EFFECT OF SODIUM CHLORIDE ON FLY ASH BASED BLENDED CEMENT CONCRETE

B. Madhusudhana Reddy[1], H. Sudarsana Rao[2] and Vaishali.G.Ghorpade[3]
[1]Delhi Pollution Control Committee, ISBT Building, Kashmere Gate, New Delhi, India
[2]JNT University, Anantapur, India
[3]Department of Civil Engineering, JNTUA College of Engineering, Anantapur, India

ABSTRACT
This paper presents the effect of sodium chloride (NaCl) on blended cement concrete (BCC). The BCC was prepared with NaCl concentrations of 0.5, 2, 4, 6, 8, 10, 12, 14, 16 and 20 g/l by adding in deionised water. In addition to this, control specimen was prepared with deionised water (without NaCl) 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 NaCl concentration increases, there is acceleration in initial and final setting of blended cement (BC). The compressive strength of BCC increases as the concentration of NaCl goes up at both 28 and 90 days. Compressive strengths of BCC show a significant increase at 12 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 NaCl. X-ray diffraction analysis has been carried out for BCC specimens at NaCl concentration of 12 g/l in deionised water.

KEYWORDS*: NaCl, 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 NaCl 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 NaCl at different concentrations was studied when the NaCl 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, NaCl 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 NaCl at different concentrations of 0.5, 2, 4, 6, 8, 10, 12, 14, 16 and 20 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 NaCl effect on setting time of blended cement

The effect of NaCl 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 accelerated with an increase in NaCl 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 NaCl concentration exceeded 12 g/l, the acceleration of initial and final setting times of BC was significant (i.e., more than 30 minutes). When NaCl content is 20 g/l (maximum), initial setting time was 95 minutes which is 38 minutes less than that of control mix. Similarly, a significant difference of 39 minutes was observed in the case of final setting time.

Table 2. Setting times of blended cement (BC) corresponding to NaCl 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	126	-5.62	354	-1.9
3	2 g/l	116	-12.78	347	-3.98
4	4 g/l	112	-16.1	340	-5.76
5	6 g/l	109	-18.23	336	-6.86
6	8 g/l	107	-19.56	333	-7.84
7	10 g/l	106	-20.28	332	-7.98
8	12 g/l	103	-22.54	330	-8.68
9	14 g/l*	102	-22.96	329	-8.94
10	16 g/l*	100	-24.88	327	-9.44
11	20 g/l*	95	-28.26	322	-10.93

***Significant**

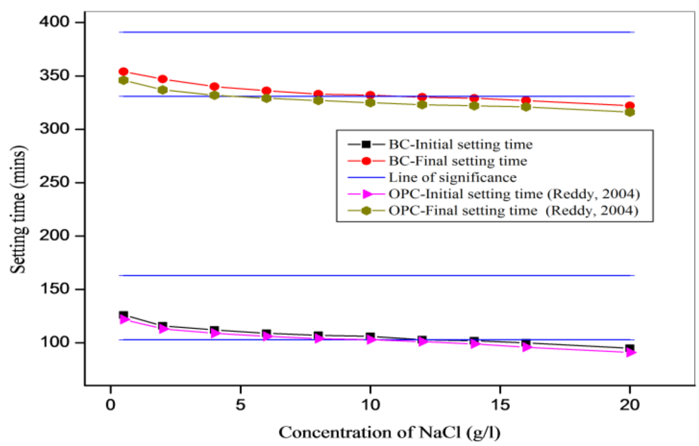

Fig. 1. Setting times of blended cement vs NaCl concentrations

3.2. NaCl effect on compressive strength of blended cement concrete

The effect of NaCl 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 NaCl concentration. In case of BCC, marked increase in 28 days and 90 days compressive strength is observed with increase in concentration of NaCl. Compressive strength for BCC, with NaCl concentration from 0.5 to 20 g/l, has increased from 23.89 to 27.51 and 27.48 to 31.63 for 28 and 90 day aged specimen respectively. The result is significant when the concentration of NaCl is equal to 12 g/l. When NaCl concentration is maximum, i.e., 20 g/l the increase in compressive strength is 15.14% for both 28 days age and 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 NaCl concentrations

Sl. No	Water Sample	Blended Cement Concrete			
		Compressive Strength		% variation	
		28 days	90 days	28 days	90 days
I	Deionised Water (Control)	23.89	27.47	--	--
II i	0.5 g/l	23.89	27.48	0.02	0.03
ii	2 g/l	24.17	27.72	1.19	0.91
iii	4 g/l	24.46	27.99	2.37	1.91
iv	6 g/l	24.81	28.27	3.84	2.91
v	8 g/l	25.34	28.86	6.09	5.07
vi	10 g/l	25.94	29.64	8.59	7.91
vii	**12 g/l***	**26.50**	**30.22**	**10.94**	**10.01**
viii	14 g/l	26.78	30.53	12.09	11.13
ix	16 g/l	27.06	30.82	13.29	12.21
x	20 g/l	27.51	31.63	15.14	15.14

*Significant

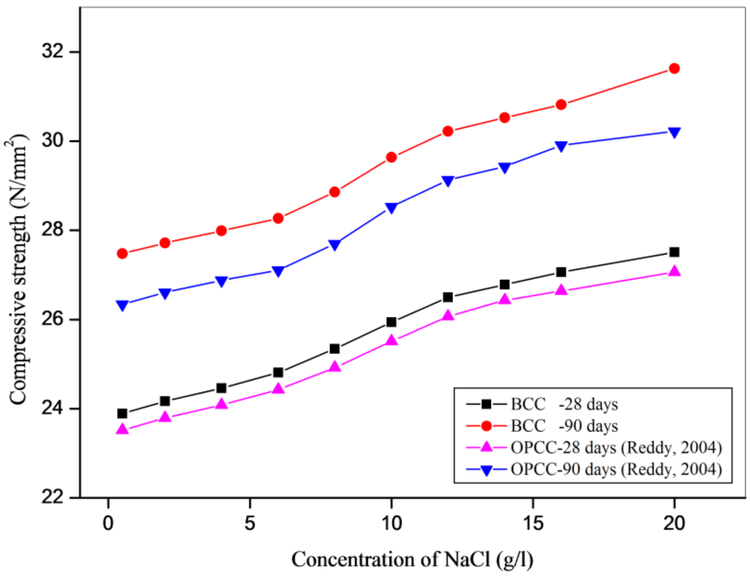

Fig. 2. Compressive strength of BCC vs NaCl concentrations

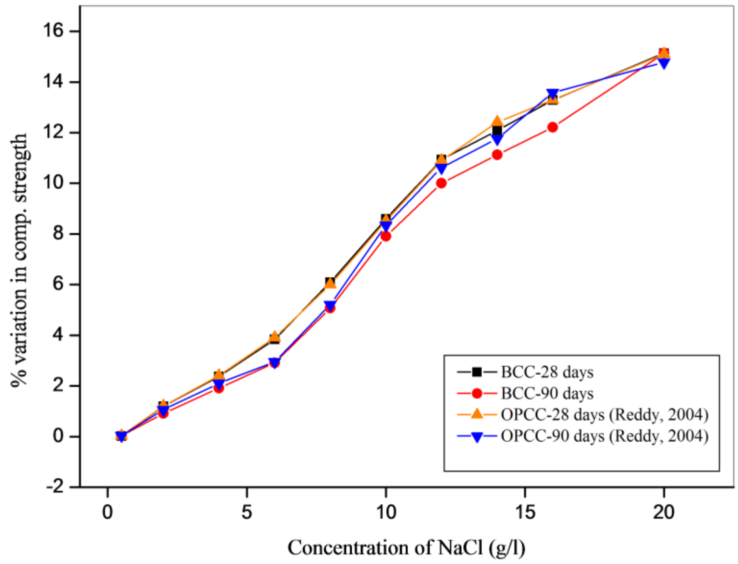

Fig. 3. % variation in compressive strength of BCC vs NaCl concentrations

3.3. NaCl 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 NaCl up to 20 g/l which is the maximum experimented concentration. Quantum of variation in coulombs passed is 16.41% at 28 days for BCC when compared with the control sample i.e., it has decreased from 2036 to 1702 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 NaCl concentrations

Sl. No	Water sample	Coulombs passed			
		28 days	% change	90 days	% change
1	Deionised water (Control)	2036		1187	
2	0.5 g/l	2006	-1.45	1166	-1.73
3	2 g/l	1983	-2.62	1157	-2.49
4	4 g/l	1957	-3.89	1143	-3.68
5	6 g/l	1942	-4.62	1130	-4.79
6	8 g/l	1877	-7.83	1098	-7.51
7	10 g/l	1836	-9.84	1061	-10.62
8	12 g/l	1803	-11.46	1035	-12.81
9	14 g/l	1739	-14.61	1010	-14.87
10	16 g/l	1723	-15.37	1001	-15.68
11	20 g/l	1702	-16.41	978	-17.61

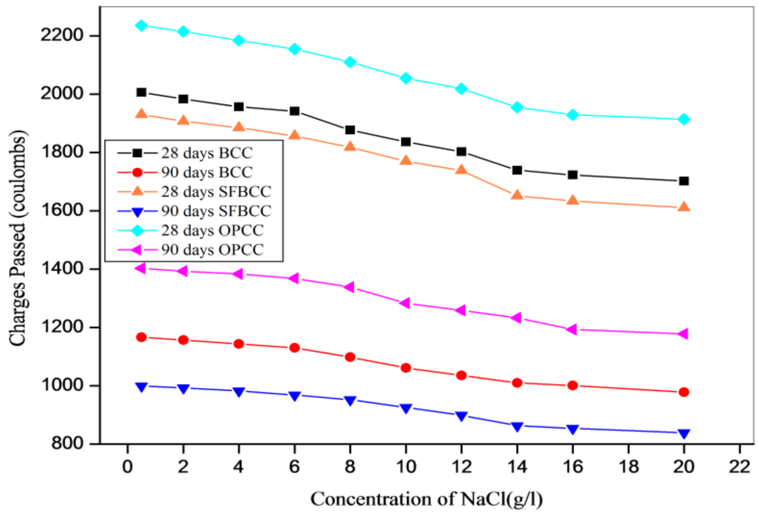

Fig. 4. Charge passed vs NaCl concentrations

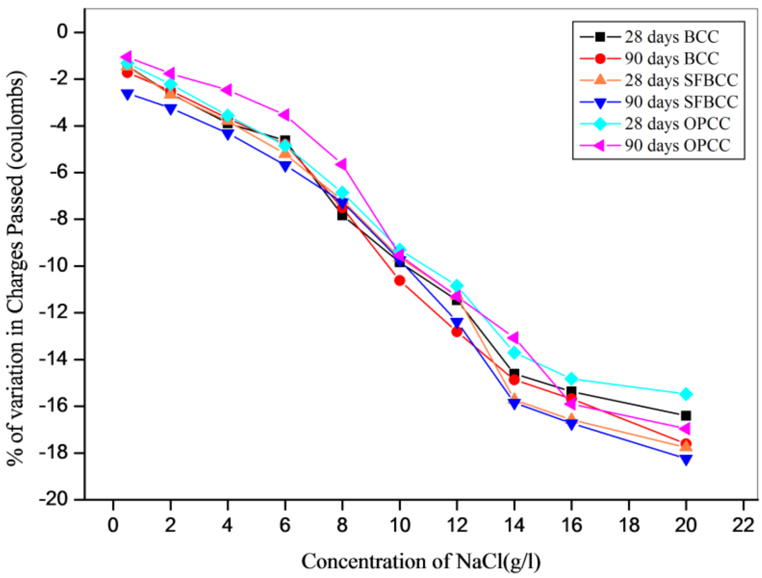

Fig. 5. %variation in Charge passed vs NaCl concentrations

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

The setting times and compressive strengths are significant at 12 g/l concentration of NaCl. 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 NaCl concentration of 12 g/l are presented in Fig. 7.

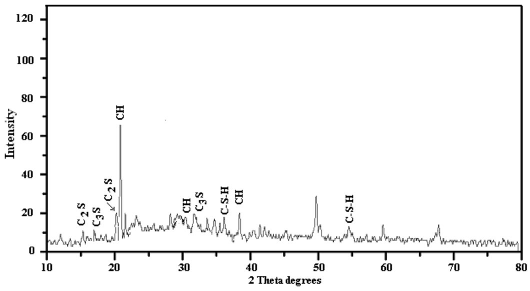

Fig. 6. XRD pattern of BCC sample prepared with deionised water

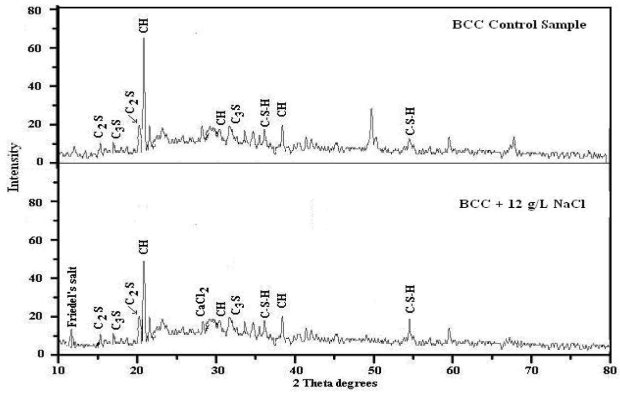

Fig. 7. XRD pattern of BCC sample spiked with NaCl (12 g/l) in deionised water

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 NaCl additionally consists of Friedel's salt and Calcium Chloride.

Compressive strength has increased with an increase in the concentration of NaCl. Same observations were reported by Brough et al (2000). Chemical equations when NaCl is added in mixing water with cement are given below. The XRD patterns indicate that the peak of C-S-H at in NaCl is higher than the peaks of C-S-H of control sample, which indicate the strength of the NaCl added samples has increased when compared with the control sample.

$$2NaCl + Ca(OH)_2 \rightarrow 2NaOH + CaCl_2$$

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

IV. CONCLUSIONS

Based on the results obtained in the present investigation the following conclusions can be drawn:

It is observed that as NaCl concentration increases, there is acceleration in initial and final setting of blended cement (BC). The compressive strength of BCC increases as the concentration of NaCl increases at both 28 and 90 days. Compressive strengths of BCC show a significant increase at 12 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 NaCl.

REFERENCES

[1]. Kejin W, Daniel EN and Wilfrid AN (2006). Damaging effects of deicing chemicals on concrete materials, *Cement and Concrete Composites* 28(2) 173-178.

[2]. Gorninsi JP, Dal MDC and Kazmierczak CS (2007). Strength degradation of polymer concrete in acidic environments, *Cement and Concrete Composites* 29(8) 637-645.

[3]. Adnan C, Turgay C and Ahmet EB (2009). Effects of environmental factors on the adhesion and durability characteristics of expoxy bonded concrete prisms, *Construction and Building materials*

23(2) 758-767.
[4]. Fikret T, Fevziye A, Sema K and Nabi Y (1997). Effects of magnesium sulfate concentration on the sulfate resistance of mortars with and without silica fume, *Cement and Concrete Research* 27(2) 205-214(1997)
[5]. Venkateswara Reddy V, Sudarshan Rao H and Jayaveer KN (2006). Influence of strong alkaline substances (sodium carbonate and sodium bicarbonate) in mixing water on strength and setting properties of concrete, *Indian Journal of Engineering and Material Sciences* 13(2) 123- 128.
[6]. IS: 456-2000. Plain and reinforced concrete code for practice. Bureau of Indian Standards, New Delhi (India).
[7]. Ali Reza Bagheri, Hamed Zanganeh, Mohamad Mehdi Moalemi(2012). Mechanical and durability properties of ternary concretes containing silica fume and low reactivity blast furnace slag, Cement & Concrete Composites, 34, 663–670.
[8]. Erhan Guneyisi, Mehmet Gesoglu, Seda Karaoglu, Kasım Mermerdas, Strength, permeability and shrinkage cracking of silica fume and metakaolin concretes, Construction and Building Materials, vol 34, 2012, pp. 120–130
[9]. IS: 383-1970. Specification for coarse and fine aggregates from natural sources for concrete. Bureau of Indian Standards, New Delhi (India).
[10]. IS: 10262-2009. Concrete Mix Proportioning-Guidelines. Bureau of Indian Standards, New Delhi (India).
[11]. IS 4031-1988. Methods of physical tests for hydraulic cement: Part 5 – Determination of initial and final setting times. Bureau of Indian Standards, New Delhi.
[12]. IS: 516-1991. Methods of tests for strength of concrete. Bureau of Indian Standards, New Delhi (India).
[13]. ASTM C 1202-07. Standard Test Method for Electrical Indication of Concrete's Ability to Resist Ion Penetration.

AUTHORS

B. Madhusudhana Reddy has received B.Tech in Civil Engineering from SV University, Tirupati and M.Tech in environmental engineering from Mysore University in the year 1990. He has completed Ph. D in civil Engineering from JNT University, Anantapur. He has a vast experience of more than 22 years in the field of pollution control and environment management. Presently working as Senior Environmental Engineer in Delhi Pollution Control Committee, Govt. of Delhi, Delhi.

H. Sudarsana Rao is Professor in the Department of Civil Engineering, JNTUA, Anantapur. He received M.Tech from J.N.T. University, Hyderabad and Ph.D from IITB. His research interests include FRC, SIFCON, HPC, Non Destructive Test Evaluation and F.E.M. He has more than 25 years of teaching experience and guiding research scholars. Presently he is working as Rector at JNT University, Ananatapur, Andhra Pradesh.

Vaishali G Ghorpade is an Associate Professor and HOD in the Department of Civil Engineering, JNTUA, Anantapur. She received M.Tech and Ph.D from J.N.T. University, Hyderabad. Her research interests include FRC, SIFCON, HPC, AND Non Destructive Test Evaluation. She has co – authored more than 50 scientific and technical publications. She has more than 13 years of teaching experience and guiding research scholars. She was an active member as a Placement Officer at JNTUA College of Engineering, Anantapur, Andhra Pradesh.