RESEARCH ARTICLE OPEN ACCESS

Effect of Potassium Chloride on Fly Ash Based Blended Cement Concrete

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ABSTRACT
This paper presents the effect of potassium chloride (KCl) on blended cement concrete (BCC). The BCC was prepared with KCl concentrations of 0.5, 2, 4, 6, 8, 10, 12 and 14 g/l by adding in deionised water. In addition to this, control specimen was prepared with deionised water (without KCl) for the purpose of comparison. The setting times and compressive strength were evaluated for 28 and 90 days apart from studying rapid chloride ion permeability. The results show that, as KCl concentration increases, there is retarding in initial and final setting of blended cement (BC). The compressive strength of BCC increases as the concentration of KCl goes up at both 28 and 90 days. Compressive strengths of BCC show a significant increase at 10 g/l when compared with the control specimens. It was also observed that chloride ion permeability has decreased with an increase in the concentration of the KCl. X-ray diffraction analysis has been carried out for BCC specimens at KCl concentration of 10 g/l in deionised water.

KEYWORDS: KCl, Setting time, Compressive strength, Chloride ion permeability, X-ray diffraction

I. INTRODUCTION

Water is an important ingredient of concrete, in both fresh and hardened state of concrete. Cement is a mixture of complex compounds, the reaction of cement with water leads to setting and hardening. All the compounds present in the cement are anhydrous, but when brought in contact with water, they get hydrolyzed, forming hydrated compounds. Since water helps to form the strength giving cement gel, the quality of water is to be maintained equally during the process of concrete making. Natural water is available abundantly in universe as a good solvent, but there are more chances of containing large number of impurities ranging from less to very high concentration of them. Many studies show more importance on properties of cement and aggregate, but the quality of water is often neglected.

A normal indicator to the suitability of water for mixing concrete is that, if it is fit for drinking, it is fit for making concrete. This doesn't appear to be a true statement for all conditions. Sometimes, water contains a small amount of sugar would be suitable for drinking, but not for making concrete and conversely water suitable for making concrete may not be necessarily be fit for drinking, especially if the water contains pathogenic microbial contaminants. Research work has been carried out on effect of polluted/chemical water on hardened concrete strength and durability. The damage impact of various deicing chemicals and exposure conditions on concrete materials were studied by Kejin *et al.*, and results indicated that the various deicing chemicals penetrated at different rates in to a given paste and concrete resulting in different degree of damages [1]. Gorniniski *et al.*, presented an assessment of the chemical resistance of eight different compositions of polymeric mortars [2]. Adnan *et.al.*, reported the effects of environmental factors on the addition and durability characters of epoxy bonded concrete prisms [3]. Fikret *et al.*, investigated the resistance of mortars to magnesium sulphate attack and results reported that there is a significant change in compressive strength properties [4]. Venkateswara Reddy *et al.*, studied the influence of strong alkaline substances (Na_2CO_3 and $NaHCO_3$) in mixing water on strength and setting properties of concrete [5]. In many places ground water and surface water contains the impurities, more than that of limits specified by the IS 456:2000 [6]. Ali Reza Bagheri *et al.*, in their study on the effect of incorporation of silica fume in enhancing strength development rate and durability characteristics of binary concretes [7]. Erhan Guneyisi *et al.*, investigated the effectiveness of metakaolin (MK) and silica fume (SF) on the mechanical properties, shrinkage, and permeability related to durability of high performance concretes [8].

1.1 Research Significance

As there is scarcity of potable water in many places, this impure water is being used for mixing as well as curing of concrete in the civil engineering constructions. Hence an attempt is made to study the effect of water containing KCl at various concentrations in cements and their concretes.

1.2 Outline of This Paper

This paper includes the experimental program, selection of materials and test methods. Discussion of results and conclusions are presented.

II. EXPERIMENTAL PROGRAM

The influence of KCl at different concentrations was studied when the KCl is spiked with deionised water. Test samples were compared with the control samples. This comparison may not be possible in case of control samples made with locally available potable water since it varies in chemical composition from place to place. With the above reason, KCl was mixed with deionised water as per the dosage mentioned above. This water was used for preparation of test samples for determining the setting times (initial and final) of BC and compressive strength of BCC.

2.1. Materials

Portland Pozzolana cement containing 30% of fly ash was used in this investigation. The major chemical composition of cement used in the present study is presented in the Table 1. Locally available river sand was used as fine aggregate. Machine crushed granite stones of maximum size 20 mm confirming to IS 383:1970 [9] was used as coarse aggregate. Deionised water was spiked with KCl at different concentrations of 0.5, 2, 4, 6, 8, 10, 12 and 14 g/l.

Table 1. Chemical composition of blended cement

Sl. No	Parameter	Result
1	Insoluble Material (% by mass)	18.90
2	Magnesia (% by mass)	0.99
3	Sulphuric Anhydride (% by mass)	2.67
4	Loss on Ignition (% by mass)	2.04
5	Total Chlorides (% by mass)	0.001

2.2. Test Methods

The IS 10262:2009 [10] mix design was adopted for concrete mix. For determining the initial and final setting times of cement, Vicat apparatus was used as per IS 4031:1988 [11]. To assess the compressive strength of concrete, 30 concrete cubes of size 150 mm were cast and tested as per IS 516:1959 [12]. Rapid chloride permeability test (RCPT) was used as per ASTM C 1202 [13] to determine the chloride ion permeability of concrete, for which 15 specimens of size 100 mm x 50 mm were cast.

III. RESULTS AND DISCUSSION

3.1 KCl effect on setting time of blended cement

The effect of KCl on initial and final setting times is shown in Table 2 and Fig. 1, from which it is observed that both initial and final setting times have got retarded with an increase in KCl concentration in deionised water. IS 456:2000 (Clause 5.4.1.3) [6] stipulates that, when the difference in setting time(s) is less than 30 minutes, the change is considered to be negligible or insignificant and if it is more than 30 minutes, the change is considered to be significant. From the experimentation work it is observed that, when the KCl concentration exceeded 10 g/l, the acceleration of initial and final setting times of BC was significant (i.e., more than 30 minutes). When KCl content is 14 g/l (maximum), initial setting time was 177 minutes which is 44 minutes greater than that of control mix. Similarly, a significant difference of 43 minutes was observed in the case of final setting time.

Table 2. Setting times of blended cement (BC) corresponding to KCl concentrations

Sl.No	Water sample	Setting time in minutes & Percentage change			
		Initial	% change	Final	% change
1	Deionised water (Control)	133	00	361	00
2	0.5 g/l	138	3.74	372	2.91
3	2 g/l	142	6.45	378	4.75
4	4 g/l	146	9.99	382	5.83
5	6 g/l	153	14.96	385	6.62
6	8 g/l	160	20.47	389	7.69
7	**10 g/l***	**166**	**24.74**	**393**	**8.88**
8	12 g/l	170	27.93	397	10.02
9	14 g/l	177	32.76	404	11.84

*Significant

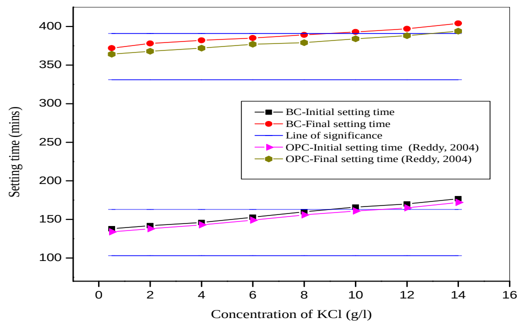

Fig. 1. Setting times of blended cement vs KCl

concentrations

3.2. KCl effect on compressive strength of blended cement concrete

The effect of KCl concentration on the compressive strength of BCC is presented in Table 3 and Fig. 2. The degree of variation in compressive strength is also presented in Fig. 3. The results indicated that there is a gain in compressive strength of the BCC irrespective of KCl concentration. In case of BCC, marked increase in 28 days and 90 days compressive strength is observed with increase in concentration of KCl. Compressive strength for BCC, with KCl concentration from 0.5 to 14 g/l, has increased from 23.89 to 27.55 and 27.47 to 31.49 for 28 and 90 day aged specimen respectively. The result is significant when the concentration of KCl is equal to 10 g/l. When KCl concentration is maximum, i.e., 14 g/l the increase in compressive strength is 15.32% for both 28 days age and 14.65% for 90 days age when compared with that of cubes prepared with the deionised water (control test sample).

Table 3. Compressive strength of BCC corresponding to KCl concentrations

Sl. No	Water Sample	Blended Cement Concrete (BCC)			
		Compressive Strength (N/mm^2)		% variation	
		28 days	90 days	28 days	90 days
1	Deionised Water (Control)	23.89	27.47	--	--
2	0.5 g/l	24.14	27.70	1.04	0.82
3	2 g/l	24.71	27.88	3.44	1.48
4	4 g/l	25.25	28.80	5.69	4.83
5	6 g/l	25.69	28.98	7.54	5.49
5	8 g/l	26.15	29.66	9.48	7.98
6	**10 g/l***	**26.48**	**30.29**	**10.83**	**10.25**
7	12 g/l	26.78	31.00	12.08	12.85
8	14 g/l	27.55	31.49	15.32	14.65

*Significant

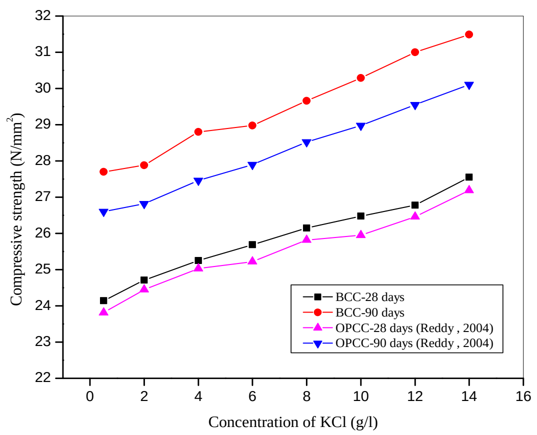

Fig. 2. Compressive strength of BCC vs KCl concentrations

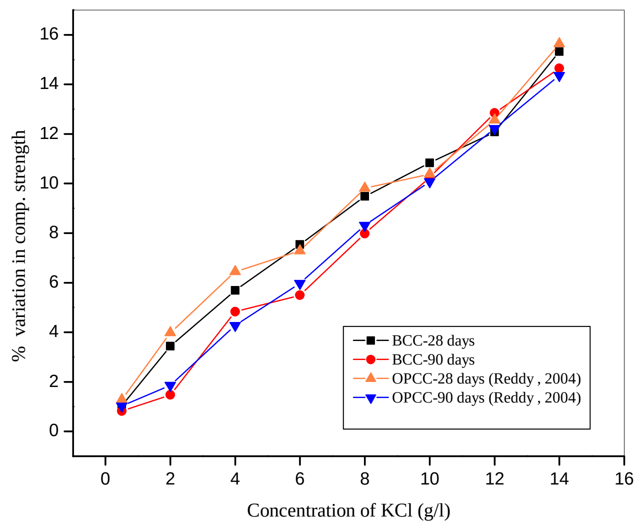

Fig. 3. % variation in compressive strength of BCC vs KCl concentrations

3.3. KCl effect on Chloride ion Permeability of Blended cement concrete

The rapid chloride permeability levels in terms of coulombs passed through BCC observed are tabulated and listed in the Table 4 and Fig. 4. A glance at the said results establishes that the chloride ion permeability of the concrete studied has come down with the increase in the concentration of KCl up to 14 g/l which is the maximum experimented concentration. Quantum of variation in coulombs passed is 16.34% at 28 days for BCC when compared with the control sample i.e., it has decreased from 2036 to 1703 coulombs. The degree of variation in compressive strength is also presented in Fig. 5.

Table 4. Chloride ion permeability in terms of coulombs passed in BCC corresponding to KCl concentrations

Sl.No	Water sample	Coulombs passed			
		28 days	% change	90 days	% change
1	Deionised water (Control)	2036		1187	
2	0.5 g/l	2008	-1.36	1162	-2.08
3	2 g/l	1958	-3.82	1152	-2.98
4	4 g/l	1918	-5.79	1144	-3.64
5	6 g/l	1868	-8.24	1133	-4.57
6	8 g/l	1838	-9.72	1076	-9.37
7	10 g/l	1784	-12.36	1038	-12.54
8	12 g/l	1747	-14.21	1018	-14.26
9	14 g/l	1703	-16.34	1001	-15.69

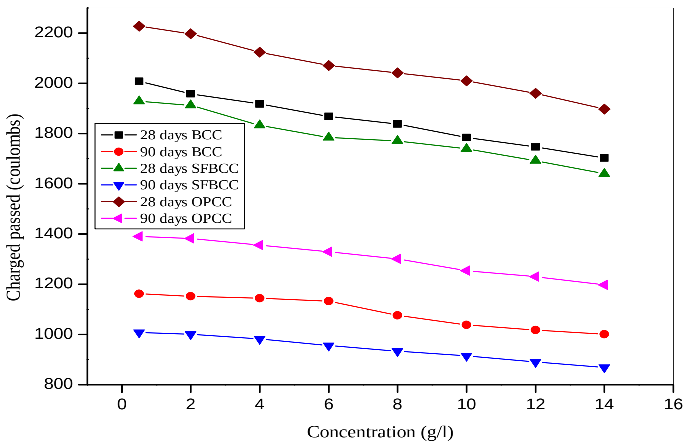

Fig. 4. Charge passed vs KCl concentrations

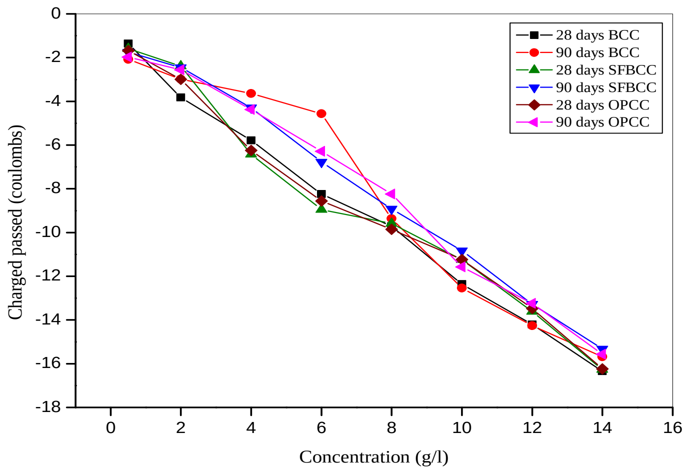

Fig. 5. %variation in Charge passed vs KCl concentrations

3.4. Powder X- ray diffraction analysis on Blended Cement Concrete spiked with KCl

The setting times and compressive strengths are significant at 10g/l concentration of KCl. The Powder X-ray diffraction analysis was carried out to know the behavior and probable chemical reaction(s) for the concrete. Fig. 6 depicts the Powder X-ray Diffraction patterns for BCC prepared with deionised water and the Powder X-ray Diffraction patterns for BCC with mixing water containing KCl concentration of 10 g/l are presented in Fig. 7.

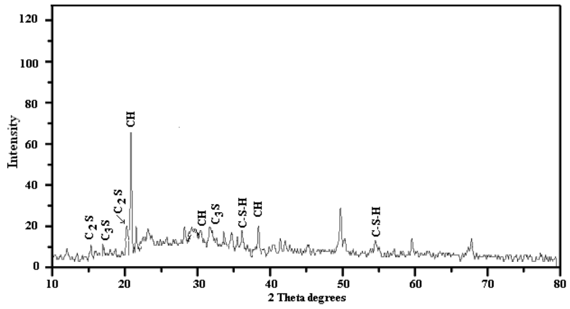

Fig. 6. XRD pattern of BCC sample prepared with deionised water

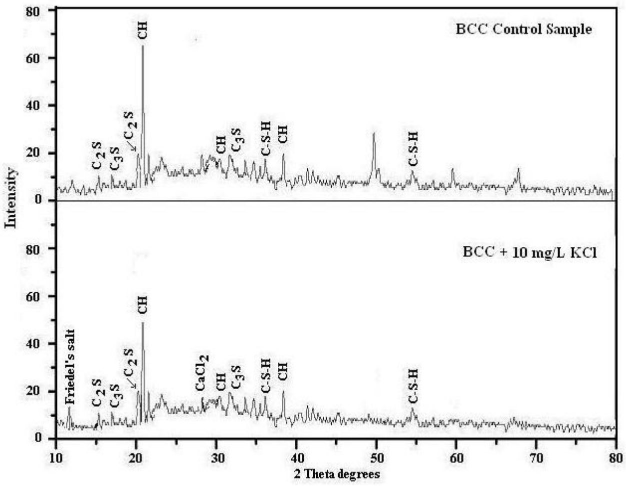

Fig. 7. XRD pattern of BCC sample spiked with KCl (10 g/l) in deionised water

Upper portion of the said graph, at Fig.7, indicates the XRD pattern of the control sample prepared with deionised water. Perusal of the said graphs establishes that the compounds such as $3CaO.Al_2O_3.CaCl_2.10H_2O$ (Friedel's salt), C_2S, C_3S, Calcium Hydroxide (CH), $CaCl_2$ and C-H-S are found at 11.9^0, $16^{0,}$ 17^0, 21^0, 28.2^0 and 37^0 respectively. Comparing with control sample, the sample of KCl additionally consists of Friedel's salt and Calcium Chloride.

Compressive strength has increased with an increase in the concentration of KCl. Same observations were reported by Lee and Van Deventer (2002). Chemical equations when KCl is added in mixing water with cement are given below. The XRD patterns indicate that the peak of C-S-H at in KCl is higher than the peaks of C-S-H of control sample, which indicate the strength of the KCl added samples has increased when compared with the control sample.

$2KCl + Ca(OH)_2 \rightarrow 2KOH + CaCl_2$

$CaCl_2 + 3\ CaO.Al_2O_3 + 10H_2O \rightarrow 3CaO.Al_2O_3.CaCl_2.10H_2O$ (Friedel's salt)

IV. CONCLUSIONS

Based on the results obtained in the present investigation the following conclusions can be drawn: It is observed that as KCl concentration increases, there is aretarder in initial and final setting of blended cement (BC). The compressive strength of BCC increases as the concentration of KCl increases at both 28 and 90 days. Compressive strengths of BCC show a significant increase at 10 g/l when compared with the control specimens. It is also observed that chloride ion permeability has decreased with an increase in the concentration of the KCl.

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