

## Effect of magnesium chloride ( $MgCl_2$ ) on ordinary Portland cement concrete

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### Abstract

This paper reports the effect of Magnesium chloride ( $MgCl_2$ ) on Ordinary Portland Cement (OPC) concrete. The OPC concrete was produced with  $MgCl_2$  dosage of 0.2, 0.5, 1.0, 1.5 and 2.0 g/lit and deionised water was used in concrete mix (M20 & M50). In addition to this, control specimens were prepared with deionised water (without  $MgCl_2$ ) for comparison. The compressive and tensile strengths were evaluated for 28 and 90 days. The results show that, as the  $MgCl_2$  concentration increases, the compression and tensile strengths decrease. The X-ray diffraction analysis for concrete has been carried out at 1.5 g/lit concentration.

**Keywords:** Portland cement, concrete

### Introduction

The chemical impurities of industrial effluents can impose deleterious effect on concrete. This creates great concern on mixing of water in hydration of cement and the properties of resultant concrete. The water during preparation of concrete usually comes from two sources, namely the added water and the moisture in the aggregates. Most specifications on quality of water concentrate on the added water rather than the moisture contained in the aggregates (fine and coarse). The quality of water is usually ignored with the expectation that added potable water would dilute any contaminant. The presence of dissolved inorganic substances in groundwater is mostly through mineral origin and would be expected in varied concentrations geographically. Water may contain salts of sodium, potassium, calcium and magnesium etc.

There is a need to investigate effect of polluted/chemical water on hardened concrete strength and durability. Kejin *et al.* (2005) reported the damage impact of various deicing chemicals and exposure conditions on concrete materials, results indicated that the various deicing chemicals penetrated at different rates into a given paste and resulting in different degree of damages to concrete. Gorniniski *et al.* (2007) presented an assessment of the chemical resistance of eight different compositions of a polymeric mortars. Adnan *et al.* (2009) reported the effects of environmental factors on the addition and durability characters of epoxy bonded concrete prisms. Fikret *et al.* (1997) investigated the resistance of mortars to magnesium sulphate attack and results reported that there is a significant changes in compressive and flexural properties. Venkateswara Reddy *et al.* (2006) studied the influence of strong alkaline substances (sodium carbonate and bi-carbonate) in mixing water on strength and setting properties of concrete. Hence, there is need to assess the effect of magnesium chloride presence in the water in various

concentrations on setting times of cement and strengths of concrete.

### Materials and methods

**Cement:** 53 grade 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.

Table 1. Compositions of major compounds in cement

Name of the compound	%
Tricalcium Silicate ( $3CaO SiO_2$ )	11.70
Dicalcium Silicate ( $2CaO Al_2O_3$ )	23.30
Tricalcium Aluminate ( $3CaO Al_2O_3$ )	9.31
Tetracalcium Alumino Ferrite ( $4CaO Al_2O_3 Fe_2O_3$ )	51.40

**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.

Table 2. Properties of aggregate

Property	Coarse aggregate	Fine aggregate
Specific gravity	2.62	2.53
Bulk density	15.65 kN/m <sup>3</sup>	15.54 kN/m <sup>3</sup>
Fineness modulus	6.65	2.84

**Water:** De-ionised water spiked with Magnesium chloride ( $MgCl_2$ ) at different concentrations i.e. 0.2, 0.5, 1.0, 1.5 & 2.0 g/lit.

**Experimental program:** The influence of  $MgCl_2$  on concrete was studied. For this,  $MgCl_2$  at different concentrations (0.2, 0.5, 1.0, 1.5 & 2.0g/lit) was spiked with deionised water. Test samples were 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,  $MgCl_2$  at the dosage of 0.2, 0.5, 1.0, 1.5 & 2.0 g/lit was mixed with deionised water. This water was used for preparation of samples for setting times (initial & final) of

Fig. 1. Variation of setting times of cement corresponding to various concentrations of  $MgCl_2$  in deionised water

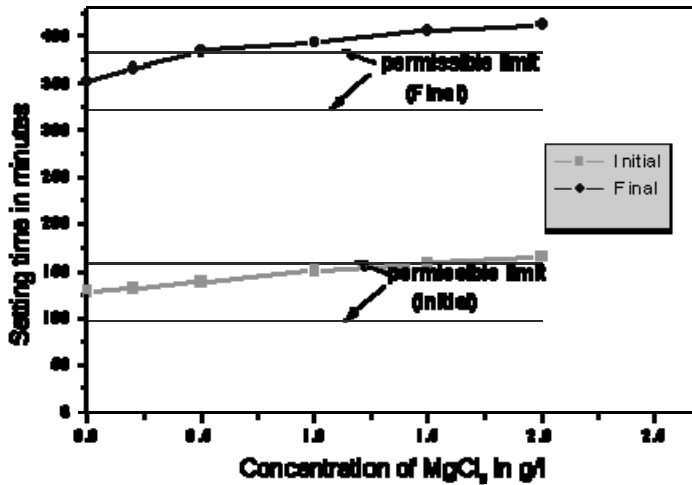


Fig.2. Variation of compressive strength of OPC concrete corresponding to various concentrations of  $MgCl_2$  in deionised water

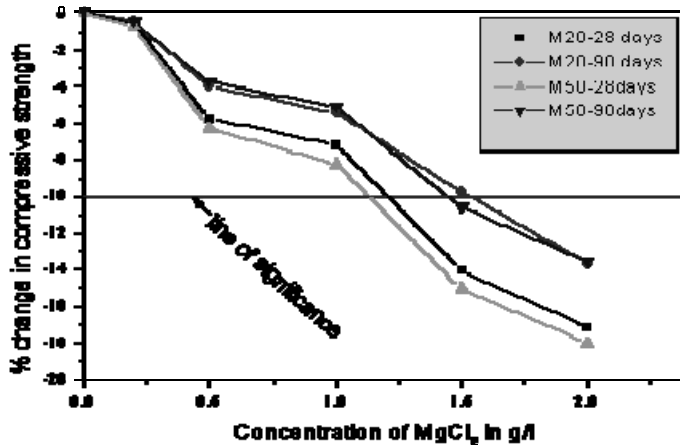
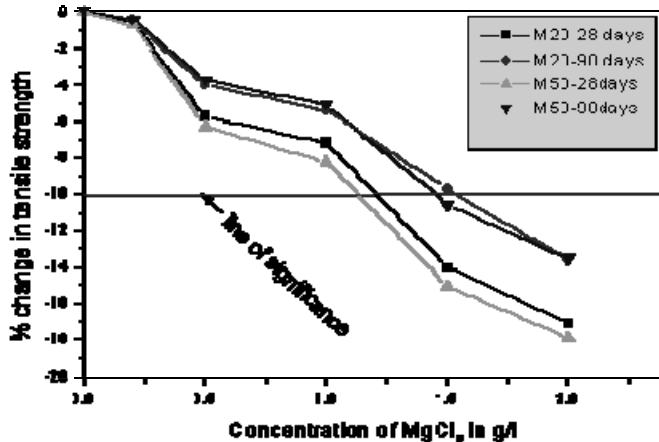


Fig.3. Variation of tensile strength of OPC concrete corresponding to various concentrations of  $MgCl_2$  in deionised water



cement and M20 & M50 grade concrete. The IS mix design was adopted for M20 and M50 grade concrete mix. Vicat apparatus was used for finding the initial and

final setting times of the cement. A total of 168 standard specimens were cast and tested for predicting compression (84 cubes) and split tension (84 cylinders) strengths.

**Results and discussion**

The effect of Magnesium chloride ( $MgCl_2$ ) 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  $MgCl_2$  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  $MgCl_2$  on initial and final setting times is shown in Fig. 1. Both the initial and final setting times got retarded with an increase in magnesium chloride concentration in deionised water. The retardation was significant when the magnesium chloride content is 1.5 g/l and 0.5 g/l respectively. With regard to initial setting time, significant change occurred at relatively higher concentration, i.e., at 1.5 g/l onwards. However, significant change in the final setting time has occurred at relatively lower concentration, i.e. at 0.5 g/l. At the maximum concentration (1.5g/l) the initial and final setting times are 37 and 59 minutes more than those of control mix.

*Effect on strength of OPC concrete*

Average compressive strength of three cubes and split tensile strength of three cylinders prepared with different concentrations of  $MgCl_2$  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  $MgCl_2$  concentration on the compressive strength and tensile strength of concrete of ordinary Portland cement concrete is presented in Fig. 2 and 3. Decrease in compressive strength and tensile strength of ordinary Portland cement concrete specimens prepared with  $MgCl_2$  solution is observed as the magnesium chloride concentration increases, the maximum concentration being 2 g/l. There is significant decrease in the compressive strength of concrete cubes of M20 (90<sup>th</sup> day) and M50 (28<sup>th</sup> day & 90<sup>th</sup> day) at concentration of 1.5 g/l, whereas this significant decrease in compressive strength observed for M20 (28<sup>th</sup> day) samples at concentration of 2.0 g/l. When  $MgCl_2$  concentration is 2.0 g/l, the decrease in compressive strength is 17.15% for M20 (28<sup>th</sup> day) grade concrete and 18.02% for M50 (28<sup>th</sup> day) grade concrete respectively, when compared with that of cubes prepared with the deionised water (control sample). Similarly, significant decrease in tensile strength is observed when the concentration of  $MgCl_2$  is 1.5 g/l for M20 (90<sup>th</sup> day) and M50 (28<sup>th</sup> day & 90<sup>th</sup> day) samples;

whereas this significant decrease in tensile strength is observed for M20 (28<sup>th</sup> day) samples at concentration of 2.0 g/l. When MgCl<sub>2</sub> concentration is 2.0 g/l, the decrease in tensile strength is 17.13% for M20 (28<sup>th</sup> day) grade concrete and 17.91% for M50 (28<sup>th</sup> day) grade concrete respectively, when compared with that of cylinders prepared with the deionised water (control test sample).

Fig.4. X-Ray diffraction pattern of powdered concrete sample prepared with MgCl<sub>2</sub> (1.5 g/l) in deionised water

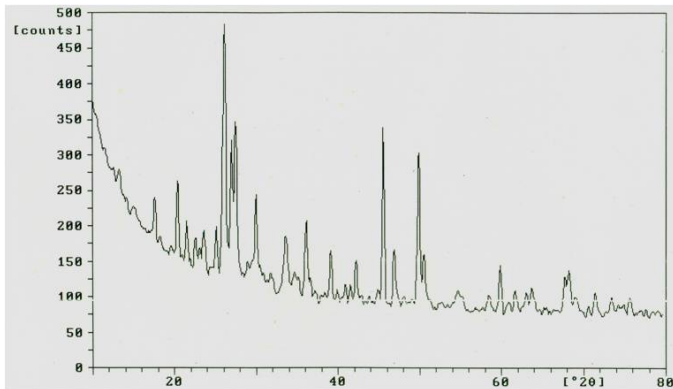
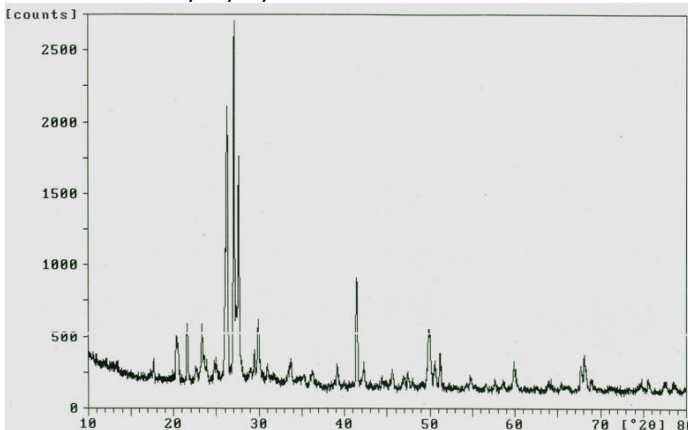


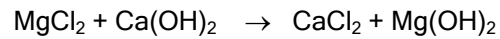
Fig.5. X-Ray diffraction pattern of powdered concrete sample prepared with deionised water



### Powder X-ray diffraction analysis

Powder X-ray diffraction pattern for the concrete prepared with MgCl<sub>2</sub> (1.5 g/l) and for control specimen is depicted in Fig. 4 and Fig. 5. The comparison of MgCl<sub>2</sub> pattern with that of the control specimen indicates the formation of brucite [Mg(OH)<sub>2</sub>] and CaCl<sub>2</sub> compounds. These are characterized by the sets of d-spacings 2.8182 Å, 1.8102 and 1.3767 Å for Mg(OH)<sub>2</sub> and 4.1361 Å, 3.2505 Å and 1.825 Å for CaCl<sub>2</sub> respectively in this pattern, these peaks not being present in the pattern for the control mix (Fig. 5). The probable reasons for above behaviour of concrete with MgCl<sub>2</sub> in mixing water are discussed below through corresponding chemical reaction.

The possible chemical reaction upon the hydration of cement with mixing water containing MgCl<sub>2</sub> is



MgCl<sub>2</sub> solution reacts with slaked lime to form CaCl<sub>2</sub> and Mg(OH)<sub>2</sub>. The formation of soluble CaCl<sub>2</sub> leads to initial strength loss. As Mg(OH)<sub>2</sub> is insoluble in water, its formation does not increase the porosity and the permeability of the system. Thus the formation of magnesium hydroxide (brucite) leads to loss of strength.

Sl.No	Angle	d-value Å	Rel.int. (%)
1	13.275	6.6806	3.2
2	17.620	5.0418	20.9
3	21.520	4.1361	16.8
4	23.125	3.8526	7.7
5	25.155	3.5461	20.5
6	26.190	3.4083	100.0
7	26.980	3.3102	60.6
8	27.485	3.2505	51.4
9	30.010	2.9826	36.5
10	33.600	2.6717	17.2
11	36.140	2.4895	29.4
12	40.905	2.2099	7.0
13	42.230	2.1436	20.1
14	46.855	1.9422	17.2
15	49.930	1.8296	57.0
16	50.500	1.8102	18.4
17	59.875	1.5473	16.5
18	63.700	1.4633	7.7
19	68.235	1.3767	18.0
20	68.985	1.3636	4.3

### Conclusions

Initial setting time gets retarded with increase in magnesium chloride concentration and it is significant from 1.5 g/l concentration onwards. Final setting time gets retarded with increase in magnesium chloride concentration and is significant from 0.5 g/l concentration onwards. Compressive and tensile strengths of OPC concrete reduces as magnesium chloride concentration increases.

### References

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