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Effect of $MgCl_2$ Solution (gauging solution) Densities and Temperatures on Compressive Strength of Magnesium Oxychloride Cement (MOC)

KEYWORDS: Abrasion, Density, Compressive strength

R N Yadav	Upendra Singh	Priyanka Gupta
Department of Chemistry, Govt. RR (PG) College, Alwar 301001, India; Mob- 09414637692	Department of Chemistry, Govt. RR (PG) College, Alwar 301001, India; Mob-09414680789	Department of Chemistry, Govt. RR (PG) College, Alwar 301001, India; Mob-09461407968

Madhu Sharma	Akhilesh K. Meena	Navin Dagar
Govt. G.D. College for Women, Alwar 301001, India; Mob-09462470987	Department of Chemistry, Govt. RR (PG) College, Alwar 301001, India; Mob-09413901265	Department of Chemistry, Govt. RR (PG) College, Alwar 301001, India; Mob-09887777190

ABSTRACT *Magnesium oxychloride cement (MOC) was invented by S.T. Sorel in 1867. It is superior to the ordinary Portland cement, such as rapid setting and hardening properties, higher fire resistance, lower thermal conductivity, better resistance to abrasion and chemicals. MOC draws much research interest due to energy saving and environmental protection*

consideration. The effect of densities and temperatures of $MgCl_2$ solution on the compressive strength of magnesium oxychloride cement (MOC) has been comprehensively investigated by authors. The results show that compressive strength is increased with increasing density of $MgCl_2$ solution whereas compressive strength is decreased on increasing temperature of MgCl2 solution within experimental limits.

1. Introduction

Magnesium oxychloride cement (MOC) was discovered by S.T. Sorel in 1867. It is also known as Sorel's cements {1}. It is a type of non-hydraulic cement formed by mixing powdered magnesium oxide with a concentrated solution of magnesium chloride ($MgCl_2.6H_2O$). MOC has many superior properties compared to ordinary Portland cement, i.e. high fire resistance, low thermal conductivity and good resistance to abrasion {2-6}. It is also distinguished by a high bonding, quick setting time and does not require humid curing {7}. MOC draws much research interest due to energy saving and environmental protection consideration. Production of lightly burnt MgO used in MOC requires much lower calcination temperatures compared to that for Portland cement. This reduces vast amount of energy consumption {8, 9}. The major commercial and industrial applications of MOC are industrial flooring, fire protection, grinding wheel and light weight wall panels and also used for rendering wall insulation panels, interior plaster and decorative panels {2, 10-11}.

The setting and hardening of the MOC cement takes place in a through-solution reaction {12}. Four main reaction phases in the ternary MOC system are found; $2Mg(OH)_2.MgCl_2.4H_2O$(phase2),$3Mg(OH)_2.MgCl_2.8H_2O$ (phase 3), $5Mg(OH)_2.MgCl_2.8H_2O$ (phase 5) and $9Mg(OH)_2$. $MgCl_2.5H_2O$ (phase 9) {13-16}. These phases exist as reinforced component in the ternary system at ambient temperature.

It has many good engineering and mechanical properties. But it has a poor water resistance, causing significantly decreased strength of hardened MOC paste in water thereby limiting its engineering applications. Consequently, many investigations on the water resistance of MOC cements have been carried out over the years {17-20}. There are only a few reports available worldwide on MOC cement concrete.

In the present study, the effect of densities and temperatures of $MgCl_2$ solution on compressive strength of MOC have been investigated.

MOC cement composition was prepared by mixing magnesia and inert filler (dolomite) in the ratio of 1:1 dry-mix, gauged with different densities (20°Be, 24°Be, 28°Be & 32°Be) of $MgCl_2$ solution at different temperature (30⁰C, 35⁰C, 40⁰C & 45⁰C) for the determination of compressive strength of MOC. The results of investigations have been presented and discussed in this paper by authors.

2. Materials and Methods

Materials: The raw materials used in the study were calcined magnesite (magnesia), magnesium chloride and dolomite powder.

Calcined magnesite:
Commercial grade magnesia used in this study is of Salem origin having the following characteristics:

MgO	SiO_2	CaO	Fe_2O_3	Al_2O_3	L O I
71.80%	10.18%	6.72%	0.19%	0.75%	9.82%

Magnesium chloride ($MgCl_2$.6H20):
Magnesium chloride($MgCl_2.6H_20$) used in the study is IS grade 3 of IS:254-1973 with following characteristics: (i) colorless, crystalline, hygroscopic crystals (ii) highly soluble in water (iii) magnesium chloride minimum 94% and (iv) magnesium sulphate, calcium sulphate and alkali chloride content < 5%.

Inert filler (dolomite):
Dolomite dust was used as inert filler with following grading: (i) 100 % passing through 125 micron Indian Standard Sieve (ii) 50% retained on 250 micron IS Sieve

$CaCO_3$ - 55.50% ; $MgCO_3$ - 42.21%

SiO_2	CaO	MgO	Fe_2O_3	Al_2O_3	L O I
0.75 %	31.08 %	20.10 %	0.85 %	0.22 %	46.50%

Preparation of $MgCl_2$ solution:
$MgCl_2$ solution was prepared in water. Flakes of magnesium chloride were transferred into plastic containers to which

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potable water was added to prepare concentrated solution. This solution was allowed to stand overnight so that insoluble impurities settle down. The supernatant concentrated solution was taken out in other plastic containers and well stirred after each dilution before determining the specific gravity. Density of the solution is expressed in terms of specific gravity on Baume scale (°Be).

Preparation of dry-mix composition:
Dry-mixes were prepared by mixing equal amount of lightly calcined magnesite (magnesia) and dolomite (inert filler) in the ratio of 1:1 by their weight.

3. Experimental:
Effect of density and temperature of $MgCl_2$ solution on compressive strength of have been studied for 1:1 dry-mix composition of MOC. Following investigations have been carried out during the experimental works.

Determination of compressive strength:
The effect of densities and temperatures of $MgCl_2$ solution on compressive strength of the product was studied with the help of standard 70·6x70·6x70·6 mm^3 cubes, prepared for the I.S. consistency paste at various densities (20°Be, 24°Be, 28°Be & 32°Be) of $MgCl_2$ solution at different temperature (30°C, 35°C, 40°C and 45°C). These cubes were allowed to be cured under identical conditions for one month and then subjected to compressions just sufficient for their rupture {21-23}. Experimental findings are recorded in table 1 to 9.

Table.1 Effect of density of $MgCl_2$ solution (temperature 30⁰C) on compressive strength of MOC
Temperature of $MgCl_2$ solution – 30⁰C Dry-mix composition – 1:1* Humidity - 85 ± 5%

S. No.	Density of $MgCl_2$ solution	Compressive strength (In MPa)
1	20⁰Be	56.168
2	24⁰Be	58.174
3	W 28⁰Be	60.180
4	32⁰Be	64.192

*** One part by weight of magnesia and one part by weight of dolomite**

Table.2 Effect of density of $MgCl_2$ solution (temperature 35⁰C) on compressive strength of MOC
Temperature of $MgCl_2$ solution – 35⁰C Dry-mix composition – 1:1* Humidity - 85 ± 5%

S. No.	Density of $MgCl_2$ solution	Compressive strength (In MPa)
1	20⁰Be	52.156
2	24⁰Be	54.162
3	28⁰Be	58.174
4	32⁰Be	60.180

*** One part by weight of magnesia and one part by weight of dolomite**

Table.3 Effect of density of $MgCl_2$ solution (temperature 40⁰C) on compressive strength of MOC
Temperature of $MgCl_2$ solution – 40⁰C Dry-mix composition – 1:1* Humidity - 85 ± 5%

S. No.	Density of $MgCl_2$ solution	Compressive strength (In MPa)
1	20⁰Be	40.120
2	24⁰Be	48.144
3	28⁰Be	52.156
4	32⁰Be	54.162

*** One part by weight of magnesia and one part by weight of dolomite**

Table.4 Effect of density of $MgCl_2$ solution (temperature 45⁰C) on compressive strength of MOC
Temperature of $MgCl_2$ solution – 45⁰C Dry-mix composition – 1:1* Humidity - 85 ± 5%

S. No.	Density of $MgCl_2$ solution	Compressive strength (In MPa)
1	20⁰Be	38.114
2	24⁰Be	46.138
3	28⁰Be	48.144
4	32⁰Be	50.150

*** One part by weight of magnesia and one part by weight of dolomite**

Table.5 Effect of temperature of $MgCl_2$ solution (density 20⁰Be) on compressive strength of MOC
Density of $MgCl_2$ solution – 20⁰Be Dry-mix composition – 1:1* Humidity - 85 ± 5%

S. No.	Temperature of $MgCl_2$ solution	Compressive strength (In MPa)
1	30⁰C	56.168
2	35⁰C	52.156
3	40⁰C	40.120
4	45⁰C	38.114

*** One part by weight of magnesia and one part by weight of dolomite**

Table.6 Effect of temperature of $MgCl_2$ solution (density 24⁰Be) on compressive strength of MOC
Density of $MgCl_2$ solution – 24⁰Be Dry-mix composition – 1:1* Humidity - 85 ± 5%

S. No.	Temperature of $MgCl_2$ solution	Compressive strength (In MPa)
1	30⁰C	58.174
2	35⁰C	54.162
3	40⁰C	48.144
4	45⁰C	46.138

*** One part by weight of magnesia and one part by weight of dolomite**

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Table.7 Effect of temperature of $MgCl_2$ solution (density 28⁰Be) on compressive strength of MOC
Density of $MgCl_2$ solution – 28⁰Be Dry-mix composition – 1:1* Humidity - 85 ± 5%

S. No.	Temperature of $MgCl_2$ solution	Compressive strength (In MPa)
1	30⁰C	60.180
2	35⁰C	58.174
3	40⁰C	52.156
4	45⁰C	48.144

*** One part by weight of magnesia and one part by weight of dolomite**

Table.8 Effect of temperature of $MgCl_2$ solution (density 32⁰Be) on compressive strength of MOC
Density of $MgCl_2$ solution – 32⁰Be Dry-mix composition – 1:1* Humidity - 85 ± 5%

S. No.	Temperature of $MgCl_2$ solution	Compressive strength (In MPa)
1	30⁰C	64.192
2	35⁰C	60.180
3	40⁰C	54.162
4	45⁰C	50.150

*** One part by weight of magnesia and one part by weight of dolomite**

Summarized Table.9 Effect of density and temperature of $MgCl_2$ solution on compressive strength of MOC
Dry-mix composition: 1:1* Humidity-85 ± 5% Temperature of $MgCl_2$ solution

Dry-mix composition: 1:1* Humidity-85 ± 5%

S. No	Density of $MgCl_2$ solution	Temperature of $MgCl_2$ solution: 30°C	35°C	40°C	45°C
		Compressive strength (in MPa)			
1.	20°Be	56.168	52.156	40.120	38.114
2	24°Be	58.174	54.162	48.144	46.138
3	28°Be	60.180	58.174	52.156	48.144
4	32°Be	64.192	60.180	54.162	50.150

*One part by weight of magnesia and one part by weight of dolomite

***One part by weight of magnesia and one part by weight of dolomite**

4. Result and Discussion:

The effect of densities and temperatures of $MgCl_2$ solution on compressive strength of MOC trial blocks is shown in the Table- 1 to 8.

Effects of densities of $MgCl_2$ solution on compressive strength of moulds prepared by 1:1 dry-mix composition are recorded in tables 1 to 4. It is revealed from table1 to 4 that compressive strength of MOC trial blocks increases with increasing concentration of $MgCl_2$ solution from 20°Be to 32°Be. The increasing trend of compressive strength is possibly because of increased amount of magnesium chloride in the wet-mix. More perfect three dimensional network of interlacing crystals of strength giving forms (F5-five form and F3- three form) is formed. This contributes to increase in mechanical strength.

$$MgO + MgCl_2{\cdot}6H_2O + Mg/CaCO_3 \rightarrow 5Mg(OH)_2{\cdot}MgCl_2{\cdot}8H_2O/3Mg(OH)_2{\cdot}MgCl_2{\cdot}8H_2O + \text{Heat} + \text{Inert filler (Thermal shock absorber)}$$

On the other hand effects of temperature of $MgCl_2$ solution on compressive strength of moulds prepared by 1:1 dry-mix composition are recorded in tables 5 to 8. It is noticed from table 4 that compressive strength decreases as temperature of $MgCl_2$ increases from 30 to 45°C. This can be explicable due to more exothermic reaction occur during the reaction between MgO and $MgCl_2$ at higher temperature. Because of this more heat evolved which is responsible for decomposition of $Ca/MgCO_3$ present in matrix and liberation of free lime and CO_2. Hence, compressive strength decreases. Same trend is followed at each concentration.

$$Ca/MgCO_3 \xrightarrow{\text{Heat}} CaO/MgO + CO_2\uparrow$$

Effects of both factors are collectively summarized in table 9. From the tables, it is clear that both factors (temperature and concentration) shown great effect on compressive strength of MOC.

5. Conclusions:

It is concluded that-

a. The temperature and concentration of gauging solution to be used for the desired strength should be worked for the given mixture to facilitate the formation of strength giving compositions.
b. Temperature of gauging solution should preferably be 30° ± 5°C and density of $MgCl_2$ solution should preferably be 30° ± 2°Be.
c. Higher temperature of $MgCl_2$ solution (>35°C) should be avoided due to higher exothermic reaction proceed during wet-mixing, resulted reduce mechanical strength.

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