

Effect of supersulphated cement on sulfate attack of cement mortar

Niu quanlin^{1, a *} zhang rui^{2, b}

¹school of material science and engineering, Shandong university of technology, Zibo, Shandong 255049, P.R .China

²Library of shandong university of technology, Zibo, Shandong 255049, P.R .China

^aniuql00@sdut.edu.cn

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Abstract: Supersulphated cement with 5%--10% of clinker, 15% of gypsum, 75-80% of slag was prepared, sulfate attack on mortars blended with ordinary portland cement and supersulphated cement was examined according to ASTM C1012 and the Chinese nation standard GB2420. It is shown that supersulphated cement exhibits excellent durability in sulfate attack environment, the 15-week expansion (ASTM C1012) decreased to less than 0.06%, 3-month corrosion coefficient (GB2420) of the SSC mortars immersed in Na₂SO₄ solution was 50% higher than that of the ordinary portland cement.

Introduction

Deterioration of drainage pipeline due to Sulfate attack is a composite process including both physical and chemical reactions. physical attack is due to the reversible change of anhydrous sodium sulfate (thenardite) into decahydrate (mirabilite) accompanied by large crystallization pressure and the subsequent deterioration [1], chemical attack of domestic sewage H₂S related sulfate is the result of both acid corrosion and ettringite expansion.

Formation of ettringite through reaction between C₃A and CaSO₄ brings inhomogeneous expansion in the hardened cement stone, as expansion stress is much bigger than the tensile strength of cement and concrete, soften and corrosion happens.

Replacement of cement with admixtures such as ground granulated blast-furnace slag (GGBS), fly ash (FA), metakaoline and silica fume were found effective in improving the sulfate resistance of concrete [2-4], concrete incorporating 45-72% of GGBFS were also perfectly preserved after 10.5 years of immersion in 3000mg/l SO₄²⁻ solution, while the controlled specimens exhibit different extent of deterioration regardless of the C₃A content (3.5 ~ 12.3%) [5].

Incorporation of admixtures in portland cement relieves the expansion pressure by dilution effect and pozzolanic effect. Dilution of C₃A content decreases the content of ettringite, while pozzolanic effect decreases the Ca(OH)₂ content in hydration products, densification of cement paste through pozzolanic reaction is also helpful because harmful ions could not penetrate into concrete easily in densified cement paste.

Supersulphated cement (SSC) made with 10%-20% of gypsum is widely accepted as sulfate attack resistant material. As the complete reaction between CaSO₄ and C₃A at early age, no additional reaction happens when the cement stone is subjected to sulfate environment. As clinker or lime content is very small in SSC, little Ca(OH)₂ was found in hydration products, which is also beneficial for mortar and concrete to resistant sulfate attack.

In this paper, expansion ratio and corrosion coefficient of cement mortar specimens were examined according to ASTM C1012) and GB2420 respectively, visual examination of concrete immersed in Na₂SO₄ solution were also visually examined for comparison.

Experimental

Materials. P.O42.5 cement, GGBS and gypsum were used, chemical composition of the materials was shown in Table 1.

Table 1 Composition of the materials used in the test

materials	Chemical composition								
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	K ₂ O	Na ₂ O	LOI
Cement P.O42.5	20.88	4.72	3.10	63.26	3.43	1.85	0.61	0.28	2.04
Blast furnace slag	36.33	10.64	0.79	38.51	8.11	0.14	0.51	0.26	/
gypsum	/	/	/	40.71	/	56.6	/	/	0.25

Test details. Three specimens were prepared: supersulphated cement, ordinary portland cement (P.O42.5), and 50% P.O42.5 +50%GGBS.

Expansion ratio of the mortars was examined according to ASTM C1012, mix proportion was shown in table.2. The corrosion coefficient or ratio of flexual strength of mortar was tested according to Chinese standard GB 2420, mix proportion was given in table.3.

Table 2. Mix proportion of the cement and mortars according to ASTM C1012

specimen	P.O42.5	admixture	Standard sand	water
P.O 42.5	1250g	/	3438g	606ml
SSC2	62.5g	GGBS 468.75g gypsum 93.75g	3438g	606ml

Table 3. The mix proportion of the mortar specimens according to GB2420

specimen	P.O 42.5	Mineral powder	water	Standard sand
K1	100g	/	50ml	250g
K2	50g	GGBS 50g	50ml	250g
SSC1	10g	GGBS 75g gypsum 15g	50ml	250g
SSC 2	5g	GGBS 80g gypsum 15g	50ml	250g

Corrosion coefficient is the ratio of the flexual strength of the mortars immersed in water to that immersed in 3% Na₂SO₄ solution at curing age of 3 months.

By the way, 100×100×100 mm concrete specimens with binder mix proportion as table.3 were immersed in 5% Na₂SO₄ solution for 3 months, specimens were visually examined.

Result and discussion

Expansion ratio of mortar specimens. Though not consistent with field investigation in some respects [6], ASTM C1012 is an important method to examine the sulfate resistance of cement

containing mineral admixtures. The test result was shown in fig.1.

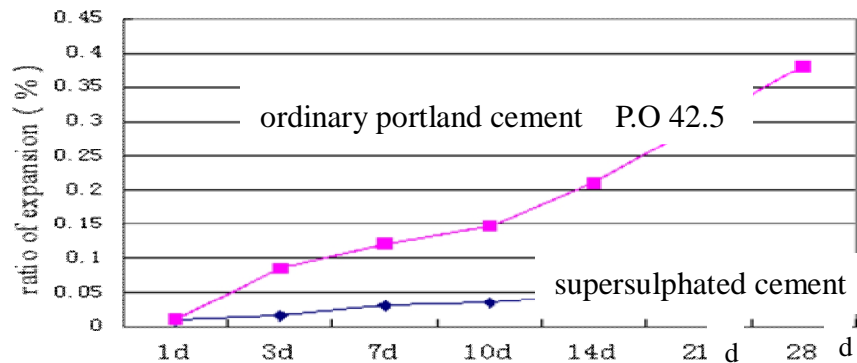
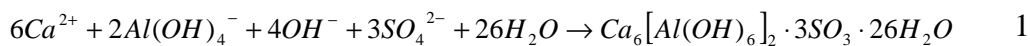


Fig.1. Expansion of mortar specimens

It is seen in fig.1 that supersulphated cement mortars exhibits excellent volume stability in 5% sodium sulfate solution, with expansion rate of less than 0.06%, while the controlled specimen prepared with P.O. 42.5 cement was over 0.16% after 15 weeks of immersion.

Expansion of the mortars was generally considered as the result of ettringite formation accompanied by volume increase:



It is known in equation 1 that formation of ettringite was determined by concentration of Ca^{2+} , $Al(OH)_4^-$ and SO_4^{2-} in alkaline solution, especially the ion with minimum concentration.

For Portland cement, complete hydration of the clinker materials releases 20% to 25% of $Ca(OH)_2$, therefore the C_3A content was crucial and cement with low C_3A was recommended in sulfate environment.

For supersulphated cement, there is only 5% to 10% of P.O 42.5, most of the $Ca(OH)_2$ was consumed through pozzolanic reaction to form ettringite and C-S-H gel, little free lime was left for further reaction when immersed in Na_2SO_4 solution.

Corrosion coefficient. Corrosion coefficient of the specimens K1, K2, SSC1, SSC2 was shown in fig.2.

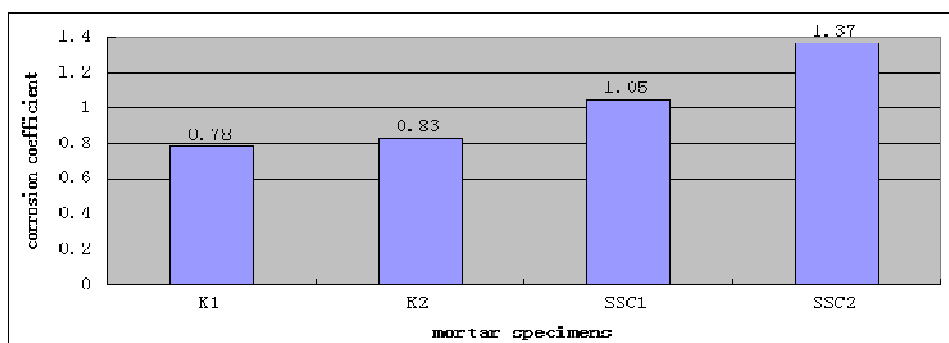


Fig.2 Corrosion coefficient of mortars at 3 months age

It is shown in fig.2 that the value of R_c for controlled specimen K1 blended with pure P.O42.5 cement is 0.78, for specimen K2 with addition of 50% of GGBS, the R_c value is 0.83, this means incorporation of GGBS is beneficial as a result of dilution effect and pozzolanic effect.

Corrosion coefficient is used to evaluate the sulfate resistant ability of cement by comparison of the flexural strength, as flexural strength of mortar specimens is more sensible to sulfate attack

than compressive strength, ratio of flexural strength of mortars immersed in water to that of immerse

in 3% Na_2SO_4 , is defined as corrosion coefficient, R_c ,
$$R_c = \frac{R_{\text{sulfate}}}{R_{\text{water}}}.$$

For supersulphated cement the R_c value increased from 1.03 to 1.37, both are much better than K1 and K2. The highest R_c value of SSC2 specimen with 5% P.O42.5+80%GGBS+15% gypsum is 1.37, as there is little $\text{Ca}(\text{OH})_2$ content in hydration products, both ettringite and gypsum formation is inhibited.

100×100×100 mm concrete specimens with binder mix proportion as table.3 was prepared, when compressive is 20MPa, specimens were immersed in 5% Na_2SO_4 solution for 3 months, visual examination was employed as shown in fig.3.



Fig. 3. Deterioration of mortars after 3 months of immersion in 5% Na_2SO_4 solution

Summary

Supersulphated cement exhibits excellent resistance to sulfate attack according to ASTM C10212 and GB 2420 test, the expansion rate in 5% Na_2SO_4 solution is less than 0.06%, corrosion coefficient is 1.05 for SSC1 and 1.37 for SSC 2, for concrete drainage pipeline subjected to H_2S and domestic sewage related sulfate attack, application of supersulphated cement is helpful for the improvement of concrete durability.

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