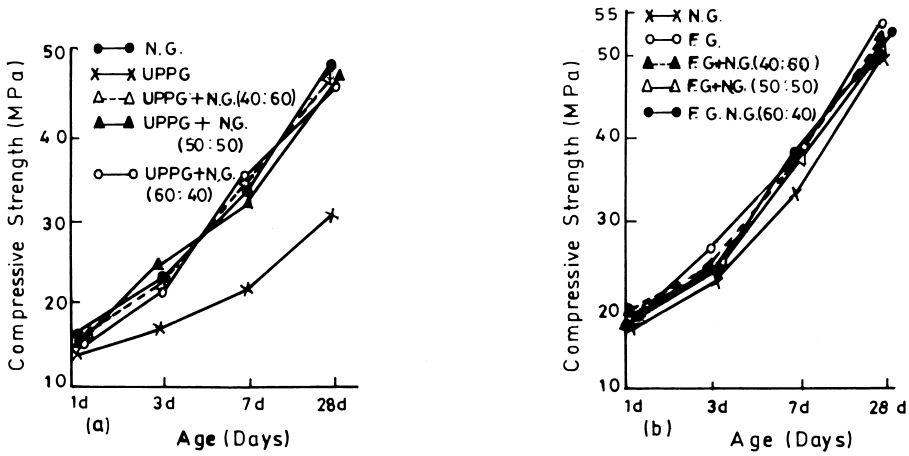

Fig. 1. Effect of blended gypsum (a) NG+PG and (b) NG+FG on the compressive strength of portland cement.

cement samples was studied as per Bond's grindability test [6].

3. Results and discussion

The effect of unprocessed PG and FG as well as blended gypsum on the physical properties of OPC and PSC are reported in Tables 2 and 3, respectively. It can be seen that setting time of cements is prolonged while the compressive strength was reduced (Figs. 1 and 2) on the addition of PG and FG alone. However, the retardation of setting time has been found lower with the FG than the PG. The retardation of setting time can be attributed to the protective coatings of $Ca_3(PO_4)_2$ and CaF_2 compounds as inert and inactive substances formed by the impurities of phosphates and fluorides on the hydrating cement particles [7], thereby causing temporary suppression of the hydration of cement grains. On addition of blended gypsum (UPPG/FG+NG) to the cement clinker, the setting time gets accelerated and the strength improved considerably (Figs. 1 and 2). This may be ascribed to the dilution of impurities with the addition of NG. It is interesting to note that strength development of cement mortars were not affected by the impurities of fluoride of hydrofluoric acid, hence FG does not so markedly retard the hydration of cement as the water soluble fluoride of PG [8]. The retardation is due to formation of silica gel or CSH ($Na_2SiF_6+Ca(OH)_2 \rightarrow CaF_2+C\text{-}S\text{-}H+NaOH$) on the surface of cement grains. The autoclave expansion of experimental cements was within the maximum specified value of 0.8 laid down in IS: 269-1989.

3.1. Energy saving

The data on grindability of OPC and PSC obtained in the presence of blended gypsum is reported in Table 4. The power consumption for grinding cements with FG was reduced on blending it with NG and found comparable to the values attained with NG. The presence of argillaceous

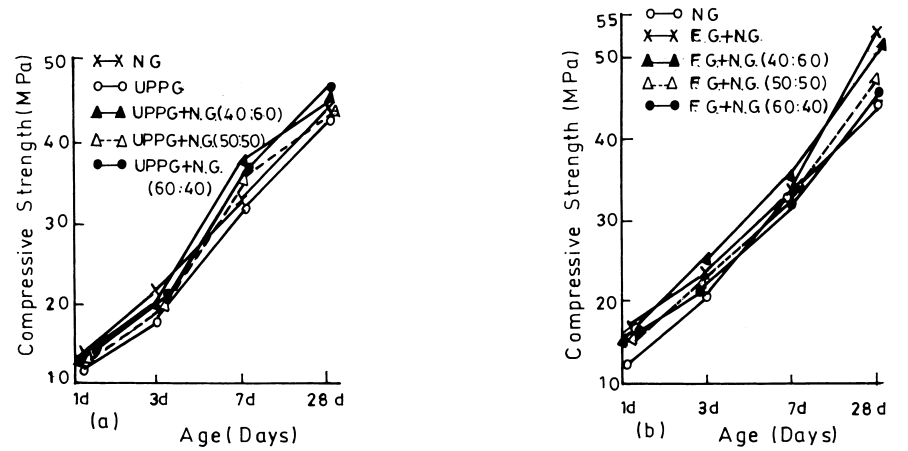

Fig. 2. Effect of blended gypsum (a) NG+PG and (b) NG+FG on the compressive strength of PSC.

Table 4
Grindability of OPC and PSC in presence of blended gypsum

Sl. no.	Type of gypsum	Grindability (g/r)	Work index (kW h/t)	Fineness (cm^2/g) (Blaine)	Power (kW h)
OPC					
1	NG	0.86	20.50	3200	30.1
2					
a	FG	0.90	21.50	3200	32.6
b	FG+NG				
	40 60	0.86	20.66	3200	30.2
	50 50	0.84	20.40	3200	30.2
	60 40	0.83	20.42	3200	30.1
PSC					
1	NG	0.80	23.80	4000	58.0
2					
a	UPPG	0.88	24.90	4000	59.1
b	UPPG+NG				
	40 60	0.82	23.70	4000	58.04
	50 50	0.84	24.20	4000	58.10
	60 40	0.82	23.90	4000	58.22

matter in NG apparently reduces the time of grinding, thus affecting power consumption [9].

4. Conclusions

1. The decrease in setting time and increase in the compressive strength of cements was observed on addition of blended gypsum.
2. Maximum attainment of compressive strength achieved on using blended gypsum having proportion of 40:60, PG/FG– NG by weight.
3. The power consumption for grinding cement mitigated with the use of blended gypsum (FG plus NG) to a level of grinding cement with NG.
4. The use of blended gypsum (PG/FG+NG) is recommended in the manufacture of cements to eliminate costly processing of the by-product gypsum.

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