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THE EFFECT OF $MgSO_4$ AND HCl SOLUTIONS ON THE STRENGTH AND DURABILITY OF POZZOLAN CEMENT MORTARS

F.M. Kilinçkale
Department of Civil Engineering, Faculty of Engineering, Istanbul University Avcılar, Istanbul, Turkey

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ABSTRACT

Pozzolan cements are produced by adding pozzolans such as silica fume, rice husk ash, blast furnace slag, fly ash, trass in 20% replacement for Portland cement. On the 28th day of production, the produced specimens are stored in water, in $MgSO_4{\cdot}7H_2O$ (5%) solution and in HCl (pH = 2) solution. The strengths and weights were determined after the mortars are stored in solutions for 56 days. Compressive strengths of the mortars stored in water for 28 days are silica fume, rice husk ash, and control, 43.3, 40.1, and 31.0 MPa, respectively. The highest loss of compressive strength is 20% and the highest gain of weight is 4.2%, occurring in blast furnace slag mortar in $MgSO_4$. *© 1997 Elsevier Science Ltd*

Introduction

Concrete structures can be exposed to sulfate and chloride salts and various acids because of the environmental pollution. Therefore changes in physical and chemical properties and also variations in the microstructure of the mortars and cements caused by interaction with acids and various salts should be examined (1–4). Sulfates are found as Na^+, Mg^{2+}, Ca^{2+}, $NH_4{}^+$ in the solutions. The type of action of these salts on the concrete also varies. An investigation of the effects of Na^+, Mg^{2+}, $NH_4{}^+$ sulfate solutions on trass cements showed the most aggressive solution is $(NH_4)_2$ SO_4 (5).

Pozzolans also show different durability properties with the content and type of active silica present in their composition. In relation to the effect of pozzolan on concrete strength, it should be stated that type, amount and fineness of pozzolan, and also the type of cement are factors that affect the strength of concrete (6).

CSH is produced by the reaction between the amorphous glassy silica that is present in pozzolan and CH that is produced as a result of the hydration of cement. This product is also effective on the durability of concrete. This experimental study is aimed to investigate the strength and durability properties of mortars that are produced by using pozzolans with a high degree of fineness such as silica fume or rice husk ash and also by other pozzolans such as fly ash, blast furnace slag, and as a natural pozzolan trass. Blast furnace slag is a cementitious and it has some pozzolanic properties. These mortars are stored in $MgSO_4$ and HCl solutions to investigate the effects of the action of salts and acids on the strength and durability properties.

TABLE 1
Properties of Cement (8)

Physical properties		Chemical composition, by wt (%)	
Specific mass (Mg/m^3)	3.12	SiO_2	20.16
Setting Times		Insoluble residue	0.40
Initial (h, min)	2.20	Al_2O_3	7.0
Final (h, min)	3.20	Fe_2O_3	3.20
Soundness (mm)	3.0	CaO	62.96
Specific surface (m^2/kg) (Blaine)	302	MgO	1.41
Fineness % retained on		SO_3	2.94
200 μ	0.6	Loss on ignition	1.85
90 μ	8.0		

Mechanical properties	Strengths (MPa)	
Ages (days)	Flexural Strength	Compressive Strength
7	5.5	32.0
28	7.3	44.6

TABLE 2
Properties of Pozzolanas (8)

	Physical properties		Chemical Composition, by wt (%)							
	Specific mass (Mg/m^3)	Specific surface (m^2/kg)	Soluble SiO_2	Insoluble residue	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	• LI
Rice husk ash	1.90	56000 (BET)	80.25	7.25	4.75	2.00	0.89	0.64	—	4.05
Silica fume	2.21	26000 (BET)	75.54	17.46	1.00	2.00	1.50	0.70	0.40	0.74
Fly ash	2.20	403 (BLAINE)	56,25*	—	32.10	3.90	3.92	1.40	—	2.22
B. furnace slag	3.08	277 (BLAINE)	35.85	0.32	20.77	0.98	37.2	4.90	—	—
Trass	1.90	118 (BLAINE)	25.71	35.74	20.04	1.46	3.43	0.70	—	12.15

* SiO_2: Total SiO_2

TABLE 3
Strength of the Mortars in Pozzolanic Activity Test (according to TS 25 (9)) (8)

	Rice husk ash	Silica fume	Fly ash	Blast furnace slag	Trass	TS25
Flexural strength (MPa)	1.4	1.6	1.6	2.0	2.3	1.0
Compressive strength (MPa)	4.8	5.8	5.2	6.9	5.4	4.0

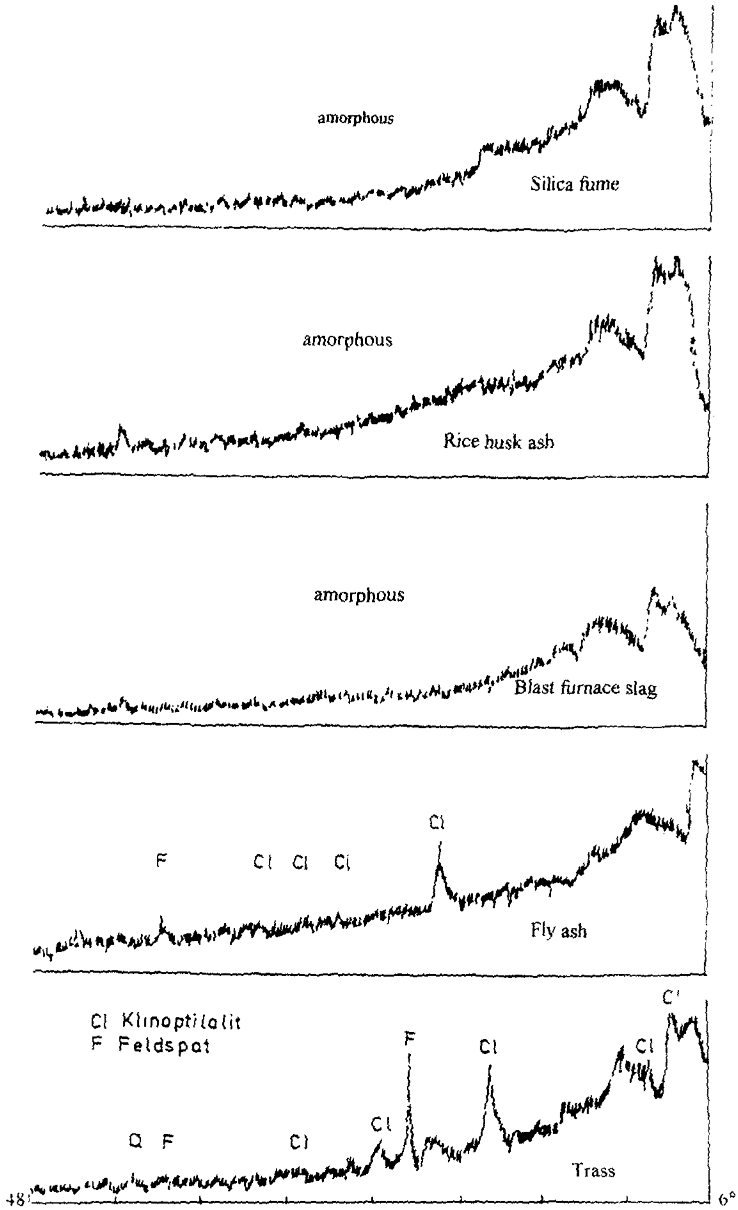

FIG. 1.
X-Ray Diffractograms of Pozzolans (8).

Experimental Work

Portland cement, pozzolan, sand, water, and superplasticizer were used in the production of mortar. The properties of cement are given in Table 1. As is seen in Table 1, cement is of PC 32.5 type (7). Blast furnace slag was produced from Karabük (Zonguldak), fly ash is from

TABLE 4
Mortars Codes and Materials (g) (8)

Mortar	Code	Cement	Pozzolan	Sand	Water + Superplastiazer
Control	C	450	—	1350	250 + 9
Silica fume	S	360	90	1350	250 + 9
Rice husk ash	R	360	90	1350	250 + 9
Fly ash	F	360	90	1350	250 + 9
Blast furnace slag	B	360	90	1350	250 + 9
Trass	T	360	90	1350	250 + 9

Çatalağzı Thermic Power Plants (Zonguldak), Silica fume is from Etibank Ferrochrome Plants (Antalya), trass is from Şile (İstanbul), and rice husks from Ayvansaray (İstanbul) in the laboratory. The properties of pozzolans are given in Table 2. Pozzolanic activity tests were made on these pozzolans (8). The results of the activity tests are given in Table 3. X-ray diffractograms of pozzolans, which show that they are amorphous, as given in Figure 1 were obtained by Cu (Ni) K_α radiation and a current of (20 mA, 40 kV) at a speed of 2θ = 1°/minute using a Philips Diffractometer.

The composition of mortars (produced by cements) are given in Table 4. $MgSO_4 \cdot 7H_2O$ solution (5%) and HCl (pH = 2.0) solution are prepared in order to test enhance the resistance of mortars to the attack of chemicals. On the 28th day of the production, the mortars are put in these solutions, which are changed in every 15 days. Flexural and compressive strength properties of the mortars are given in Table 5.

Evaluation and Discussion

Strengths of Mortars

Relative compressive strengths of the mortars stored in water, HCl, and $MgSO_4$ solutions are given in Figure 2, which has been drawn according to the results given in Table 5. Relative flexural strengths of the mortars kept in the same solutions are depicted in Figure 3.

It can be observed in Figures 2 and 3 that silica fume, rice husk ash, and trass mortars exhibited the highest strength properties. The 56th day strength of the mortars are compared to their 28th day strength and are given in Table 6. An examination of Table 6 indicates that compressive strength of all pozzolans that are stored in water were increased in comparison to their initial strength. The order of the amounts of increases are compared to the initial

TABLE 5
Compressive and Flexural Strengths of Mortars at 28th days

Mortar Code	C	S	R	F	B	T
Compressive strength (MPa)	31.10	43.4	40.1	27.0	27.5	34.6
Flexural strength (MPa)	3.5	6.7	6.8	5.7	5.3	6.0

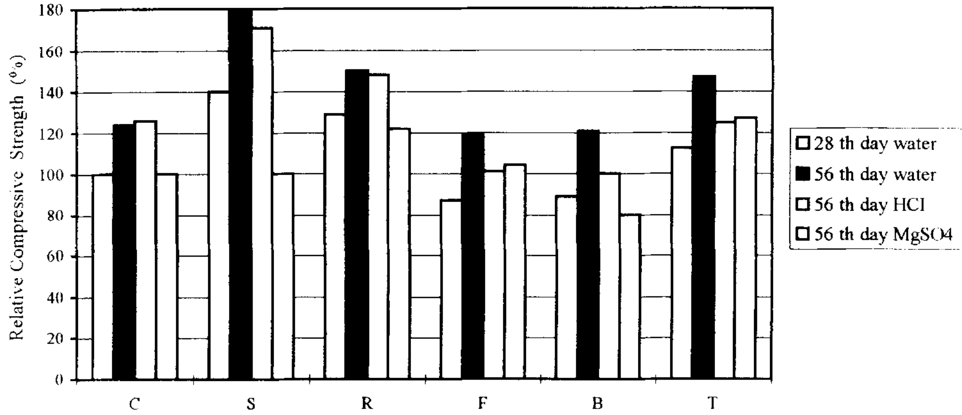

FIG. 2.
Relative Compressive Strengths of Mortars.

strengths are 137, 136, 131, 128, 124, and 116% for fly ash, blast furnace slag, trass, silica fume, control, and rice husk ash, respectively.

The compressive strength of mortars stored in HCl solution had also increased compared to their original strength but the amount of increase was less than that of the measured strength for samples stored in water.

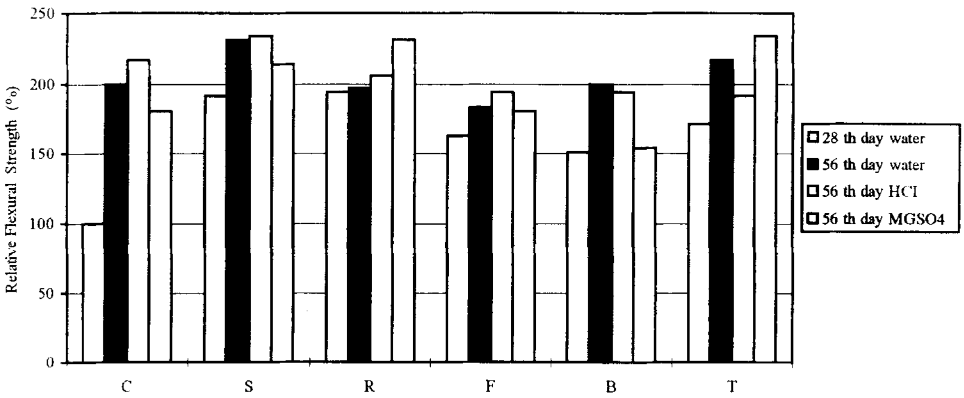

FIG. 3.
Relative Flexural Strengths of Mortars.

TABLE 6
Relative Compressive Strengths of Mortars R_{56}/R_{28}

Mortar Code Solution	C	S	R	F	B	T
Water	124	128	116	137	136	131
HCl	126	122	115	116	112	112
$MgSO_4$	100	71	95	119	90	113

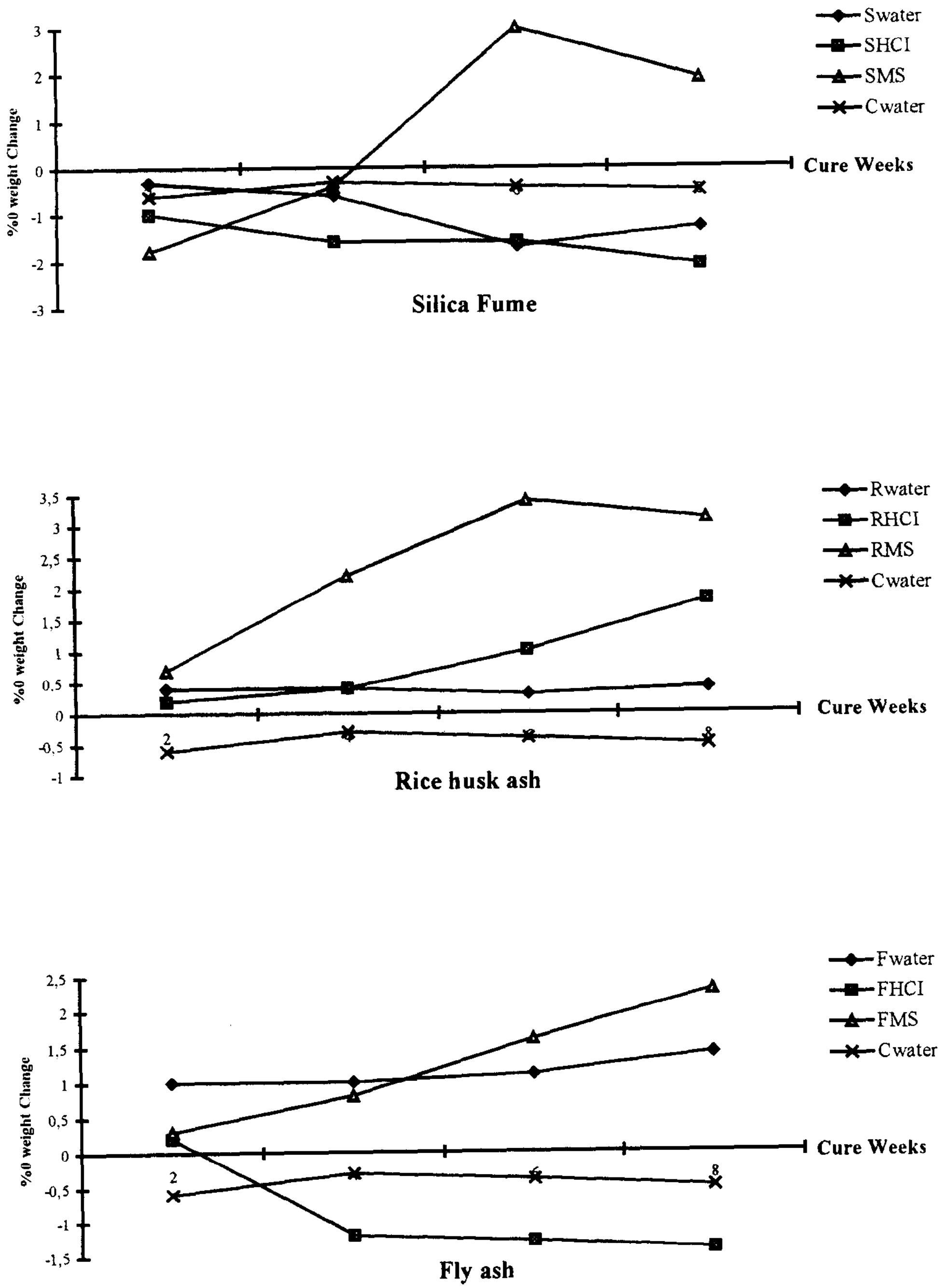

FIG. 4A.

Weight changes of the silica fume, rice husk ash, and fly ash mortars.

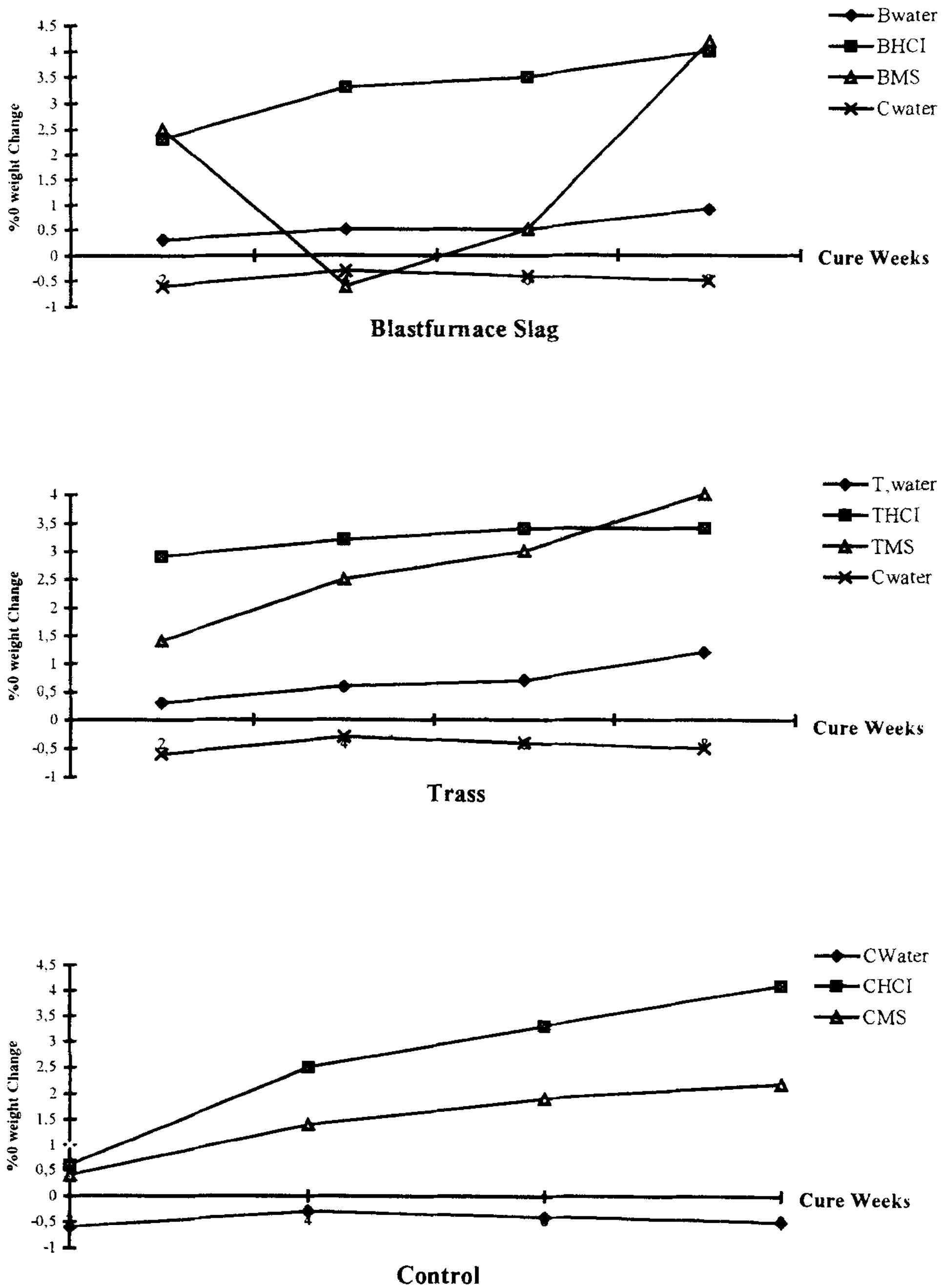

FIG. 4B.
Weight changes of the blast furnace slag, trass, and control mortars.

Control mortar had not changed for mortars stored in $MgSO_4$ solution. Increases of 19 and 13% for fly ash and trass were observed, while reductions of 5, 10, and 29% had been experienced by rice husk ash, blast furnace slag, and silica fume, respectively.

The higher rate of loss in strength in silica fume mortars exposed to stronger acid solutions such as HCl and HNO_3 can be explained as follows: Silica fume imparts colloidal stability and cause better dispersion of cement particles and may also be acting as seeds for the precipitation of CSH products, thus resulting in a more homegenous structure and higher strength. However, due to progressively lowered rate of hydration, smaller amounts of CSH gel may be forming, which upon exposure to dissolving acid attack higher solubility corrosion products form and be leached. This results in a relatively higher rate of loss in strength than for cement paste, which has a higher CSH resource in the solid structure.

Weight Changes

Changes of weight with respect to exposure time and the type of solution are depicted in Figures 4a and b. Considered changes of the weight haven't been observed for any of the samples that were stored in water for 8 weeks.

Among the mortars that were stored in HCl solution, weight losses were observed for silica fume mortars and fly ash mortars, but weight increases have been measured for the others.

Weight increase have been measured for all of the mortars stored in $MgSO_4$ solution.

Conclusions

1) All pozzolans have pozzolanic activity.
2) Flexural strength of all pozzolan mortars are higher than control mortars at 28th days.
3) All mortars have higher compressive strength than control mortars except fly ash and blast furnace slag mortars.
4) All mortars are durable exposed to $MgSO_4$ and HCl solutions except blast furnace slag mortars in $MgSO_4$.

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