

Effect of Sodium Carbonate as an Additive on Some Properties of Magnesium Oxysulphate Cement: A study

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ABSTRACT: Non calcareous Magnesium Oxysulphate Cement (also known as Sorel's cement) was invented by Frenchman Stanislas Sorel in 1867. It is formed by the reaction between Magnesium oxide and Magnesium sulphate. Its formation process does not require any type of energy whether heat or light making it ecofriendly cement. In this study Sodium carbonate is used as an additive and results are very encouraging. Incorporation of different proportions of Sodium carbonate in Magnesia cement gradually increases the setting periods and improves compressive strength of the product.

KEYWORDS: Magnesium Oxysulphate Cement, Setting periods, Compressive strength, Moisture ingress, Weathering effects, Linear changes.

I. INTRODUCTION

Cements are the inorganic binders[1]. Chemical binders are the substances which can be used directly or indirectly for binding, adhering or fastening substances[2]. Magnesium Oxysulphate Cement was first produced in 1867 by a French engineer Stanislas Sorel. It has many properties superior to those of Portland cement[3]. It is used as flooring and insulating materials[4]. It is a promising material for fire proofing[5]. The resistance of Magnesium Oxysulphate Cement to abrasion is about 1.5 times to that of Portland cement[6]. It has no corrosion to steel and effective inhibition of the frost[7]. The principal application of Magnesium oxysulphate cement is in the manufacture of light weight insulating panels[8]. It has also used in architecture, fire protection and decorative purposes[9]. It is also considered for nuclear applications[10].

It is obtained by the reaction between lightly calcined Magnesite and aqueous solution of Magnesium sulphate of suitable density. Mechanical properties and binding qualities developed during setting (hardening) process are attributable to the exothermic chemical reaction occurring between the two. Inert filler dolomite was mixed in the matrix to absorb excess heat evolved during the exothermic formation of Magnesium Oxysulphate Cement. [11]

According to temperature ranges and preparation conditions five types of Oxysulphate Cement are known. They are $5\text{Mg}(\text{OH})_2 \cdot \text{MgSO}_4 \cdot 3\text{H}_2\text{O}$, $3\text{Mg}(\text{OH})_2 \cdot \text{MgSO}_4 \cdot 8\text{H}_2\text{O}$, $5\text{Mg}(\text{OH})_2 \cdot \text{MgSO}_4 \cdot 8\text{H}_2\text{O}$, $\text{Mg}(\text{OH})_2 \cdot \text{MgSO}_4 \cdot 5\text{H}_2\text{O}$ and $\text{Mg}(\text{OH})_2 \cdot \text{MgSO}_4 \cdot 3\text{H}_2\text{O}$. Magnesium Oxysulphate Cement of $\text{Mg}(\text{OH})_2 \cdot \text{MgSO}_4 \cdot 8\text{H}_2\text{O}$ composition is most commonly found.

The object of the study was to determine the effect of Na_2CO_3 on setting periods, moisture ingress, weathering effect, compressive strength and linear changes of Sorel's Cement. The chemical composition of commercial grade sodium carbonate is Na_2CO_3 . The anionic part of sodium carbonate reacts with active lime and other harmful impurities and forms inactive insoluble phase. Thus the harmful effects of these impurities on the quality of Magnesium Oxysulphate Cement are minimized.

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II. MATERIALS

In this study Magnesium oxide, Magnesium sulphate and Dolomite were used-

- (I) Magnesium Oxide[12]→ Commercial grade Magnesia (lightly calcined) was used in this study. The analysis of Magnesite powder is :- $\text{SiO}_2=8.51\%$, $\text{CaO}=2.80\%$, $\text{MgO}=82.70\%$, $\text{Fe}_2\text{O}_3=0.12\%$, $\text{Al}_2\text{O}_3=0.98\%$, $\text{LOI}=4.40\%$.
- (II) Magnesium sulphate (Epsom salt)[13] → Technical grade magnesium sulphate was used in the formation of Magnesium Oxysulphate Cement. The chemical composition of Epsom salt is $\text{MgSO}_4=96.80\%$, $\text{Fe}_2\text{O}_3=0.02\%$, $\text{Al}_2\text{O}_3=0.07\%$, $\text{CaO}=1.40\%$, Acid insoluble=0.11%, moisture=0.98%.
- (III) Dolomite[14]→ Commercial grade dolomite was used in this study. The chemical composition of Dolomite is $\text{SiO}_2=5.06\%$, $\text{CaO}=29.40\%$, $\text{MgO}=19.50\%$, $\text{Fe}_2\text{O}_3=0.82\%$, $\text{Al}_2\text{O}_3=0.23\%$, $\text{LOI}=44.50\%$, $\text{CaCO}_3=52.50\%$, $\text{MgCO}_3=40.95\%$, Brightness=93.00%, Whiteness=95.30%.

III. METHODS

Following five experiments were conducted to investigate the influence of Na_2CO_3 on Magnesium Oxysulphate Cement.

- (I) Setting Time Investigations:- The effect of Na_2CO_3 on setting characteristics of Magnesium Oxysulphate Cement was studied by admixing Na_2CO_3 in the dry-mix in varying proportions. The quantity of additive was calculated by weight of Magnesia .Wet mixes were prepared by gauging 1:2 dry-mixes (by weight of Magnesia and Dolomite) having different quantities of additive with Magnesium sulphate solution of 25° Be. The volume of gauging solution was kept constant for each lot of dry- mix. Standard procedures were adopted according to IS specification to determine standard consistency, Initial and final setting times using Vicat needle apparatus[15]. Results are summarized in Table1.
- (II) Weathering Effects :- Standard blocks prepared for setting time investigations were used in this test. Variation in weights of blocks was measured with passage of time after 24 hrs, 7days, 15 days, 30 days and 45 days using chemical balance. Different weathering effects may increase or decrease the weights of the trials blocks with passage of time. Experimental findings are recorded in Table2.
- (III) Moisture Ingress Test :- All the setting time blocks with different proportions of the additive were first cured for 60 days under identical conditions and then were exposed to boiling water for atleast 30 hours in a closed steam bath. Their relative moisture ingress efficacies were studied as a function of time. Moisture ingress and soundness are inversely proportional. Results are shown in Table 3.
- (IV) Compressive Strength :- To study the effect of Na_2CO_3 on compressive strength of Oxysulphate Cement, standard 50cm^2 cubes ($70.6\text{mm}\times 70.6\text{mm}\times 70.6\text{mm}$) were prepared from the standard consistency pastes having Na_2CO_3 in different amounts. These cubes were tested after 30 days of curing under identical conditions. Strength of the blocks were measured by the help of compressive strength testing machine as per standard procedure. Results are recorded in Table 4.
- (V) Linear Changes :- The effect of Na_2CO_3 on linear changes of Magnesium Oxysulphate Cement was studied by preparing wet mixes having varying quantities of the additive and then filled into standard sized moulds ($200\text{mm}\times 25\text{mm}\times 25\text{mm}$). Trial beams were kept under 90% humidity and about 30°C temperature for 24 hours. Initial length of the beams were measured after 24 hours and final lengths were measured after 28 days of curing. The difference of the two readings show the linear change. If the difference is less, more will be the soundness of the product. Results are recorded in Table 5.

IV. RESULTS

Table1 represents the effect of Na_2CO_3 on setting periods of Magnesium Oxysulphate Cement. It is observed that initial as well as final setting periods of Magnesium Oxysulphate Cement increases with increasing quantity of additive. When ratio of additive increases, the amount of MgO decreases in the matrix(eq ii & iv). Also carbonate ions react with divalent cations Which results in the formation of insoluble and inactive phase of their carbonates(eq iii & iv) .This decreases the active quantities of MgO available in the matrix. Such situation retards the setting process.

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The effect of Na₂CO₃ as an additive on weathering characteristics is shown in Table 2. Incorporation of Na₂CO₃ reduces the weight of the trial blocks with time up to 30 days of observation period. This is attributable mainly to the uncombined free moisture present in the matrix which slowly evaporates with time causing decrease in weights. Observations recorded on the 45th day reveal almost insignificant increase in weights. This shows that major reactions involved in cement formation are almost over by that period. Minor increase in weights may be explained due to rehydration or carbonation (eq vi).

Effect of Na₂CO₃ on moisture ingress characteristics of Magnesium Oxysulphate Cement is represented in Table 3. Incorporation of Na₂CO₃ increases watertightness of the product. Inactivation of harmful impurities like active lime (eq iii & iv), formation of inert solid phases like basic magnesium carbonates (eq viii) etc. contribute to watertightness.

Table 4 shows the effect of Na₂CO₃ on compressive strength of Magnesium Oxysulphate Cement. Compressive strength is improved by the incorporation of additive. It is noted that strength decreases with increasing proportion of additive. Small proportion of the additive inactivate harmful impurities like active lime (eq iii & iv). In such a situation compressive strength of the trial blocks is found to increase initially. With subsequent addition of the additive, compressive strength is found to decrease sharply as the chances of formation of strength giving composition decreases and also due to the porous structure of the trial blocks on account of the evolving CO₂.

Effect of Na₂CO₃ on linear changes is noted in Table 5. Incorporation of Na₂CO₃ causes contraction in the linear beams to some extent. This can be accounted on the basis of the conversion of expansive or bulky materials (oxides and hydroxides) into compact crystalline phase (carbonates) (eq ii, iv & vii).

The above discussion can be interpreted on the basis of the following chemical changes :-

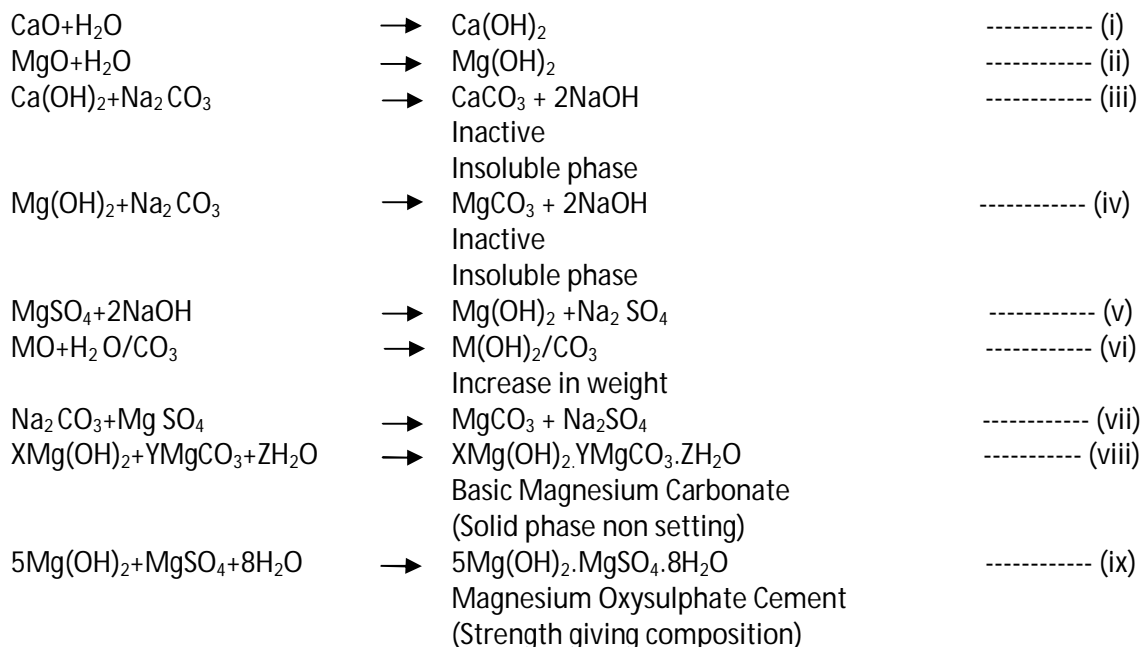


Table 1. Effect of Na₂CO₃ on Setting Characteristics of Magnesium Oxysulphate Cement.

Conc. Of gauging solution = 25°Be
Vol. Of g.s. = 83.0ml
Temperature = 30 ± 2°c

Dry-Mix Composition 1:2
(a) One part by weight of magnesia
(b) Two parts by weight of dolomite + additive

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Relative humidity above 90%

Quantity of dry-mix..200gm.

S.No.	Dry-mix composition (% additive)	Setting Time	
		Initial (min.)	Final (min.)
1	0%	70	210
2	5%	76	453
3	10%	85	496
4	15%	99	511
5	20%	132	544

Table2. Effect of Na₂CO₃ on Weathering Characteristics of Magnesium Oxysulphate Cement.

Conc. Of gauging solution=25°Be

Vol. Of g.s.=83.0ml

Temperature =30± 2°c

Relative humidity above 90%

Dry-Mix Composition 1:2

(a)One part by weight of magnesia

(b)Two parts by weight of dolomite + additive

Quantity of dry-mix..200gm.

S. No.	Dry-mix composition (% additive)	Weight of blocks in gm after				
		24 Hrs.	7days	15days	30days	45days
1	0%	259.05	255.39	253.11	252.87	252.07
2	5%	260.16	250.57	247.27	244.97	245.41
3	10%	248.09	235.27	231.96	230.51	231.30
4	15%	246.47	232.79	229.06	227.25	228.07
5	20%	245.00	228.38	225.48	223.87	225.06

Table3. Effect of Na₂CO₃ on Moisture Ingress Characteristics of Magnesium Oxysulphate Cement.

Conc. of gauging solution=25°Be

Vol. of g.s.=83.0ml

Temperature =30± 2°c

Relative humidity above 90%

Dry-Mix Composition 1:2

(a) One part by weight of magnesia

(b) Two parts by weight of dolomite + additive

Quantity of dry-mix..200gm.

S. No.	Dry-mix composition (% additive)	Trial blocks kept in boiling water for					
		0-5hrs	5-10hrs	10-15hrs	15-20hrs	20-25hrs	25-30hrs
1	0%	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
2	5%	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
3	10%	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
4	15%	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
5	20%	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.

g.s.=gauging solution, N.E.= No Effect

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Table4. Effect of Na_2CO_3 on Compressive Strength of Magnesium Oxysulphate Cement.

Conc. of gauging solution= 25°Be Vol. of g.s.=235.0ml Temperature = $30 \pm 2^\circ\text{c}$ Relative humidity above 90%	Dry-Mix Composition 1:2 (a) One part by weight of magnesia (b) Two parts by weight of dolomite + additive Quantity of dry-mix..565gm.
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S. No.	Dry-mix composition (% additive)	Compressive Strength in Kg/cm ²
1	0%	260.53
2	5%	372.75
3	10%	356.71
4	15%	318.64
5	20%	278.56

Table5. Effect of Na_2CO_3 on Llinear Changes of Magnesium Oxysulphate Cement.

Conc. of gauging solution= 25°Be Vol. of g.s.=212.0ml Temperature = $30 \pm 2^\circ\text{c}$ Relative humidity above 90%	Dry-Mix Composition 1:2 (a) One part by weight of magnesia (b) Two parts by weight of dolomite + additive Quantity of dry-mix..565gm.
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S. No.	Dry-mix composition (% additive)	Length of Beam (mm)		Change length in (mm)
		Initial	Final	
1	0%	200.00	199.98	0.020
2	5%	200.00	199.936	0.064
3	10%	200.00	199.887	0.113
4	15%	200.00	199.874	0.126
5	20%	200.00	200.844	0.156

V. CONCLUSION

- 1) Na_2CO_3 increases setting periods in all proportions within the experimental limits.
- 2) Incorporation of Na_2CO_3 improves water tightness and strength of the cement.

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