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Effect of aluminium phosphate as admixture on oxychloride cement

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Abstract. The effect of admixing of aluminium phosphate on oxychloride cement in the matrix has been investigated. It is shown that aluminium phosphate retards the setting process of the cement and improves water-tightness.

Keywords. Aluminium phosphate; oxychloride cement.

1. Introduction

Oxychloride cement (magnesia cement) has many superior properties to that of portland cement (Sorel 1867; Beaudin and Ramachandra 1975; Beaudin *et al* 1977). The chemical composition of the additive or admixture available in commercial grade is $AlPO_4$. Little scientific data are available about its effect on oxychloride cement. We have investigated the effect of $AlPO_4$ on oxychloride cement because its anionic part forms inactive insoluble phase with active lime and other harmful impurities. Similarly the cationic part of it is known to be a cementing ingradient with inter-locking chain forming tendencies. This is due to its polyvalent character.

2. Materials

The following materials are used in this investigation:

Magnesia. Commercial grade magnesia used in the study is of Salem origin having the following characteristics: (i) bulk density 0·85 hg/I, (ii) 95% passing through 75 μ (200 mesh) IS sieve, (iii) magnesium oxide 90%, (iv) CaO < 1·5% and (v) ignition loss at 110°C–2·5 + 0·5%.

Dolomite. Inert filler (dolomite) with the following grading was used: (i) 100% passing through 150 μ IS sieve, (ii) 50% retained on 75 μ IS sieve, (iii) CaO 28·7%, (iv) MgO 20·8%, (v) having insoluble and sesquioxide contents < 1·0% and (vi) loss on ignition 50%.

Magnesium chloride. Magnesium chloride ($MgCl_2 \cdot 6H_2O$) used in the study is IS grade 3 of IS: 254-1973 with following characteristics: (i) colourless, crystalline, hygroscopic crystals, (ii) highly soluble in water, (iii) magnesium chloride, minimum 95% and (iv) magnesium sulphate, calcium sulphate and alkali chlorides (NaCl) contents < 4%.

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3. Experimental

Effect of aluminium phosphate on some properties of oxychloride cement has been studied by incorporating it in different amounts in wet-mix.

3.1 *Setting periods*

Effect of aluminium phosphate on setting characteristics of magnesia cement (oxychloride cement) has been studied by incorporating it in different amounts. Setting periods of the wet-mixes prepared by gauging 1 : 2 dry-mixes of diverse compositions separately with the gauging solution were determined adopting the standard procedure (Indian Standard Institution 1982). Observed results are summarized in table 1.

3.2 *Weathering investigation*

Variation in weights of the setting time blocks (taken from vicat moulds) for 24 h, 7 and 30 days is recorded. Weights of test blocks increase or decrease with time due to the different weathering effects promoted by the admixture. Experimental findings are recorded in table 2.

3.3 *Moisture ingress test*

Standard setting time blocks were used to find out the effect of aluminium phosphate on moisture ingress in oxychloride cement. These were subjected to moisture treatments (steam test) to estimate their relative moisture

Table 1. Effect of aluminium phosphate on setting characteristics of oxychloride cement.

		Composition of dry mix (% additive)				
Sl no.	Observations	0	5	10	15	20
	Gauging solution: 22° Be; temperature: 31° Dry-mix composition: 1 : 2*; and humidity: above 75%					
1.	Volume of gauging solution (ml)	60	58	58	59	59
2.	Initial setting time (min)	150	140	125	125	170
3.	Final setting time (min)	285	280	280	285	320
4.	Nature of blocks					
	Glossiness	Yes	Yes	Yes	Yes	Yes
	Volume change			insignificant		

*One part by weight of magnesia and two parts by weight of dolomite.

Table 2. Effect of aluminium phosphate on weathering of oxychloride cement.

		Composition of dry mix (% additive)				
Sl no.	Observations	0	5	10	15	20
	Gauging solution: 22° Be; and dry-mix composition: 1 : 2*					
1.	Weight after 24 h (g)	268	275	270	268	263
2.	Weight after 7 days (g)	260	270	265	267	260
3.	Weight after 30 days (g)	250	255	250	245	245

*One part by weight of magnesia and two parts by weight of dolomite.

sealing efficiencies according to the standard procedure (Yadav 1989; Gupta *et al* 1990, 1994). Observed results are summarized in table 3.

Table 3. Effect of aluminium phosphate on moisture ingress (steam test) in the trial blocks.

		Composition of dry mix (% additive)				
Sl no.	Observations	0	5	10	15	20
Gauging solution: 22° Be; and dry-mix composition: 1 : 2*						
1.	10 h	NE	NE	NE	NE	NE
2.	15 h	NE	NE	NE	NE	NE
3.	20 h	NE	NE	NE	NE	NE
4.	25 h	C	NE	NE	NE	NE
5.	30 h	–	C	C	NE	NE
6.	35 h	–	–	–	C	C

*One part by weight of magnesia and two parts by weight of dolomite (NE, no effect; C, cracked).

3.4 *Compressive strength test*

The influence of incorporation of aluminium phosphate on compressive strength of the oxychloride cement is studied with the help of standard 50 cm^3 cubes prepared from the Indian Standard consistency pastes having aluminium phosphate in different amounts. These cubes (moulds) were tested after curing for 30 days as per the standard procedure (Indian Standard Institution 1958; Yadav 1989; Gupta *et al* 1994). The results obtained are shown in table 4.

Table 4. Effect of aluminium phosphate on compressive strength of oxychloride cement.

Gauging solution: 24° Be; and dry-mix composition: 1 : 2*						
1.	% Additive ($AlPO_4$)	0	5	10	15	20
2.	Compressive strength (kg/cm^2)	450	410	390	300	375

*One part by weight of magnesia and two parts by weight of dolomite.

3.5 *Durability test*

To find the durability of product, Le-Chateliers test was conducted as per the standard procedure (Gupta 1976; Chandrawat *et al* 1994) and the results are recorded in table 5.

4. Discussion

Trends in setting of the cement when aluminium phosphate is mixed in the dry-mix are shown in table 1.

Table 5. Effect of aluminium phosphate on durability of oxychloride cement (Le-Chatelier's test).

Sl no.	Observations	Composition of dry mix (% additive)				
		0	5	10	15	20
	Gauging solution: 24° Be; and dry-mix composition: 1 : 2*					
1.	Weight of cement composition (g)					
	(i) Magnesia	13·0	13·0	13·0	13·0	13·0
	(ii) Dolomite	26·0	24·7	23·4	22·1	20·8
	(iii) Additive	Nil	1·3	2·6	3·9	5·2
2.	Use of $MgCl_2$ solution (ml)	11·5	11·0	12·0	13·0	15·0
3.	Distance between two pointers before starting (cm)	1·8	2·3	1·5	1·3	1·5
4.	Distance between two pointers after 7 days (cm)	2·0	2·1	1·4	1·1	1·3
5.	Time in water at 27°C to 32°C (h)	48·0	48·0	48·0	48·0	48·0
6.	Distance between two pointers before boiling (cm)	2·2	2·1	1·5	1·2	1·4
7.	Distance between two pointers after boiling (cm)	2·3	2·1	1·5	1·2	1·4
8.	Expansion of cement (cm)	0·1	0	0	0	0

*One part by weight of magnesia and two parts by weight of dolomite.

Volume of gauging solution required for Indian Standard consistency remains almost the same. This suggests about the indifferent nature (slow reactivity) of aluminium phosphate with respect to magnesia cement. Although percentage of the additive (admixture) increases gradually, gross amount of inert fillers (weight of dolomite + weight of aluminium phosphate) remains the same. Thus almost constant volume in the amount of the gauging solution for Indian Standard consistency is expected. It is noted that initial and final setting periods slightly decrease with increasing amount of an additive. This is due to interlocking chain forming tendencies of additive.

$$MgO + H_2O \rightarrow Mg(OH)_2, \quad (1)$$

$$Mg(OH)_2 + AlPO_4 \rightarrow AlPO_4(OH)_2Mg, \quad (2)$$

$$AlPO_4 \ldots (OH)_2\,Mg \xrightarrow[\text{slow reaction}]{\text{gauging solution}} \text{magnesia cement} + AlPO_4. \quad (3)$$

Rate of evolution of heat due to the above interaction is also lowered down. Thermal shocks are therefore reduced. This explains insignificant volume changes in the set blocks and their glossy appearance.

Effect of aluminium phosphate on weathering of magnesia cement are shown in table 2. Weights of the trial blocks are found to decrease constantly with time. This trend can be explained on the basis of two plausible reasons. Firstly, weak interaction of aluminium phosphate with magnesia retards the solid state setting mechanism. Hence setting reaction proceeds for prolonged periods even after the final setting time. Uncombined moisture is thus given out slowly. Secondly, almost inner nature of aluminium phosphate does not promote processes like carboration, hydration, sulphonation etc which are usually involved in weathering mechanism responsible for increase in weight.

Above generalizations are supported further from the investigation pertaining to the effect of aluminium phosphate on moisture ingress (steam test) in trial blocks (table 3). Low heat tendency of anionic part of additive to form inactive insoluble phase with harmful impurities like active lime and tendency of cationic parts to form inter locking changes owing to its polyvalent character contribute to soundness of structure. Accordingly increase in moisture resisting efficiencies is noted with increasing amount of aluminium phosphate. However, tendency of phosphate ions to form inactive phases with magnesium ions seems to interfere with the usual setting mechanism. This is obvious from table 4 which reflects the effect of aluminium phosphate on compressive strength of magnesia cement. Thus in spite of increasing water tightness of the product, compressive strength is found to decrease slightly with incorporation of aluminium phosphate.

The above experimental findings are further confirmed by the investigations pertaining to the effect of aluminium phosphate on durability of magnesia cement (table 5). Improved water tightness of the product for the reason mentioned above contributes to little volume changes in the product in spite of its severe exposure to moisture in Le-Chateliers test.

5. Conclusion

Aluminium phosphate, though an inert filler, retards setting process of oxychloride cement and improves water tightness of the cement. Hence it can be considered a good additive for high heat magnesia cement.

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