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# IMPACT OF SODIUM SILICATE AS AN ADDITIVE ON THE PROPERTIES OF MAGNESIUM OXYCHLORIDE CEMENT (MOC)

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## ABSTRACT

The authors have investigated effect of sodium silicate as an additive on magnesium oxychloride cement (Sorel's cement) in the present work. It has been found that after admixing sodium silicate in magnesium oxychloride cement (Sorel's cement), it shows encouraging improvement in properties results. It retards the setting process of cement and improves strength and durability of the product.

**Key words**: Cement, Curing, Compressive strength, MgO, Additive.

## INTRODUCTION

Magnesium oxychloride cement (Sorel's cement) was discovered by S. T. Sorel in 1867. It has many superior properties to those of Portland cement as observed by several researchers[1-7]. It is a tough, stone like fire proof compound[4,8] that can be used for light or heavy floorings[9]. Having tremendous load bearing capacity, it can withstand the least trace of cracks or fissures. It is relatively light in weight (sq. gr. 2.5). It has low coefficient of thermal expansion and shows negligible volume change during setting. It is used in industrial floorings, ship decks, railway passenger coach floorings, hospital floors, ammunition factories floors and missile. The major reaction product of MOC paste (magnesium oxychloride cement) ($MgO$-$MgCl_2$-$H_2O$ system) has long been revealed to be four crystalline phases : $5Mg(OH)_2.MgCl_2.8H_2O$ (5 phase); $3Mg(OH)_2.MgCl_2.8H_2O$ (3 phase); $2Mg(OH)_2.MgCl_2.8H_2O$ (2 phase) and $9Mg(OH)_2.MgCl_2.8H_2O$ (9 phase). All of the phases are the basic salts whose formal formula can be written as $Mg_x(OH)_y.Cl.nH_2O$. It has been find out that soluble phosphates increase the water resistance of the MOC[10-15]. A

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parametric study has been conducted to investigate the influence of the molar ratio of $MgO/MgCl_2$ and $H_2O/MgCl_2$ on the properties of (MOC) magnesium oxychloride cement[16]. The chemical composition of the additive available amply in commercial grade is $Na_2SiO_3$ x $H_2O$. The literature is silent about its effect on magnesium oxychloride cement[17]. Nevertheless, the authors have investigated the effect of sodium silicate on magnesium oxychloride cement purposefully; one basic reason behind this was that its anionic parts forms inactive insoluble phases with active lime, calcium chloride and other harmful impurities[4,18].

The experimental investigations with sodium silicate as an additive was therefore carried out in order to find out its effect on strength and durability of magnesium oxychloride cement.

## Materials

**Raw materials:** The following materials were used in this investigation:

**Magnesia:** Magnesia used in this study was of Salem (Chennai). It had the following characteristics – (i) Bulk density 0.85 Kg/I (ii) 95% passing through 75 micron (200 IS sieve) (iii) Magnesium oxide 90% (iv) Ca0 < 1.5% (v) Ignition loss at $100^oC$ – 2.5 + -0.5%.

**Inert filler (Dolomite):** Dolomite with following grading was used : (i) 100% passing through 150 micron IS Sieve (ii) 50% retained on 75 micron IS Sieve (iii) Ca0 28.7% (iv) Mg0 20.8% (v) Insoluble and other sesquioxide contents were less than 1.0%

**Magnesium chloride ($MgCl_2.6H_20$):** Used in the study was IS Grade 3 of IS: 254–1973 with following characteristics: (i) Colourless, crystalline, hygroscopic crystals. (ii) Highly soluble in water. (iii) Magnesium chloride minimum and 95% (iv) magnesium sulphate, Calcium sulphate and alkali chlorides (NaCl) contents were less than 4%.

# EXPERIMENTAL

Effect of sodium silicate on setting and strength of magnesium oxychloride cement was studied after incorporation it in different proportions in the wet-mix, on the basis of the following investigations.

## Setting time test

Experiments pertaining to the consistency, initial and final setting periods were performed as per standard procedures mentioned in the I.S. specifications with the help of Vicat needle apparatus[19-22]. Separate investigations were carried out with the dry-mix, containing powdered sodium silicate and the gauging solution containing saturated sodium silicate in different proportions. The observed results are summarized in Table 1.

**Table1: Effect of sodium silicate of setting characteristics of Sorel's cement**

Gauging Solution: $22^0$ Be Temperature: $30^0$

Dry-mix composition: 1:2* Humidity: Above 75%

| Observations | composition of dry mix (w/w% additive of magnesia) | | | | |
|---|---|---|---|---|---|
| | **0** | **5** | **10** | **15** | **20** |
| Volume of gauging solution (mL) | 60 | 55 | 53 | 52 | 50 |
| Initial setting time (min) | 160 | 150 | 140 | 135 | 125 |
| Final setting time (min.) | 320 | 305 | 310 | 315 | 320 |
| Nature of blocks | | | | | |
| (i) Glossiness | Yes | Yes | Yes | Yes | Yes |
| (ii) Volume Change | Normal------Slight expansion------- | | | | |

## Weathering effects

Investigation were made by recording the variation in weights of the setting time blocks (as taken from the vicat moulds) with time after 24 h, 7 and 30 days respectively. Weight of the test blocks may increase or decrease with time due to different weathering effects promoted by the admixture[3,23-24]. The experiential findings are recorded in Table 2.

**Table 2: Effect of sodium silicate on weathering of Sorel's cement**

Gauging Solution: $22^0$ Be Dry-mix composition: 1 : 2*

| Observations | composition of dry mix (w/w% additive of magnesia) | | | | |
|---|---|---|---|---|---|
| | **0** | **5** | **10** | **15** | **20** |
| Weight after 24 hr. (g) | 260 | 266 | 268 | 265 | 275 |
| Weight after 7 days (g) | 255 | 256 | 260 | 260 | 267 |
| Weight after 30 days (g) | 243 | 250 | 252 | 250 | 253 |

## Moisture ingress test (Steam tests)

To find out the effect of sodium silicate on moisture ingress in magnesium oxychloride cement, standards setting time blocks were used. These were subjected to steam tests after one month air curing under identical conditions to estimate their relative moisture sealing efficiencies according to the standard procedure[20,22,24-25]. The observed results are summarized in the Table 3.

**Table 3: Effect of sodium silicate on moisture ingress (steam test) in the trial blocks**

Gauging Solution: $22^0$ Be Dry-mix composition: 1 : 2*

| Observations | composition of dry mix (w/w% additive of magnesia) | | | | |
|---|---|---|---|---|---|
| | **0** | **5** | **10** | **15** | **20** |
| 10 hrs. | N.E. | N.E. | N.E. | N.E. | N.E. |
| 15 hrs. | N.E. | N.E. | N.E. | N.E. | N.E. |
| 20 hrs | N.E. | N.E. | N.E. | N.E. | N.E. |
| 25 hrs. | N.E. | N.E. | N.E. | N.E. | N.E. |
| 30 hrs. | C | N.E. | N.E. | N.E. | N.E. |
| 35 hrs. | - | N.E. | N.E. | N.E. | N.E. |
| 40 hrs. | - | N.E. | N.E. | N.E. | N.E. |
| 45 hrs. | - | + | + | + | + |

N.E. : No Effect; + : Moisture ingress but not cracked; C : Cracked

**Compressive strength test**

The effect of sodium silicate on compressive strength of the magnesium oxychloride cement was determined with the help of compressive strength testing machine as per the standard procedures[25-27]. The practical results are recorded in the Table 4.

**Table 4: Effect of sodium silicate on compressive strength of Sorel's cement**

Gauging solution: $24^0$ Be Dry-mix composition: 1 : 2*

| % Additive (w/w of magnesia) | 0 | 5 | 10 | 15 | 20 |
|---|---|---|---|---|---|
| Compressive Strength (Kg/cm$^2$) | 480 | 900 | 800 | 720 | 620 |

**Soundness tests (Le-Chaterlier's test)**

This test was carried out with the Le-chatelier's test apparatus which consists of small split cylinder forming a mould and two glass plates to cover each side of the cylinder.

Two parallel indicating arms with pointed ends are attached on either side. The wet-mix which is to be tested for soundness of the products is placed into the mould resting on a glass plate and then covered with another glass plate. The wet-mix is than allowed to set for the one week. Then difference (x) between pointed ends of the indicating arms is measured. Now the mould is immersed in water at $27^0$ to $32^0$C for 48 hours. Again the distance (x) between pointed ends of the indicating arms is measured. Then the mould is immersed in a beaker of boiling water for 1 h, cooled and again the distance (y) measured. The difference (y-x) measures the soundness or expansion of the product. The value of (y-x) should not be more than 5 mm for a good product[7,12,26]. The results of the investigation are summarized in the Table 5.

**Table 5: Effect of sodium silicate on soundness of Sorel's cement (Le-Chatelier's Test)**

Gauging Solution: $24^0$ Be Dry-mix composition: 1 : 2*

| Observations | composition of dry mix (w/w% additive of magnesia) | | | | |
|---|---|---|---|---|---|
| | **0** | **5** | **10** | **15** | **20** |
| Weight of cement composition (g) | | | | | |
| (i) Magnesia | 13 | 13 | 13 | 13 | 13 |
| (ii) Dolomite | 26 | 24.7 | 23.4 | 22.1 | 20.8 |
| (iii) Additiv | - | 1.3 | 2.6 | 3.9 | 5.2 |
| Use of $MgCl_2$ Solution (mL) | 11.5 | 10 | 10 | 10 | 10 |
| Distance between two pointers before starting (Cm.) | 1.8 | 1.1 | 1.4 | 1.4 | 2.0 |
| Distance between two pointers after 7 days (Cm.) | 2.0 | 1.2 | 1.5 | 1.4 | 2.1 |
| Time in water at $27^0$C to $32^0$C (hr) | 48 | 48 | 48 | 48 | 48 |
| Distance between two pointers before boiling (Cm.) | 2.2 | 1.2 | 1.6 | 1.5 | 2.1 |
| Distance between two pointers after boiling (Cm.) | 2.3 | 1.2 | 1.6 | 1.5 | 2.1 |
| Expansion of cement (Cm.) | 0.1 | 0 | 0 | 0 | 0 |

## RESULTS AND DISCUSSION

Table 1, reveals the effect of sodium silicate on setting characteristics of magnesium oxychloride cement. Volume of the gauging solution is found to decrease with its increasing proportion in the dry-mix. Such a situation arises because of the reaction of magnesium chloride (gauging solution) with silicate ions to form an insoluble solid phase of magnesium silicate. Thus lot of free water content in the gauging solution is available to form a thinner paste with the dry-mix. Hence for the same standard consistency decreasing volumes of gauging solution are expected. It is noted that initial setting periods shows a decreasing trend. Because the hydration of magnesia (a faster process) is a major factor for initial setting. Final setting periods initially decrease (up to 5%) and then increase gradually. This may be attributable to the inactivation of impurities like active lime, calcium chloride etc. as a primary role of the additive. Formation of calcium and magnesium silicate in this way (both are solid phases) occurs initially without much affecting the formation of magnesium oxychloride. These solid phases accelerate initial setting process to some extent. Accordingly gradual decrease in later process of final setting involves formation of strength giving composition. This is affected adversely on account of inactivation of available $Mg^{+2}$ ions as insoluble and inert silicate phases (reaction 1). Therefore, gradual increase in the final magnesia and active lime contents contribute of glossiness of the surface. Slight expansion as observed in the volume of the blocks owes to the possible formation of calcium and magnesium hydroxides and other hydration process which are exothermic in nature (reaction 2).

$$Mg/CaCl_2 + Na_2SiO_3 \longrightarrow Mg/CaSiO_3 + 2NaCl \qquad \ldots(1)$$

$$MgO/CaO + H_2O \longrightarrow Mg/Ca\,(OH)_2 + Energy \qquad \ldots(2)$$

Slow setting and inactivation of calcium and magnesium ions level a lot of uncombined moisture in the matrix. This moisture evaporates slowly. Thus almost uniform decrease in weights of the trial blocks with time is expected Table 2. It is interesting to note that formation of interlocking crystals of calcium and magnesium silicate along with magnesium oxychloride contributes to water tightness of the products. Accordingly it is noted that sodium silicate improves water tightness remarkable (Table 3). It should be emphasized that magnesium oxychloride composition is the major strengths giving factor in Sorel’s cement. The compressive strength first increases and then decreases gradually with decreasing chances of its formation for obvious reasons (Table 4). Initial increase may be attributed to inactivation of active lime and unused magnesia or magnesium chloride, which by themselves are not strength giving compositions. Their inactivation is associated with formation of interlacing crystalline phases of silicates. This contributes to strength initially.

The above discussions are further supported from the investigations pertaining to the effected of sodium silicate on soundness of magnesia cement (Table 5). Thus slight expansion of the trail blocks is in harmony with the small volume changes as noticeable at the final stage of the Le-chateliers tests. In practice positive volume changes are not desirable. Because water tightness conferred by interlacing systems of calcium/magnesium silicate and magnesium oxychloride may be overcome by accompanying positive volume changes on prolonged and continuous exposure of the product to the moisture. This makes the product prone to moisture ingress.

## CONCLUSION

(i) Incorporation of sodium silicate as an admixture in magnesia cement decreases initial setting periods without affecting the final setting periods remarkably.

(ii) It contributes to strength and durability of the product.

(iii) Based on the observed data it can be concluded that use of 5% sodium silicate of magnesia contents as an admixture appears to be the optimum quantity for improved compressive strength and durability of the product.

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