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EFFECT OF ALKALI BYPASS DUST ON THE HYDRATION OF GRANULATED BLAST FURNACE SLAG BLENDED CEMENT

By
N.B. Singh, K.N. Bhattacharjee and A.K. Shukla
Department of Chemistry
University of Gorakhpur
I N D I A

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ABSTRACT

The hydration properties of blended cements made from portland cement and a waste material obtained from a Birla White Cement Factory known as an Alkali Bypass Dust were studied. The results showed that 5 to 10 percent addition of this waste material in the portland cement decreased the water requirements, accelerated the hydration, decreased the porosity and increased the compressive strengths at all the ages of hydration. Hydration properties of granulated blast furnace slag blended portland cement in presence of 5% alkali bypass dust have also been studied. The extent of hydration decreased as the amount of slag is increased but the compressive strength values were higher at 28 days.

INTRODUCTION

Blended cements are being used for the long time to save energy and natural resources(1-4). Number of industrial and agricultural wastes and byproducts are being generated world wide, which by themselves or when mixed with each other or with portland cement give cementitious properties. Further the characteristics and the properties of blending components have been changed and varied and the application of blended cements has been diversified. Therefore, it is essential to study the hydration properties of blended cements made from portland cement clinker and different type of industrial wastes in order to understand the cementitious properties.

In this article the hydration characteristics of portland cement blended with alkali bypass dust (a waste product of Birla White Portland Cement Factory) have been studied. Attempts have also been made to see whether this waste material can activate granulated blast furnace slag in the blended portland cement.

EXPERIMENTAL

MATERIALS, THEIR ORIGIN AND COMPOSITION OF BLENDS :

Alkali bypass dust is obtained from a Birla White Cement Factory at Gotan, Jodhpur, Rajshthan, India. In the manufacture of white cement, raw materials devoid of iron oxide content needs to be used otherwise whiteness of the cement will get disturbed. China clay is used as one of the raw materials and furnace iol is used as a fuel. In the latest dry process rotary kilns with five stage suspension preheater and precalcinator, alkalis and chlorides from China clay create lot of problems in the suspension preheater as they get volatilized in the burning zone of kiln (1500°C) and get deposited at cooler parts like inner walls of cyclones of preheater where the temperature is 200 to 600°C. This causes obstruction to the flow of gases and material and the cyclones have to be cleaned causing heavy down time of kiln system. Therefore, the gases rich in alkalies and chlorides are bypassed after the kiln stage so that the gases entering the cyclones in preheater have less alkalies and chlorides. The bypassed gases are collected in the form of coarse dust and is called alkali bypass dust. Its composition varies widely depending upon the process parameters and amount of gas bypassed.

Portland cement clinker was taken from a VSK plant, Bhutan. Granulated blast furnance slag was taken from M/S Indian Iron and Steel Co. Ltd., Burnpur, Asansol. The following symbols are given to the materials.

Portland Cement Clinker -PCC
Alkali Bypass Dust -ABD
Granulated blast furnace slag -GBFS

The chemical composition of the materials and mineralogical composition of PCC are given in tables 1 and 2 respectively.

Table 1

Chemical Composition of Materials (Mass %)

Constituents	PCC	ABD	GBFS
LOI	1.0	11.1	0.3
SiO_2	20.5	12.1	35.0
Al_2O_3	6.5	2.8	21.3
Fe_2O_3	4.5	0.2	1.1
CaO	63.5	52.2	33.1
MgO	3.5	0.9	8.0
Na_2O	-	2.7	-
K_2O	-	12.8	-
Cl^-	-	3.2	-

Table 2

Mineralogical Composition of PCC

Mineral Phase	Composition (%)
C_3S	52.6
C_2S	19.1
C_3A	9.6
C_4AF	13.7

Blends of PCC+ABD and PCC+ABD+GBFS with varying compositions were made in presence of 3% gypsum. The composition and symbol assigned to each blend are given in table 3.

Table 3

Composition and symbol of blends

Composition of Blends	Symbol
97%PCC+3%Gyps	P-O
92%PCC+5%ABD+3%Gyps	PA-1
87%PCC+10%ABD+3%Gyps	PA-2
62%PCC+5%ABD+30%GBFS+3%Gyps	PAG-1
52%PCC+5%ABD+40%GBFS+3%Gyps	PAG-2
42%PCC+5%ABD+50%GBFS+3%Gyps	PAG-3

METHODS :

Specific surface area of each blend was determined by Blaine Area meter. Water requirements for normal consistency were determined by usual method. Setting times, Compressive strengths of blended cement mortars, soundness by Le-Chatelier expansion method and autoclave test were performed as per Indian Standard IS 4031-1988 (Methods of Physical Tests of Hydraulic Cements).

Hydrations of the cements were allowed to continue for different intervals of time and the hydrations were stopped with isopropyl alcohol and ether. The samples were dried at 105°C for one hour and then collected in polythene bags, sealed and stored in desiccator for analysis. The W/C ratio for the control was kept to be 0.5 whereas for blended cements it was 0.3. Different amount of water was needed for making pastes of normal consistency.

Calcium hydroxide values were determined by modified Franke method(5) whereas non-evaporable water contents were determined by determining the weight loss at 1000°C.

The porosity of the control (P-O) and that in presence of 10%ABD (PA-2) hydrated at different intervals of time were recorded with the help of mercury porosimeter.

RESULTS & DISCUSSION

The specific surface area, water requirement for normal consistency, initial and final setting times, Le-Chatelier and Autoclave expansion values are given in table 4.

From table 4, it is quite clear that the specific surface areas depend on the composition of cements. All the blends clear the LeChatelier and Autoclave expansion tests indicating that the compositions are appropriate. It is also seen that as the amount of ABD is increased in the control, the water reduction is increased. In presence of GBFS, the water requirement is

Table 4
Physical Characteristics of the Cements

Properties	P-O	PA-1	PA-2	PAG-1	PAG-2	PAG-3
Sp.Area(M^2/kg)	337	321	370	380	375	350
W/C(%)	26.5	25.5	25	27.5	27	27
IST(min)	130	70	110	125	140	170
FST(min)	220	170	200	230	245	260
LeChat Exp(mm)	2.0	1.0	1.0	2.0	1.0	1.0
Autoclave Exp.(%)	0.128	0.256	0.220	0.009	0.057	0.256

slightly increased. This may be due to adsorption of more water by GBFS particles and not contributing much towards the hydration during this period.

The initial and final setting times vary with the amount of ABD and GBFS and are given in table 4. Both the values decrease at 5% ABD and increase at 10% ABD additions but lower than that of the control (P-O). It appears that the alkalies and the chlorides of ABD accelerate the setting. However at 10% addition, the amount of PCC is considerably decreased and the effect is not so pronounced as at 5% addition. However results show that ABD when added in an appropriate amounts, accelerates the setting of portland cement.

The effect of different amounts of GBFS on the initial and final setting times of portland cement in presence of 5% ABD are given in table 4. Both the setting times increase with GBFS additions. It is mainly due to dilution effect and also GBFS is not contributing much towards hydration during this period. A separate experiment was done on a cement without ABD (67%PCC+30% GBFS+3%Gyps) and the initial and final setting times were found to be 160 and 255 minutes respectively. This clearly indicates that ABD acts as an activator for GBFS and the retarding effect of GBFS on setting is not so pronounced as it would have been without ABD. It is already reported that setting time of blast furnace slag cement is delayed at a rate of 10 to 20 minutes per 10% mixing of slag compared with that of ordinary portland cement (6).

The variations of non-evaporable water content (Wn) in the presence of ABD are shown in Fig. 1. As the hydration progressed, the values of Wn increased in all the cases. The values of Wn were lowest for the control, highest for the cement containing 5%ABD and in between te two for the cement containing 10% ABD. It appears that 5% ABD has an accelerating effect on the hydration and in presence of excess of it the effect is not pronounced. This may be due to dilution effect.

The effect of different amounts of GBFS on the variation of Wn in presence of 5wt% ABD are given in Fig. 2. The values of Wn increased with time and followed the sequence :

P-O > PAG-1 > PAG-2 > PAG-3

This clearly shows that as the amount of GBFS is increased, the extent of hydration is decreased. It appears that probably ABD in small amounts might be acting as an activator to GBFS since it contains alkalies but the amounts of GBFS are so high that its effect become insignificant. It is already reported that small amount of alkalies act as an activator to GBFS and the higher amounts than required has little effect(7). The alkaline activator has the effects of accelerating the elution of Si and Al ions by breaking the glass structure of slag and depositing the hydrate by increasing the ionic concentration in the liquid phase.

The variation of calcium hydroxide with hydration time in presence of different amounts of ABD are shown in Fig. 3. The

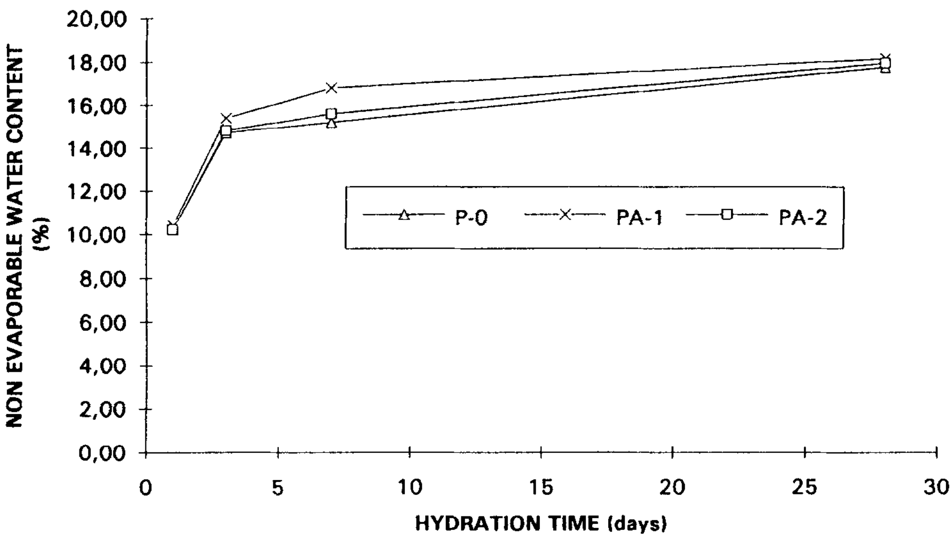

Fig. 1. Variation of non-evaporable water contents with hydration time in presence of different amounts of ABD.

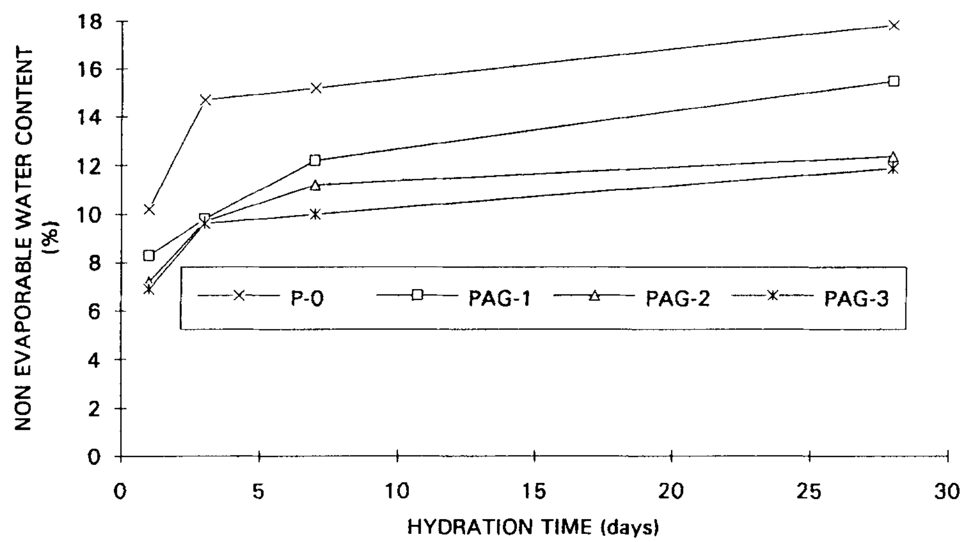

Fig. 2. Effect of GBFS on non-evaporable water contents in presence of 5wt% ABD at different intervals of time.

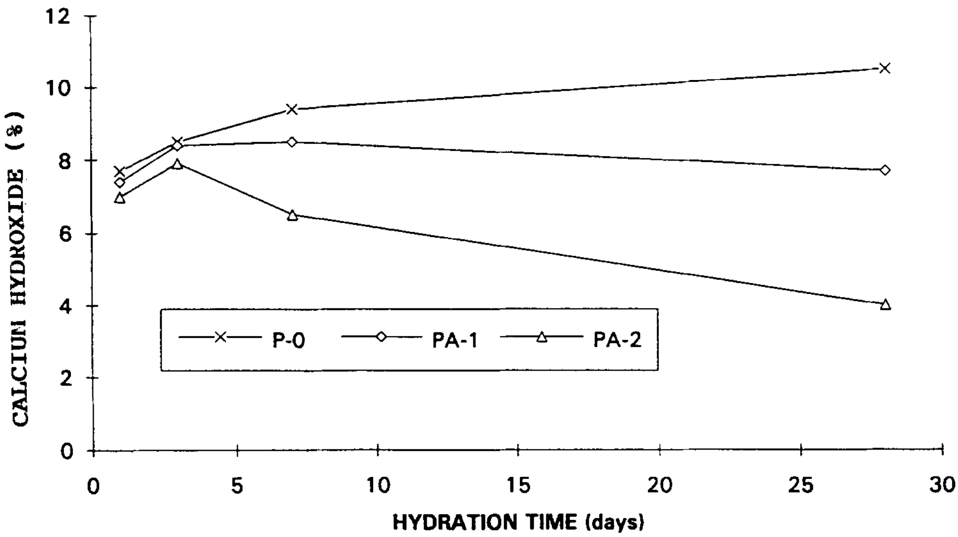

Fig. 3. Variation of calcium hydroxide with hydration time in presence of ABD

amount of calcium hydroxide increases with the hydration time in the case of control but in the pre-ence of ABD the values increased upto 3 days and after that de-reased. The decrease was more in presence of 10%ABD. The results show that ABD behaves as a pozzolanic material and reacts with $Ca(OH)_2$ obtained from the hydration of cement paste.

The effect of different amounts of GBFS in presence of 5%ABD on calcium hyxroxide is shown in Fig. 4. The amounts of calcium hydroxide are practicallyconstant upto 7 days of hydration in all the three cases and then decreased at 28 days. However the amount of calcium hydroxide decreased with GBFS content. The calcium hydroxide values followed the following sequence:

P-O > PAG-1 > PAG-2 > PAG-3

This may be due to dilution effect as well as pozzolanic activity of GBFS.

The effect of ABD on the compressive strength of cements is given in Fig. 5. The compressive strength of the control increases continuously with time. These values are increased further in the presence of ABD. Higher the amount of ABD, greater is the strength. However other hydration properties are not in support of this observation. It appears that ABD changes the rate of hydration and morphology and type of hydration products. However in order to confirm this electron microscopic pictures are needed.

In order to know the effect of porosity on the compressive strength of the cements, percent porosities of cement(P-O) and in presence of 10%ABD (PA-2) were determined. It is found that the porosity decreased with hydration time (Fig.6) and higher the porosity in a given sample, lower is the strength (Fig. 7). In the presence of 10% ABD the porosity values are lower as compared to those of control at all the ages and at the

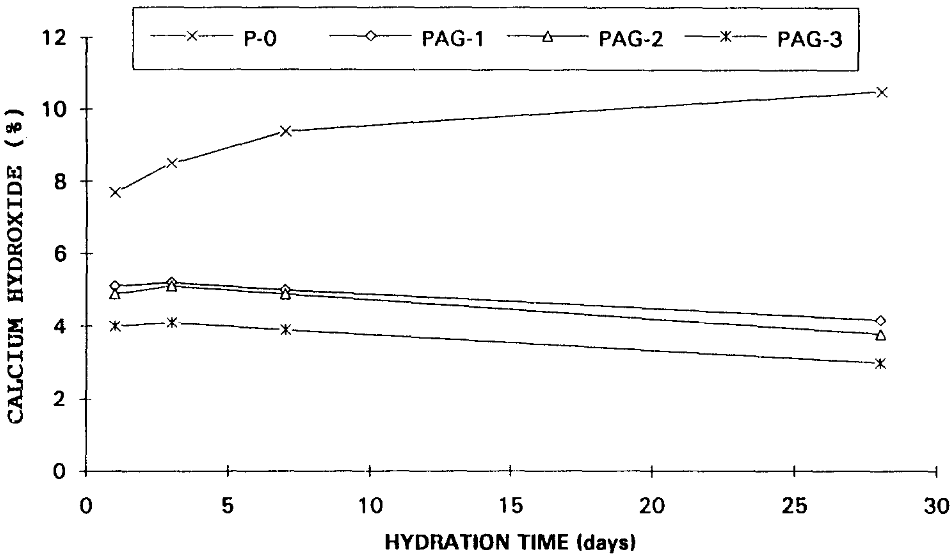

Fig. 4. Variation of calcium hydroxide with hydration time in presence of different amounts of GBFS and 5wt% ABD.

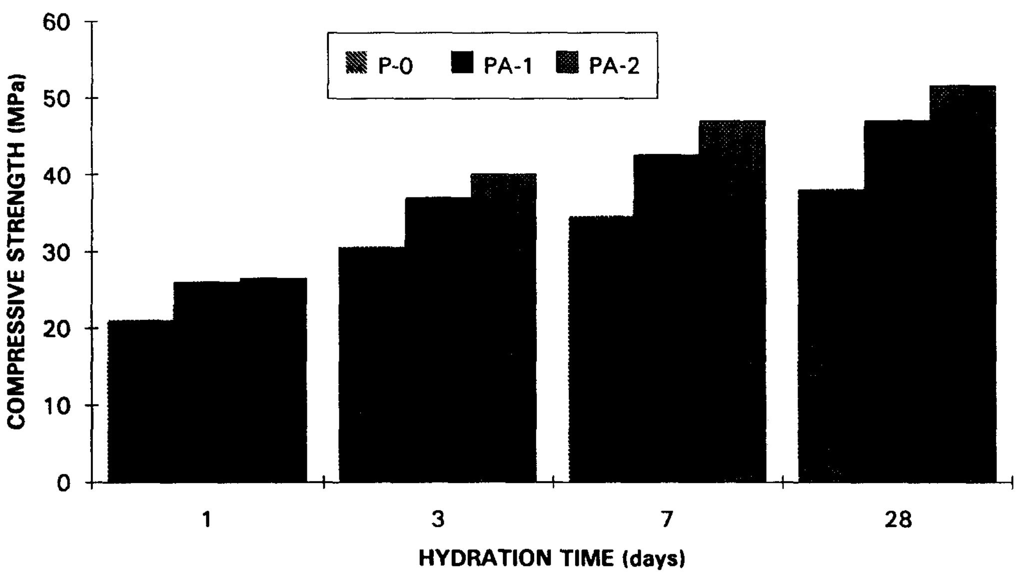

Fig. 5. Variation of compressive strength with hydration time in presence of ABD.

same time the compressive strength values are higher. It confirms that ABD lowers the porosity of the cement.

The combined effect of ABD and GBFS on the compressive strength of cement are shown in Fig. 8. When GBFS is added to the portland cement in presence of 5% ABD, the compressive strength values are lower upto 7 days and higher at 28 days as compared to that of control. The values in presence of different amounts of GBFS are almost equal (the values are slightly higher

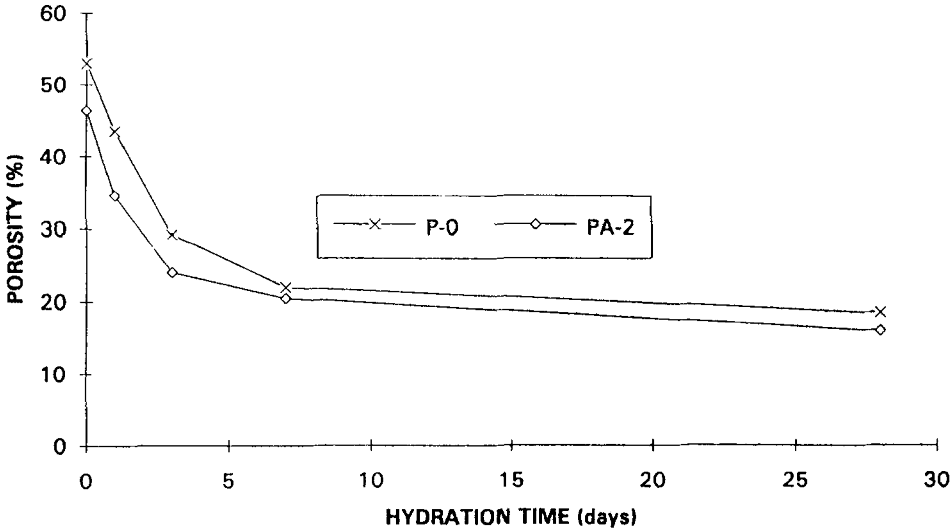

Fig. 6. Effect of hydration time on porosity

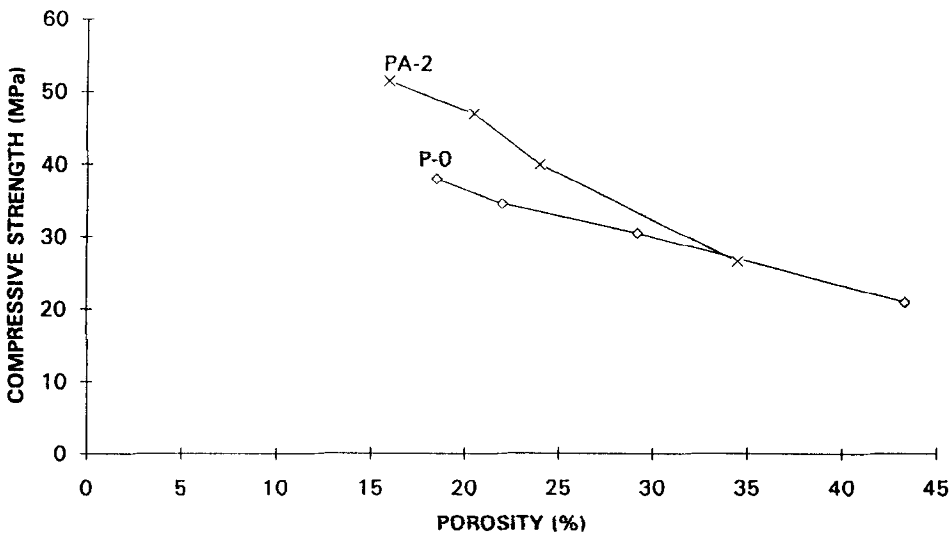

Fig. 7. Variation of compressive strength with porosity

at 40% GBFS as compared to 30 and 50% GBFS). It appears that ABD activates GBFS. It is already reported that alkali-slag system hydrates slower than OPC at the early ages, but exhibits a higher compressive strength at later ages(8). The reason may be ascribed to their different hydration characteristics including the rate and type of hydration products. It is known that the formation rate of products such as C-S-H gel with lower C/S ratio and zeolite type minerals and solid volume changes in the alkali slag cements are different from those in ordinary portland cement(8). Further the solubilities of calcium hydroxide and higher C/S ratio C-S-H gel in portland cement

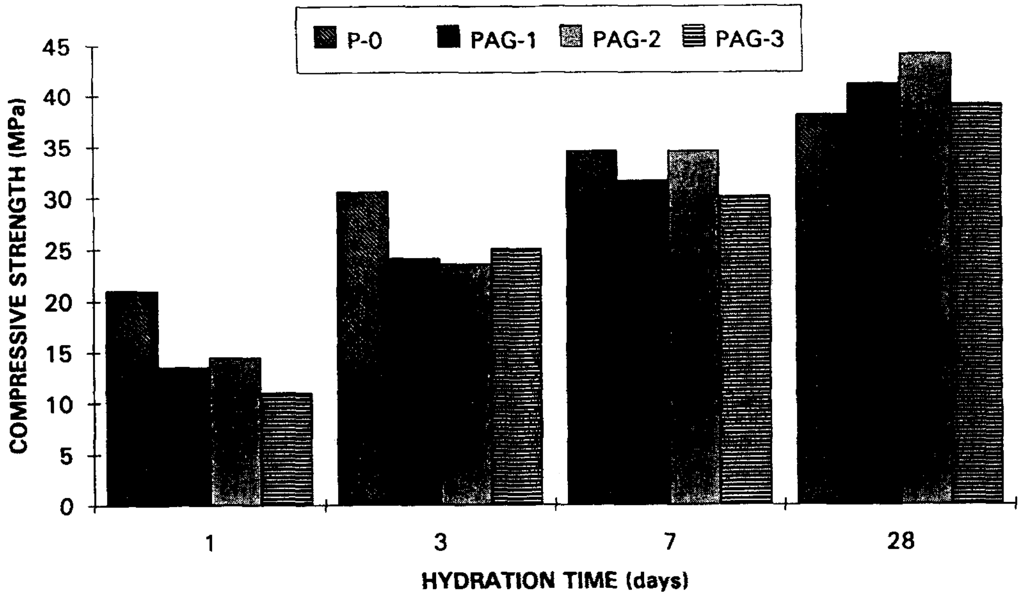

Fig. 8. Effect of GBFS on the compressive strength in presence of 5 wt% ABD.

pastes are 4-10 times than in the slag cements. Uchikawa(9) determined the chemical composition of C-S-H formed in OPC and GBFS blended cement (40% GBFS, w/s=0.4, age-4 years and temp. 293°k). The C/S, A/C and C/S+A values for OPC and blended cements were 2.03, 0.06, 1.81 and 1.62, 0.44, 0.96 respectively. Thus the changes in the C-S-H compositions in presence of GBFS may control the development of porosity and hence the compressive strength.

CONCLUSIONS

The hydration of two type of blended cements-(i) portland cement blended with alkali bypass dust and (ii) portland cement blended with granulated blast furnace slag in presence of 5% ABD, have been studied and from the results, following conclusions have been made.

1. ABD additions decrease the water requirement whereas GBFS additions increased the water requirements.
2. ABD when added in an appropriate amounts in the portland cement, accelerates the setting. GBFS on the otherhand enhance the setting times but in the presence of 5% ABD, the enhancement is not so significant as it would have been in its absence.
3. The non-evaporable water contents increased with time in all the cases and followed the sequence:

PA-1 > PA-2 > P-0 > PAG-1 > PAG-2 > PAG-3

4. The diminishing amounts of calcium hydroxide after 3 days of hydration in all the cases show that both ABD and GBFS might be acting as a pozzolanic material.
5. ABD increased the compressive strengths at all the ages of

hydration probably by changing the rate of hydration and the type of hydration products.

6. The percent porosities in the case of control and cement with 10% ABD decreased with curing time and the decrease is more in presence of ABD.

7. The compressive strengths of GBFS blended cements in presence of 5% ABD at 1,3 and 7 days are lower and higher at 28 days as compared to the control in all the cases. This may be due to different hydration characteristics in presence of GBFS.

8. The overall results have indicated that ABD acts as an activator to GBFS in the blended cements.

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