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Sulphate Attack of Concretes Containing Rice Husk Ash

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ABSTRACT

Deterioration of concrete structures in sulfate environments is a well-known phenomenon. Cement chemistry is an important parameter in coping with sulfate attack. C_3A and CA $(OH)_2$ lead to expansion, cracking and strength reduction. The use of rice husk ash (RHA) can improve the sulfate resistance of concrete. It was observed that the sulfate resistance of blended cements was significantly higher in sulfate environments. This study investigates the effect of RHA replaced by cement on the durability of concrete due to sulfate attack. Three RHA replacement levels were considered in the study which is 7%, 10% and 15% by the weight of cement. After the specified initial moist curing period (28 days), concrete specimens were immersed in sodium sulfate & magnesium sulfate solution. The degree of sulfate attack was evaluated by measuring the compressive strength reduction of concrete cubes and their weight losses in both continuous immersed and wetting-drying conditions. Expansion observed in the ordinary Portland cement mortar prisms was larger than expansion for the RHA mortar prisms. Moreover, microstructure of the mortar and concrete incorporating Rice Husk Ash were studied through SEM tests.

KEYWORDS

Rice Husk Ash, Durability of Concrete, Sulphate Attack, Mortar Prisms Expansion, Microstructure

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INTRODUCTION

Sulfate attack is one of the most aggressive environmental deteriorations that affect the long-term durability of concrete structures. The sulfate attack of concrete leads to expansion, cracking, and deterioration of many civil engineering structures exposed to sulfate environment such as piers, bridges, foundations, concrete pipes, etc. The sulfate ions in the solution, which come from soil, ground water, and seawater, are found in combination with other ions such as sodium, potassium, magnesium and calcium ions. The sulfate ions react with C3A and Ca(OH)2 to produce expansive and softening types of deterioration. The sulfate attack in the marine environment gives rise to expansive ettringite, gypsum, and brucite and is sometimes associated with calcite formation. The attack of sodium sulfate on concrete is due to two principal reactions: the reaction of Na2SO4 and Ca (OH) 2 to form gypsum and the reaction of the formed gypsum with calcium aluminate hydrates to form ettringite. In addition, it is noticed that MgSO4 reacts with all cement compounds, including C-S-H, thus decomposing cement, and subsequently forming gypsum and ettringite. The formation of gypsum and ettringite leads to expansion, cracking, deterioration, and disruption of concrete structures. In addition to the formation of ettringite and gypsum and its subsequent expansion, the deterioration due to sulfate attack is partially caused by the degradation of calcium silicate hydrate (C–S–H) gel through leaching of the calcium compounds. This process leads to loss of C–S–H gel stiffness and overall deterioration of the cement paste matrix.

To control the permeability of concrete, lower w/c ratio and pozzolans are recommended [1]. Effect of various pozzolans on the resistance of cements to external sulfate attack has also been studied by other researchers [2, 3].

1. EXPERIMEMTAL PROGRAM

2.1. Test Methods

A total of 4 concrete mixtures were made; one corresponding to a control concrete (CTL) and three others with 7%, 10% and 15% RHA replaced with cement by weight. Table 1 lists the mixed proportions of concrete. Concrete cubes of 100×100×100 mm dimension were cast for compressive strength and water penetration tests. The sulfate exposure testing procedure was conducted by immersing concrete specimens after the specified initial curing in a water tank containing 5% sodium sulfate and 5% magnesium sulfate solution at 23±2 °C (ASTM C1012-04). Some control concrete cubes were kept in the lime-saturated water solution tank at 23±2 °C for the compressive strength reduction determinations. In addition, 50×50×50 mm mortar samples were prepared for the pozzolanic activity test.

TABLE 1
MIX PROPORTIONS OF CONCRETE

	RHA (Kg/m^3)	Cement (Kg/m^3)	Aggregate (Kg/m^3) Fine	RHA (Kg/m^3) Coarse	Water (Kg/m^3)
CTL	0	350	960.29	795.66	175
7% RHA	24.5	325.5	960.29	795.66	175
10% RHA	35	315	960.29	795.66	175
15% RHA	52.5	297.5	960.29	795.66	175

2.2. Test Results

RHA cubes resulted in the highest strengths at all ages and did not show significant strength loss. This was possibly due to the filling of the pores by the reaction products of sulfate attack. The beneficial effect of pore filling to strength can also be considered for OPC specimens. However, the reduction in strength of OPC specimens shows that the destructive effect of reaction products (gypsum and ettringite) dominated their contribution to strength. When the blended cements are considered, they do not show any significant strength loss until 2 months of continuous exposure (Table 2).

TABLE 2
COMPRESSIVE STRENGTH IN LIME SATURATED WATER AND SULFATE EXPOSURE

Compressive strength of specimens after 2 months sulfate exposure (MPa)			
	28 Days Curing	2 Months In 5% Na2So4	2 Months In 5% MgSo4
CTRL	41.92	41.58	45.5
7%	44.61	49.78	50.28
10%	46.19	51.40	55.49
15%	47.46	47.74	52.16

The weight of specimens without RHA is reduced by 0.1% after 2 months of exposure in 5% $MgSo_4$ exposure but other specimens showed increase in weight, while the weight of specimens with RHA replacement of cement is increased by 0.32% or 7% RHA and 0.21% for 10% RHA and 0.19% for 15% RHA after 2 months of exposure in 5% MgSo4 solution. However, all specimens in 5%

Na2So4 showed an increase in weight after 2 months of exposure.

At the end of 13 weeks, large expansions were observed in OPC containing prism mortars, respectively. All RHA mixtures showed better performance against sulfate expansion. (Both Na2SO4 and MgSO4) The data exhibited less expansion in 5% Na2So4 than 5% MgSo4 for all specimens, while the rate of expansion is not much different in 10% Na_2So_4 and 10% $MgSo_4$.

Surface deterioration was not clearly identifiable on the concrete cubes immersed in the 5% Na_2So_4 solution except control specimens. However, surface scaling and loss of mass could be identified on the concrete cubes immersed in the 5% $MgSO_4$ solution, especially in control and 7% RHA replacement by cement weight and this effect seemed to increase with the time of exposure.

2. CONCLUSIONS

- 7% RHA replacement in this study does not guarantee sulfate resistance of concretes in sulfate environments. Blended cements prepared with RHA reduced the potential for the formation of ettringite due to the reduction in the quantity of calcium hydroxide and C_3A, and thus improved the resistance of specimens to sulfate attack.
- When subjected to continuous sulfate exposure, all specimens showed an increase in weight up to 2 months. This was attributed to the hydration of calcium silicates and to the pozzolanic reactions of blended cements. However, after 2 months, we observed that the mass loss of the OPC concretes began drastically.
- The lower expansion in blended cements was attributed to the early consumption of calcium hydroxide through pozzolanic reactions, which thus reduced the potential for the formation of gypsum and ettringite. The secondary C–S–H gel formed as a result of the pozzolanic reactions forms a coating on the alumina-rich and other reactive phases thereby hindering the formation of ettringite.
- All concrete samples showed a continuous increase in compressive strength up to 2 months except control specimens. The first increase in strength may be attributed to two types of reactions: (I) the continuous hydration of unhydrated cement components to form more hydration products, in addition to the reaction of RHA (in case of blended cements) with the free lime to form more C-S-H leading to increased compressive strength and (II) reaction of sulfate ions with hydrated cement components to form gypsum and ettringite. At earlier ages, these two reactions lead to a denser structure. Whereas, at later ages, the second type of reactions (sulfate attack) become more dominant leading to the formation of microcracks and this decreases the strength.

3. REFERENCES

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