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Research Paper

EFFECT OF AGGRESSIVE CHEMICAL ENVIRONMENT ON SETTING CHARACTERISTICS OF PLAIN AND BLENDED CEMENT

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Cement is one of the basic constituent of the reinforced cement concrete . Setting and hardening properties of cement affect the properties of concrete. When the pollutants present in atmosphere reacts with rainwater, it creates various types of weak and strong acids. The strong acids such as sulphuric and nitric acid have much influence on the basic properties of cement. Similarly soil pollution due to unplanned disposal of industrial and urban wastes on ground causes the presence of strong acids, bases and salts. The setting time of cement is very important property as it affects the concrete characteristics. In cement C_3A hydrates most rapidly followed by the iron compound C_4AF, then C_3S and C_2S. The paper presents result of an experimental investigations on setting times of cements.

Keywords: Cement Mortar, Blended Cement

INTRODUCTION

The influence of aggressive chemicals on the behavior of building materials is a topic of significance interest, as it affects the safety and durability of structures. In the construction industry, cement is widely used as a binding material. The chemical constituents of cement are sensitive to aggressive environments and thus their strength and durability of cement get reduced in due course of time. The aggressive environments affecting the setting and hardening characteristics of cement are either available in nature or produced from industries and automobiles mainly. When the pollutants present in atmosphere reacts with rainwater, it create various types of weak and strong acids. The strong acids such as sulphuric and nitric acid have much influence on the basic properties of cement. Similarly soil pollution due to unplanned disposal of industrial and urban wastes on ground causes the presence of strong acids, bases and salts. Thus air, water and soil pollution contributes to increase chemical concentrations in otherwise acceptable environments. Amongst the

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various properties of cement which are of interest, the setting times and strength are of basic importance. Cohen (1991) and (1988) reported the mechanisms of sulphate attack and accelerated testing methods based on proposed mechanisms. Lea (1970) and Mehta (1986) proposed that loss of adhesion and strength from decomposition of dominant phases in hydrated Portland cement, i.e., Ca $(OH)_2$ and C-S-H gel should be considered as an integral part of sulphate attack. The effect of acids and salts are observed on the setting times of plain cement and blended cement (cement mixed with various proportions of fly ash).

Many naturally occurring soils and water sources contain aggressive chemicals which lead to deterioration of structures. Due to the attack of aggressive environments many properties of concrete are affected. The setting time of cement is the very important property as it affects the concrete characteristics. In cement C_3A hydrates most rapidly followed by the iron compound C_4AF, then C_3S and C_2S. The stiffing and setting characteristics of Portland cement pastes are largely determined by the hydration reactions involving aluminates. The nature of hydration of C_3A is changed considerably if this compound is placed in sulphate solution. In the present investigation the attention is focused on the setting time of the ordinary Portland cement and fly ash blended cement as affected by the sulphate salts and acids. The result of experimental investigations on setting times of cements are discussed in following section.

EXPERIMENTAL PROGRAM

The cement used for the investigation was ordinary Portland cement of 53 grade. The quantities of acids and sulphate salts added to the water for making solution of concentration of 0.1 N, 0.2 N and 0.3 N are presented in Table 1.

All the tests for setting times of cement and blended cement were conducted by Vicat needle method as per BIS specifications. The Chemical composition of fly ash obtained from Parichha Thermal Power Plant, Jhansi is exhibited in Table 2.

In combination, the percentage masses of silicon oxides, aluminum oxide and iron oxide in Table 2 is 87.59%, which is above the 70% limit specified for Pozzolana by ASTM C 618-78. The amount of sulphur trioxide (SO_3) was 0.54 which was less than the specified limit of 5% as per ASTM C 618-78. The excessive level of SO_3 is undesired in concrete as they may lead to volume instability and thus loss of durability.

EXPERIMENTAL RESULTS AND DISCUSSION

The initial and final setting times of the plain ordinary Portland cement using ordinary water, acids and salt solutions were determined at a constant normal consistency of 36% by Vicat apparatus using standard procedure. The test is repeated for the cement replaced by fly ash to the extent of 20% and 30% by weight of the cement. The tests were conducted for the setting times at the normal consistency of fly ash blended cement. The normal consistency of cement with 20% and 30% fly ash was 42% and 45% respectively. The properties of the ordinary Portland cement and blended cement are shown in Table 3.

Table 1: Concentration of Chemicals

S. No.	Chemicals		Concentration (N)	Quantity per Litre of Water
1.	Acids	Sulphuric acid (H_2SO_4)	0.1	2.8 mL
			0.2	5.6 mL
			0.3	8.4 mL
		Hydrochloric acid (HCl)	0.1	9.0 mL
			0.2	18.0 mL
			0.3	27.0 mL
2.	Salts	Ammonium Sulphate ($(NH_4)_2SO_4$)	0.1	6.6 g
			0.2	13.2 g
			0.3	19.8 g
		Magnesium Sulphate ($MgSO_47H_2O$)	01	6.0 g
			0.2	12.0 g
			03	18.0 g

Table 2: Physical and Chemical Properties of Fly Ash

S. No.	Physical and Chemical Properties	Value
1.	Specific gravity	1.16
2.	Loss on ignition (%)	5.2
3.	pH	9.5
4.	Surface area (Cm^2/gm)	3000
5.	Silicon Oxide (SiO_2)	57.10
6.	Aluminum Oxide (Al_2O_3)	23.83
7.	Iron Oxide (Fe_2O_3)	6.66
8.	Calcium Oxide (CaO)	3.34
9.	Magnesium Oxide (MgO)	0.56
10.	Sulpher Trioxide (SO_3)	0.54

Table 3: Properties of Ordinary Portland Cement and Blended Cement

Fly Ash (%)	Consis-tency (%)	Setting Times (min)		Soundness (mm)
		Initial	Final	
0	36.0	105	290	0.70
20	42.0	130	320	1.00
30	45.0	140	335	1.20

The normal consistency of the cement increases with the level of cement replacement. At 20% cement replacement the normal consistency was 42% while at 30% replacement of cement it was 45%. The variation is shown in Figure 1.

The increase in normal consistency with the increase in percentage replacement of cement by fly ash is associated with the requirement of water with the increase in the percentage of

Figure 1: Variation of Normal Consistency of Cement With % Replacement of Fly Ash

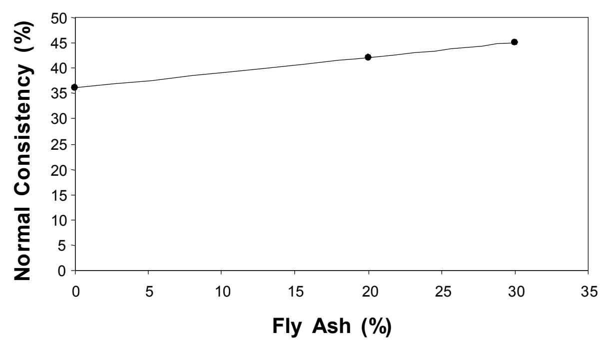


Figure 2: Variation of Soundness of Cement with % Replacement of Fly Ash

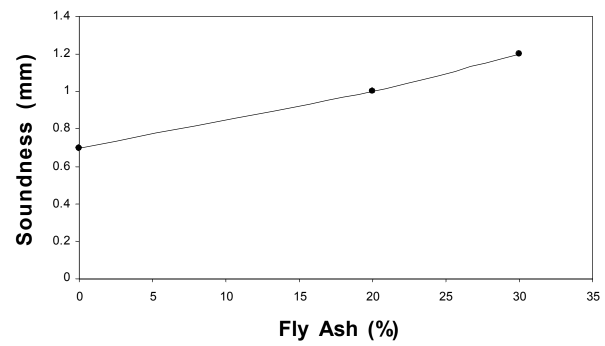
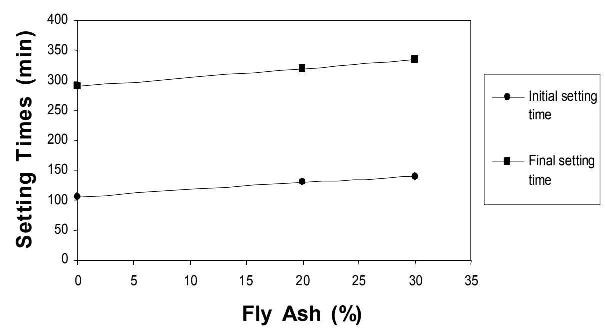


Figure 3: Variation of Setting Times of Cement With % Replacement of Fly Ash



fly ash. This may be attributed to increase in surface area of fly ash as compared to that of cement.

Expansion in cement normally takes place due to delayed or slow hydration or even other reactions of some compounds present in the cement namely free lime, magnesia and calcium sulphate (Neville, 1981). The cements that exhibit this expansion are known as unsound. The soundness of the cement was determined by Le Chatlier's apparatus as per Codal provisions.

Figure 2 indicates that the soundness increases with percentage replacement of cement with fly ash. This may be due to free lime existing in fly ash. However, both plain cement and blended cement showed insignificant expansion, well within the limiting value of 10 mm specified by code of practices IS 8112-1989, even by replacing 30% cement with fly ash.

Figure 3 indicates that, the initial and final setting times both were increased with the blending of fly ash in OPC paste. The increased setting time of OPC paste could be the result of a retarded hydration due to presence of fly ash. The similar results were reported by Flex FU and Philibus UD (2002). Kumar (1994) has reported the effect of sulphates on the setting times of cement. In the present investigation effect of sulphates and acids on the setting times of OPC and blended cements were studied.

Figures 4 and 5 shows the increase in Initial Setting Time (IST) with concentration of different sulphates and sulphuric acid. The increase in setting times may be due to decrease in solubility of anions present in cement paste as strong anion $(SO_4^{-})^{-}$ existing in the solution. The increase in setting times is more dominant in case of magnesium sulphate in comparison to aluminium sulphate. This may be due to the presence of strong cation (Mg^{++}) as compared to less strong cation (NH_4^{+}). The

Figure 4: Effect of Different Sulphates on Initial Setting Time of Cement Partially Replaced by Fly Ash

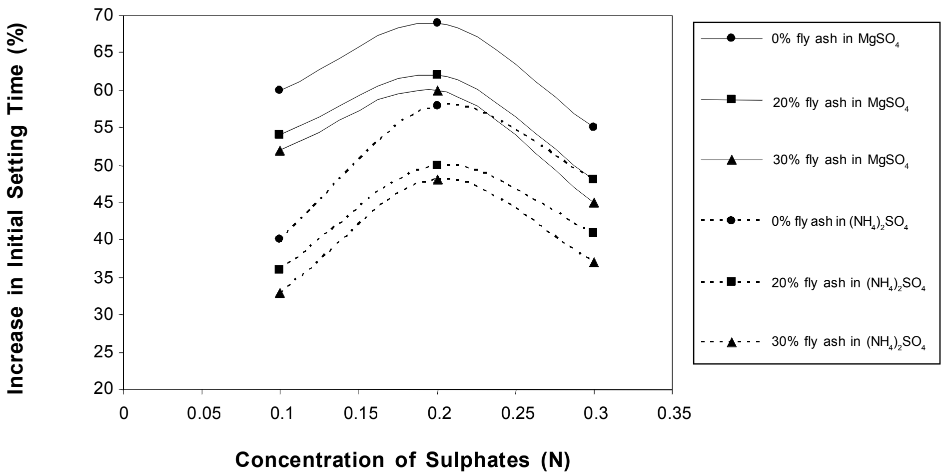
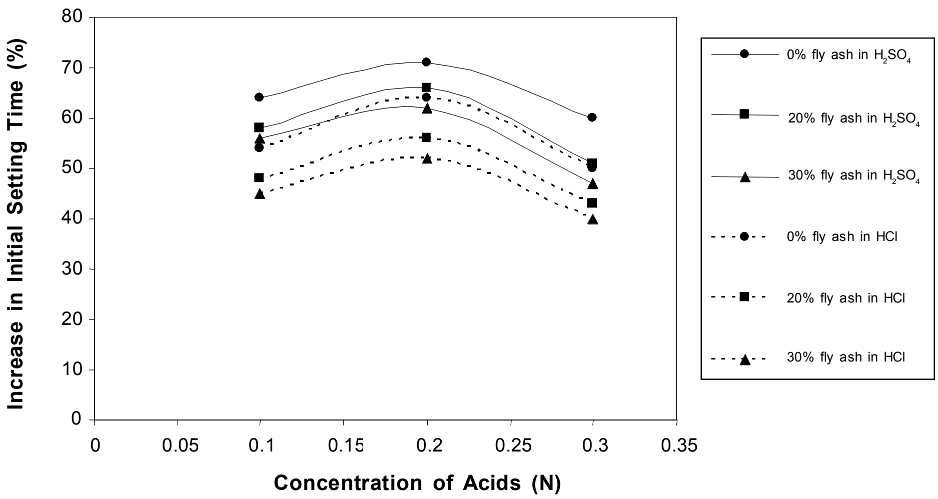


Figure 5: Effect of Different Acids on Initial Setting Time of Cement Partially Replaced by Fly Ash



similar reason may be in acids where sulphuric acid is more stronger acid than hydrochloric acid.

The rate of reaction of the anhydrous solids with water and the interplay of lime, alumina, silica and sulphate in solution determine the nature of products and the speed of setting. Depending on the concentration of sulphate ions, sulphates stop the rapid set of C_3A by forming high sulphate of calcium, sulphoaluminate, called ettringite, or low sulphate form of calcium mono sulphate. The percentage increase in the initial setting time is maximum at 0.2 N and then decreases. The reason for the decrease at higher concentrations may be due to change in behavior of alumina solubility. If alumina solubility is low, then it shows increase in setting time. Upto a particular concentration of aggressive chemicals the alumina solubility decreases and thereby increase in setting time, there appears to be change in mechanism beyond 0.2 N concentration.

Figures 4 and 5 also shows the variation of IST of cement with its replacement by fly ash equal to 20% and 30% respectively. The presence of fly ash reduces the effect of sulphates and acids. It may be due to the fact that the fly ash reduces the calcium hydroxide and aluminate bearing hydrates which are more vulnerable to sulphate attack. The fly ash with high replacement level upto 30% showed a good resistance to sulphates and acids. In case of acid exposure the resistance due to presence of fly ash is less as compared to sulphates. Figure 5 shows that the effect of sulphuric acid on setting characteristics is more dominant as compared to that of hydrochloric acid. It may be due to the fact that sulphate ions are stronger than the chloride ions.

Figure 6: Effect of Different Sulphates on Final Setting Time of Cement Partially Replaced by Fly ash

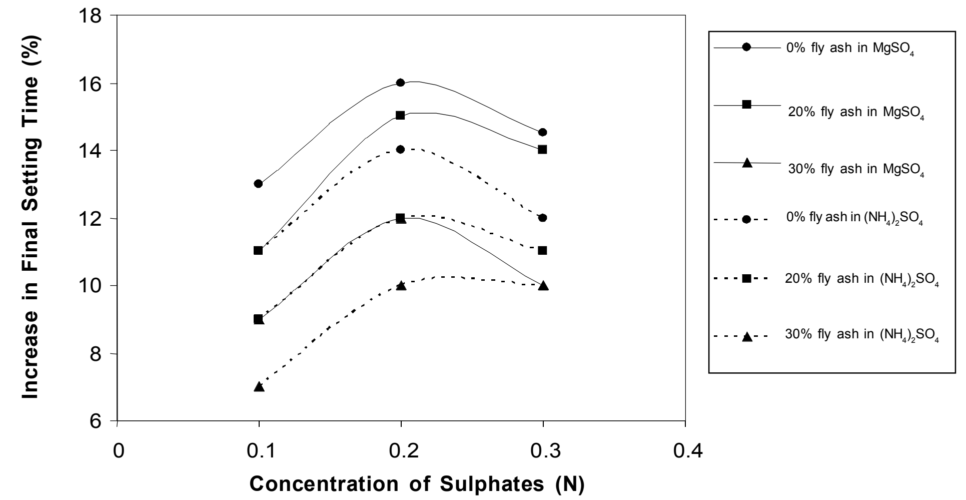
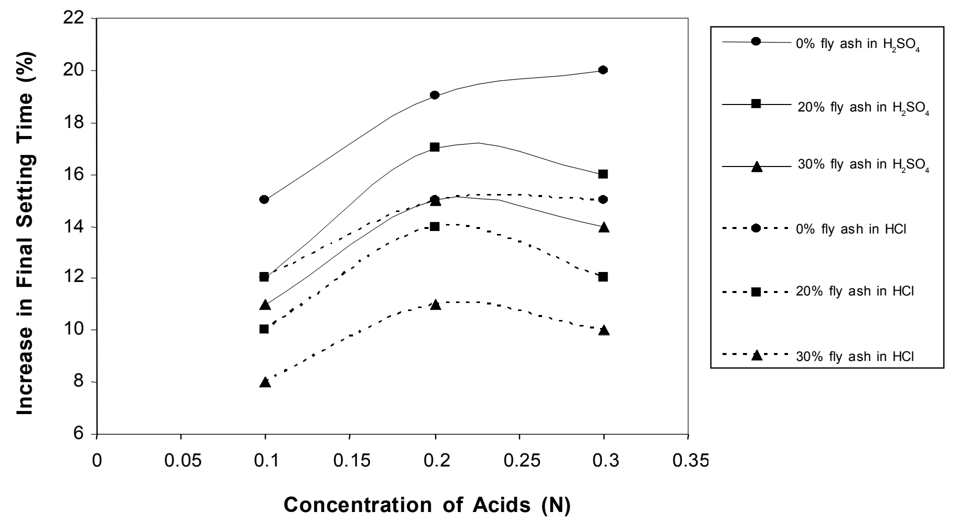


Figure 7: Effect of Different Acids on Final Setting Time of Cement Partially Replaced by Fly ash



Figures 6 and 7 shows the variation of Final Setting Times (FST) with different concentration of acids and sulphates. The percentages increase in FST is maximum at 0.2 N concentration and thereafter it decreases or almost constant. This behavior indicating a constant value of setting time is unlike the variation of IST. The reason for this change may be that overall effect depends upon all the cations and anions present in the cement and solution.

CONCLUSION

On the basis of experimental investigation regarding setting and hardening characteristics of plain and blended cement in aggressive environments, the following conclusions may be drawn.

1. The normal consistency, soundness and setting times of cement increases with the increase in blending of fly ash as cement replacement.
2. The initial and final setting times of plain cement and blended cement increases with the concentration of sulphates upto 0.2 N and there after a drop in percentage increase in the initial setting time and final setting time was observed with the further increase in aggressiveness
3. The percentage increase in IST is more as compared to that of FST for the some concentration.
4. On the replacement of cement with fly ash the % increase in setting times reduces in aggressive chemical environments and this reduction is more with 30% replacement of cement by fly ash as compared to that of 20% replacement.
5. The % increase in setting times are maximum in case of sulphuric acid followed by HCl then $MgSO_4$ and lastly $(NH_4)_2SO_4$.

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