Effect of Potassium Chloride (KCl) on Ordinary Portland Cement (OPC) Concrete

Reddy V. Venkateswara[1], Gnaneswar Kontham [2], Ramana Nelluru Venkata[3] and Sashidhar Chundupalli[4]
[1] JNTUH College of Engineering, Hyderabad, INDIA
[2] Irrigation and CAD Department,TBP HLC Circle, Anantapur , INDIA
[3,4] JNTUA College of Engineering, Anantapur, INDIA

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Abstract

This paper presents the effect of Potassium chloride (KCL) on OPC concrete. The OPC concrete produced with KCL dosage of 0.5, 2, 4, 6, 8, 10, 12 and 14 g/lit added in deionised water and the same water is used in concrete mix (M20 and M50). In addition to this control specimens were prepared with deionised water (without KCL) for comparison. The compressive and tensile strengths were evaluated for 28 and 90 days. The results exhibit that, as KCL concentration increases, there is increase in compression and tensile strengths. The X-ray diffraction analysis has been carried out at 10 g/lit concentration.

Key words: Potassium chloride, setting time, compression, tension, X-ray diffraction.

Introduction

Water is an important ingredient of concrete, which is not only actively participates in the hydration of cement but also contributes to the workability of fresh 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 critically monitored and controlled during the process of concrete making as the water universally the most abundant and naturally available solvent, can be contain large no of impurities ranging from less to very high concentration of them. In practice, very often, great control on properties of cement and aggregate is exercised but the control on the quality of water is often neglected. A popular yardstick 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 condition. Sometimes, water contain 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. In connection 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 a 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 and flexural properties[4]. Venkateswara Reddy et. al., studied the influence of strong alkaline substances (sodium carbonate and bi-carbonate) 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. 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 concrete.

Material and Methods

Cement: 53 grades ordinary Portland cement was used in this investigation. The compositions of major compounds present in the cement are presented in table 1.

Fine Aggregate: Locally available River sand was used and the properties are presented in Table 2.

Coarse Aggregate: Machine Crushed granite stone of max size 20mm confirming to IS 383 -1970 was used and the properties are presented in Table 2.

Water: Deionised water spiked with KCL at different concentrations i.e. 0.5, 2, 4, 6, 8, 10, 12 and 14 g/lit.

Experimental Programme: The influence of KCL at different concentrations (0.5, 2, 4, 6, 8, 10, 12 and 14 g/lit) may be studied when the KCL is spiked with deionised water. Test samples are compared with the control samples. This comparison is 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 is mixed with deionised water in the dosage of 0.5, 2, 4, 6, 8, 10, 12 & 14 g/lit. This water is used for preparation of samples for setting times (initial & final) of cement and M20 & M50 grade concrete. The IS mix design is adopted for M20 and M50 grade concrete mix. For determining the initial and final setting times of cement, Vicat apparatus is used and to assess the compressive and split tensile strengths, 84 cubes of size 150x150x150mm and 84 cylinder of 150x300mm were cast and tested.

Results and Discussion

The effect of presence of potassium chloride (KCL) on setting times of cement, compressive and split tensile strengths of ordinary Portland cement concrete is presented below.

Effect on setting times of Cement: The initial and final setting times of cement, for different KCL concentrations are compared with control samples. If the difference is less than 30 minutes, the change is considered to be negligible and if the difference is more than 30 minutes, the change is considered to be significant.

The effect of KCl on initial and final setting times is depicted in fig.1. It is observed from fig. 1.that both initial and final setting times got retarded with an increase in potassium chloride concentration in the deionised water. Initial and final setting times at and above 10 g/l of concentration of KCl in mixing water used for casting the test blocks, differed significantly when compared with the experimental results obtained with deionised water. The initial setting time is 171 minutes when KCl concentration is 14 g/l. Similarly the final setting time is about 393 minutes when potassium chloride content is 14 g/l, which is 40 minutes more than that of control water sample.

Effect on Strength of OPC Concrete: Average compressive strength of three cubes and split tensile strength of three cylinders prepared with different concentrations of KCL is compared with that of three similar specimens prepared with deionised water. If the difference in the strength is less than 10%, it is considered to be insignificant and if it is greater than 10% it is considered to be significant. This 10% is taken as reference for the discussion.

The effect of KCl concentration on the compressive strength and tensile strength of concrete of ordinary Portland cement concrete is presented in Fig. 2 & 3. As concentration increases there is increase in compressive strength of the OPC concrete prepared with KCl solution up to a maximum concentration of 14 g/l. At both 28-day and 90-day age, an increase in compressive strength is observed with the increase in concentration of KCl and is significant at 10 g/l concentration of KCl for OPC concrete, M 20 and M

50 when compared with that of cubes prepared with the deionised water (control test sample). When KCL concentration is 14 g/l, the increase in compressive strength is 15.93% for M 20 (28 day) grade concrete and 15.96% for M 50 (28 day) grade concrete respectively, when compared with that of cubes prepared with the deionised water (control test sample). Similarly, significant increase in 28 day and 90 day tensile strength is observed when the concentration of KCl is 10 g/l for both grades of concrete. When KCl concentration is maximum, i.e., 14 g/l the increase in tensile strength is 15.92% for M 20 (28 day) grade concrete and 15.94% for M 50 (28 day) grade concrete respectively, when compared with that of cylinders prepared with the deionised water (control test sample).

Powder X-ray diffraction analysis: Powder X-ray Diffraction pattern for the concrete cube prepared with KCl (10 g/l) and for control specimen are depicted in Fig. 4 & 5. The comparison of the KCL pattern with that of control specimens indicates the formation of $K_2Al_2Si_6Al_4O_{20}(OH)_4$ (Muscovite) compound which is evident due to the presence of d-spacings 4.2530 Å, 2.9347 Å and 1.3751 Å in Fig. 4, which are absent in Fig.5. The probable reasons for above behaviour of concrete with KCl in mixing water are discussed below through corresponding chemical reaction.

The probable chemical reaction upon the hydration of cement with mixing water containing KCl concentration is

$2KCl + 3Al_2O_3 + 7SiO_2 + 2H_2O \rightarrow K_2\ Al_2\ Si_6\ Al_4\ O_{20}\ (OH)_4 + SiOCl_2$

The reason for the retardation of setting of cement is attributed to the formation of muscovite and also the larger size of potassium ions involved in the crystallization of muscovite leading to increase in voids. Considerable increase in compressive strength may be attributed to chloride ion charge. During hydration, the soluble salts ($SiOCl_2$) might have been produced. Crystallization of these salts might have taken place in the pores.

Conclusions

Initial and Final setting times of cement gets retarded significantly with an increase in Potassium chloride concentration in the deionised water when compared with control specimens.

Compressive and Tensile strengths of OPC concrete increases with increase in potassium chloride concentration and is significant at 10 g/l. concentration when compared with that of control specimens.

The probable chemical reaction upon the hydration of cement with mixing water containing KCL concentration is $2KCl + 3Al_2O_3 + 7SiO_2 + 2H_2O \rightarrow K_2\ Al_2\ Si_6 + Al_4\ O_{20}\ (OH)_4 + SiOCl_2$

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Table-1: Compositions of major compounds in cement

S.No.	Name of the compound	%
1	Tricalcium Silicate ($3CaO\ SiO_2$)	11.70
2	Dicalcium Silicate ($2CaO\ Al_2O_3$)	23.30
3	Tricalcium Aluminate ($3CaO\ Al_2O_3$)	9.31
4	Tetracalcium Alumino Ferrite ($4CaO\ Al_2O_3\ Fe_2O_3$)	51.40

Table-2: Properties of aggregate

S.No.	Property	Coarse aggregate	Fine aggregate
1	Specific gravity	2.62	2.53
2	Bulk density	15.65 kN/m^3	15.54 kN/m^3
3	Fineness modulus	6.65	2.84

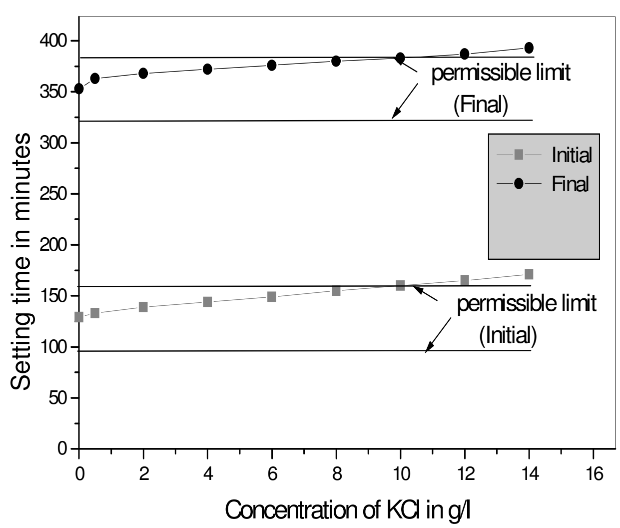


Figure-1: Variation of setting times of cement orresponding to various concentrations of KCl in deionised water

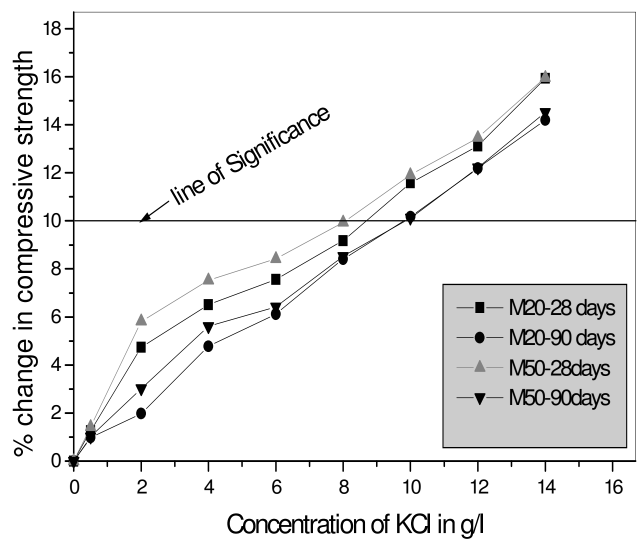


Figure-2: Variation of compressive strength of OPC corresponding to various concentrations of KCl in deionised water

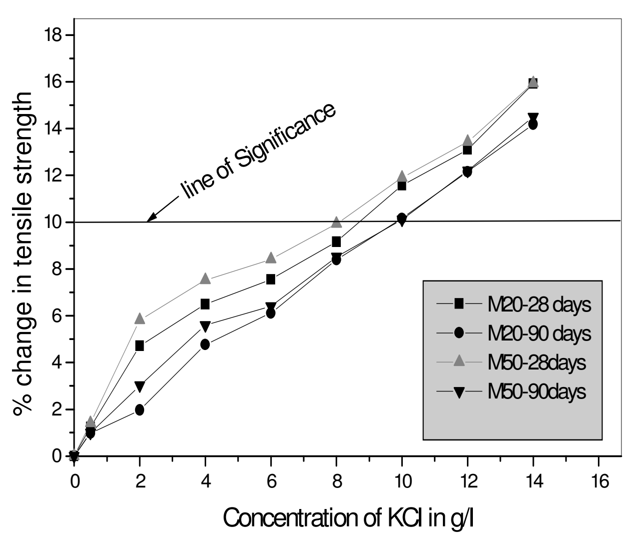
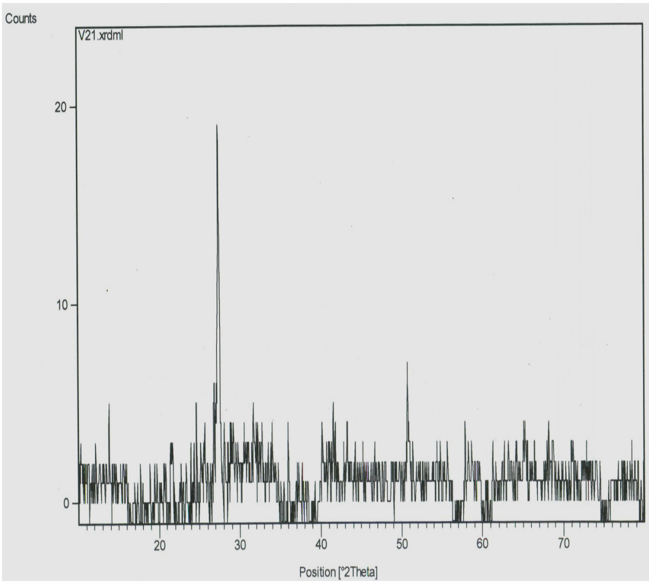
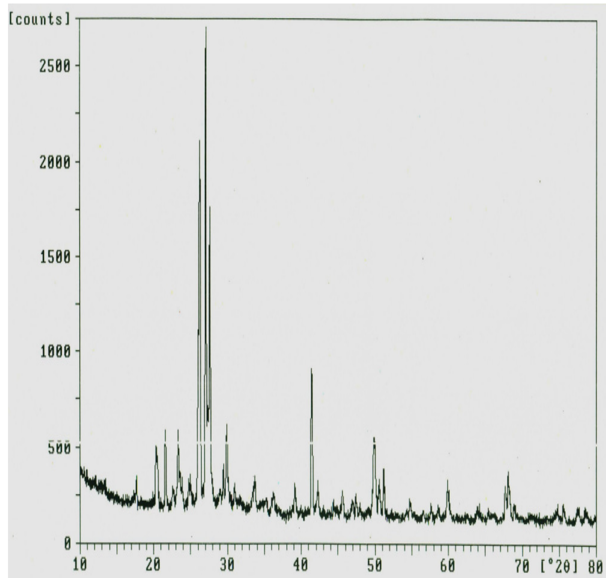


Figure-3: Variation of tensile strength of OPC corresponding to various concentrations of KCl in deionised water



S.No	Angle	d-value Å	Rel.int. (%)
1	20.8697	4.2530	8
2	23.5979	3.7671	5
3	24.8968	3.5735	5
4	26.6251	3.3453	100
5	27.0606	3.2924	10
6	27.4899	3.2420	34
7	27.9444	3.1903	36
8	29.4430	3.0312	8
9	30.4343	2.9347	4
10	32.8338	2.7255	7
11	36.6268	2.4515	4
12	42.4499	2.1277	6
13	43.7576	2.0671	4
14	45.9622	1.9730	3
15	50.1295	1.8183	5
16	59.9739	1.5412	5
17	68.1361	1.3751	4

Figure- 4: X-Ray diffraction pattern of powdered concrete sample prepared with KCl (10 g/l) in deionised water



S.No	Angle	d-value Å	Rel.int. (%)
1	10.285	8.6151	2.1
2	20.320	4.3776	12.2
3	22.675	3.9280	3.3
4	23.610	3.7745	6.6
5	24.775	3.5996	5.1
6	26.025	3.4295	28.0
7	27.070	3.2994	100.0
8	27.635	3.2332	57.7
9	29.025	3.0815	3.7
10	29.460	3.0370	9.5
11	30.995	2.8900	5.7
12	33.730	2.6617	6.6
13	35.270	2.5489	3.1
14	42.250	2.1426	6.3
15	45.610	1.9923	5.3
16	49.815	1.8335	15.5
17	57.680	1.6009	2.3
18	59.865	1.5475	8.0
19	65.765	1.4223	1.2
20	68.850	1.3659	2.9
21	78.570	1.2196	1.7

Figure- 5: X-Ray diffraction pattern of powdered concrete sample prepared with deionised water