RESEARCH PAPER | Chemistry | Volume : 3 | Issue : 10 | Oct 2013 | ISSN - 2249-555X

Influence of Inert Filler on Cementing Properties of Magnesium Oxychloride Cement Moc With MOC-Friendly Cement

KEYWORDS: Standard consistency, Compressive strength and Soundness

R N Yadav
Department of Chemistry, Govt. RR (PG) College, Alwar 301001, India

Upendra Singh
Department of Chemistry, Govt. RR (PG) College, Alwar 301001, India

Priyanka Gupta
Department of Chemistry, Govt. RR (PG) College, Alwar 301001, India

Madhu Sharma
Govt. G.D. College for Women, Alwar 301001, India

ABSTRACT *Magnesium oxychloride cement (MOC) is one of the most superior building materials. It 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. Dolomite is used as inert filler in present study. The influence of inert filler (dolomite) on cementing properties (standard consistency, setting time, moisture ingress compressive strength and soundness) of magnesium oxychloride cement has been investigated. The standard consistency, moisture ingress, compressive strength and soundness get reduced but more setting time is recorded on increasing amount of inert filler.*

1. Introduction

Magnesium oxychloride cement was discovered by S.T. Sorel in 1867. It is also known as Sorel cements {1}. It is a type of non-hydraulic cement formed by mixing powdered magnesium oxide with a concentrated solution of magnesium chloride (MgCl2.6H2O). 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; $2Mg(OH)_2.MgCl2.4H_2O$ (phase 2), $3Mg(OH)_2.MgCl_2.8H_2O$ (phase 3), $5Mg(OH)_2.MgCl_2.8H_2O$ (phase 5) and $9Mg(OH)_2.MgCl_2.5H_2O$ (phase 9) {13-16}.

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 influence of inert filler on cementing properties (standard consistency, setting times, compressive strength and soundness) of MOC has been investigated. MOC cement composition was prepared by mixing magnesia and inert filler (dolomite) in the ratio of 1:0, 1:1, 1:2 & 1:3 dry-mix, gauged with 24°Be concentration of magnesium chloride solution for the determination of cementing properties 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	SiO2	CaO	Fe2O3	Al2O3	L O I
71.80%	10.18%	6.72%	0.19%	0.75%	9.82%

Magnesium Chloride (MgCl2.6H20): Magnesium chloride (MgCl2.6H20) 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

CaCO3 - 55.50% ; MgCO3 - 42.21%

SiO2	CaO	MgO	Fe2O3	Al2O3	L O I
0.75 %	31.08 %	20.10 %	0.85 %	0.22 %	46.50%

Preparation of Magnesium Chloride Solution: Magnesium chloride solution was prepared in water. Flakes of magnesium chloride were transferred into plastic containers to which potable water was added to prepare desired concentration solution. This solution was allowed to stand overnight so that insoluble impurities settle at the bottom. The supernatant solution was taken out in other plastic containers and well stirred. Concentration of the solution is expressed in terms of specific gravity on Baume scale (°Be). In the present study 24°Be concentration of magnesium chloride solution was used.

Preparation of Dry-Mix Composition: Dry-mixes were prepared by mixing different amount of lightly calcined magne-

Volume : 3 | Issue : 10 | Oct 2013 | ISSN - 2249-555X

site (magnesia) and dolomite (inert filler) in the ratio of 1:0, 1:1, 1:2 & 1:3 by their weight.

3. Experimental

Influence of inert filler on cementing properties has been studied for 1:0, 1:1, 1:2 & 1:3 dry-mix composition of MOC at 30°C of magnesium chloride solution. Following investigations have been carried out during the experimental works.

3.1 Determination of Standard Consistency and Setting Times

Wet-mixes were prepared by gauging 24oBe concentration of magnesium chloride solution with different dry-mix composition (1:0, 1:1, 1:2 & 1:3 dry-mixes). The standard consistency, initial setting and final setting times were determined as per IS 10132-1982 using Vicat apparatus {21-23} for each dry-mix composition. The observed results for standard consistency and setting time are summarized in the table 1.

Table.1 Influence of inert filler on standard consistency and setting time of Magnesium oxychloride cement

Temperature of MgCl2 solution - 30°C Concentration of MgCl2 solution- 24°Be Humidity- 85 ± 5 %

S.No.	Dry-mix composition	Volume of MgCl2 solution (ml)	Setting time in Minutes	
			Ist	Fst
1.	1:0	110.5	48	160
2.	1:1	83	67	247
3.	1:2	72.5	85	400
4.	1:3	66	100	440

3.2 Determination of Moisture Ingress Test (Steam Tests)

Standard blocks prepared for standard consistency and setting time were used to find the influence of inert filler on moisture ingress of magnesium oxychloride cement. These blocks were subjected to steam tests after one month's curing under identical condition to determine their moisture resisting efficiency according to the standard procedure {24-26}. The obtained results are shown in table 2.

Table.2 Influence of inert filler on moisture ingress of magnesium oxychloride cement

Temperature of MgCl2 solution - 30°C Concentration of MgCl2 solution- 24°Be Humidity- 85 ± 5 %

S. No.	Dry-mix composition	Observation					
		2hr	4hr	6hr	8hr	10hr	12hr
1.	1:0	NC	NC	NC	NC	PC	C
2.	1:1	NC	NC	NC	PC	C	-
3.	1:2	NC	NC	PC	PC	C	-
4.	1:3	NC	NC	PC	C	-	-

3.3 Determination of Soundness (Lechateier's Test)

Lechatelier's test was conducted to find out the influence of inert filler on soundness of the experimental product. Less is the expansion, great is the soundness. Tests were conducted as per standard procedure {24, 27}. Observed findings are summarized in the table 3.

Table: 3 Influence of inert filler on soundness of Magnesium oxychloride cement (Lechatelier's test)

Temperature of MgCl2 solution - 30°C Concentration of MgCl2 solution- 24°Be Humidity- 85 ± 5 %

S. No.	Observations	Dry-mixes compositions			
		1:0	1:1	1:2	1:3
1.	Weight of cement composition (g)	42	42	42	42
	i. Magnesia	42	21	14	10.5
	ii.Dolomite	-	21	28	31.5
2.	Amount of MgCl2 solution (in ml)	21.9	16.5	15.4	14.5
3.	Distance between two Pointers before starting (in mm)	7	9	7	9
4.	Distance between two Pointers after 7 days before boiling (in mm)	11	11	12	13
5.	Distance between two Pointers after boiling (in mm)	12	13	15.1	18
6.	Expansion of cement (in mm)	1.0	2.0	3.1	5.0

3.4 Determination of Compressive Strength

The effect of inert filler on compressive strength of the product was studied with the help of standard 70.6 mm3 cubes, prepared for the I.S. consistency paste for various dry-mixes compositions of MOC. These cubes were allowed to be cured under identical conditions for one month and then subjected to compressions just sufficient for their rupture {21, 28-29}. Experimental findings are recorded in the table 4.

Table.4 Influence of inert filler on compressive strength of Magnesium oxychloride cement

Temperature of MgCl2 solution - 30°C Concentration of MgCl2 solution- 24°Be Humidity- 85 ± 5 %

S.No.	Dry-mix composition	Compressive strength (in MPa)
1.	1:0	60.180
2.	1:1	58.174
3.	1:2	52.156
4.	1:3	48.144

4. Result and Discussion

Table 1 shows the amount of MgCl2.6H2O solution, required for Indian Standard (IS) consistency to gauge the dry-mix compositions and setting times of MOC paste. The amount of MgCl2 solution for standard consistency for different dry-mix compositions (1:0, 1:1, 1:2 & 1:3) is found to decrease almost uniformly. This is because of increasing inert filler contents which do not take part in any chemical reaction. Dolomite used as inert filler in this study, is a double carbonate of magnesium and calcium which convert in their oxides during exothermic reaction and retard the evolution of heat. Further, heat contents of reaction are also supposed to decrease with decreasing magnesia contents in the dry-mix. Combined effects of two factors (inert filler contents & amount of heat evolved) are thus responsible for the observed trends.

From the table 1, it is also clear that more setting time is recorded with increasing ratio of dolomite in dry-mixes from 1:0 to 1:3. This can be explicable by nature of dolomite which retard the liberation of heat (exothermicity). These increasing trends for setting time of different dry-mix compositions may be explained with the help of the property of crystalline phases present in the cement paste for varying compositions. It is important to note that coupled effect of increasing in inert filler contents and decreasing rates of evolution of heat makes the setting processes slower. Hence, increasing trends in both setting time is observed.

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

Investigation pertaining to the influence of inert filler on moisture ingress of MOC cement blocks is recorded in the table 2. Dolomite has great effect on the moisture ingress of MOC. Table 2 reveals that moisture resisting efficiency decrease with increasing amount of inert filler. This is due to presence of more dolomite in the matrix which converts in their oxides during exothermic reaction. These uncombined magnesia and active lime in the block matrix is responsible for poor moisture resisting efficiency.

Table 3 shows the influence of inert filler on soundness of MOC. The result reveals that soundness decreases with increasing amount of inert filler. MOC prepared with 1:0 dry-mix composition has more soundness. But in case of dry-mix compositions having dolomite as filler, soundness get

Volume : 3 | Issue : 10 | Oct 2013 | ISSN - 2249-555X

reduced than 1:0 dry-mixes composition due to increasing chance of remaining active lime and unreacted magnesium oxide content in the matrix. Expansion in the volume of trial blocks is expected on account of the increasing chance of remaining active lime and unreacted magnesia in the matrix as ratio of inert filler increase in dry-mix compositions. These unused contents get hydrated during soundness test and form their hydroxide expansively. Thus under humid conditions positive volume changed are quite expected. On boiling the trial blocks active lime and magnesia changes in their hydroxide form. Accordingly, significant volume changes are noticed.

$Ca/MgCO_3$ $\quad$ $CaO / MgO + CO_2$
$MgO/CaO + H_2O$ $\quad$ $Mg(OH)_2/Ca(OH)_2$

Influence of inert filler on the compressive strength of MOC trial blocks are reported in the table 4. The data show that as proportion of the fillers is increased from 1:1 to 1:3 dry-mix compositions compressive strength gets reduced accordingly. Dry-mix 1:0 moulds have highest compressive strength (60.180 MPa) and the moulds of 1:3 dry-mix compositions have lowest strength (48.144 MPa) results. This is due to fact that only magnesia is present in the dry-mix matrix (1:0) to react with gauging solution which forms the strength giving composition (MgO.MgCl2.8H2O). But in case of other composition, amount of magnesia content is reduced and dolomite powder is used as filler with magnesia. Dolomite is double carbonate of calcium and magnesium. During the preparation of wet-mixes, calcium carbonate decomposes in lime and released CO2. Thus, compressive strength of moulds is reduced as filler ratio increases in the dry-mixes of MOC accordingly.

5. Conclusions

1. The cementing characteristics (strength, moisture resisting efficiency, durability and bonding characteristics) of magnesium oxychloride cement decreases with increasing amount of inert filler in the dry-mixes compositions.
2. Magnesium oxychloride cement prepared with 1:1dry-mix composition show good cementing characteristics.

6. Acknowledgement

Authors are thankful to UGC, New Delhi for financial supports under major project [F. No. 40-41/2011(SR)]. We are also grateful to the Principal Prof. Radheyshyam Meena for proving laboratory facilities in the institution.

REFERENCE [1] S.T. Sorel, (1867) sur un nouveau ciment magnésien, Comptes Rendus Hebdomadaires, 65:102-104. | [2] J. J. Beaudoin & V.S. Ramachandran, (1975) Strength development in magnesium oxychloride and other cements, Cem Concer Res, 5(6): 617-630. | [3] J. J. Beaudoin, V.S. Ramachandran & R.F. Feldman, (1977) Impregnation of magnesium oxychloride cement with Sulfur, Am Ceram Soc Bull, 56 424-427. | [4] B. Matkovic, S. Popvic, V. Rogic and T. Zunic, (1977) The Mechanism of the Hydration of Magnium Oxide, J Am. ceram. Soc. Bull, 60(11-12):504-507. | [5] M.P.S. Chandrawat & R.N. Yadav, (2000) Effect of Aluminum Phosphate as admixture on Oxychloride cement, Bull Mater Sci, 23:69-72. | [6] J. Bensted, P. Barnes, (2002) Structure and performance of cements, second ed., Spon Press, London. | [8] Z. Li, F. Qiaz & C.K. Chau, (2010) Recent Development of Magnesium-Based Cements - Magnesium Phosphate Cement and Magnesium Oxychloride Cement, Advances in Science and Technology, 69:21-30. | [9] K. Schollbach, H. Pöllmann, 13th International Congress on the Chemistry of Cement, Madrid, 3-8 July 2011. | [10] M.A. Shand, 2006The Chemistry and Technology of Magnesia , Wiley-Interscience, New Jersey. | [11] L.J. Vandeperre, M. Liska & Al-Tabbaa, (2008) Performance of magnesia cements in pressed masonry units with natural aggregates: Production parameters optimization, Constr. & Build. Mater. 22:1789-1797. | [12] L. Urwongse & C.A.Sorrell, (1980) Phase Relations in Magnesium Oxysulfate Cements, Journal of the American Ceramic Society, 63(9-10): 523-526. | [13] D.S. Hubbell, (1937) A New Inorganic Cement and Adhesive, Ind Eng Chem., 29:123–132. | [14] C.A. Sorrell & C.R. Armstrong, (1976) Reactions and Equilibria in Magnesium oxychloride cement, Journal of the American Ceramic Society, 59(1-2):51-54. | [15] M.S. Özer, A. Göktas, A. Öztürk & M. Timuçin, Production and characterization of Sorel Cement based abrasive bricks for surface polishing of ceramic tiles, SERES 2007 International Ceramic and Glaze Symposium 2007. | [16] Zongjin Li. & C.K. Chau, (2007) Influence of molar ratios on properties of magnesium oxychloride cement, Cement and Concrete Research, 37(6): 866-870. | [17] Z. Chuanmei & D. Dehua, (1995) Research on the water resistance of magnesium oxychloride cement and its improvement, J. South China Univ., 23(6) :673-679. | [18] V.M. Sglavo, et. al., (2011) Influence of curing temperature on the evolution of magnesium oxychloride cement, J. Materials Science, 46(20):6726-6733. | [19] C.K. Chau, J. Chan & Z. Li, (2009) Influences of fly ash on magnesium oxychloride mortar, Cement and Concrete Composites, 31(4):250-254. | [20] M.P.S. Chandrawat, R.N. Yadav, Priyanka Gupta & N.K. Dagar, (2011) Impact Of Sodium Silicate As An Additive On The Properties Of Magnesium Oxychloride Cement (MOC), Int J Chem Sci, 9(2):581-588. | [21] Indian Standard Institution (1982) Method of test for materials for use in the preparation of magnesium oxychloride flooring composition, IS: 10132. | [22] Y.K. Gupta, M.P.S. Chandrawat & R.N. Yadav, (1990) Effect of glycerolin setting, strength and moisture resistance of oxychloride cement (Sorel's cement), Res. and Ind., 35: 191 | [23] M.P.S. Chandrawat & R.N. Yadav, (2001) Effect of bitumen emulsion on setting, strength, soundness and moisture resistance of oxychloride cement, Bull. Mater. Sci., 24:313. | [24] B.L. Gupta, Concrete technology, Standard Publisher, New Delhi 1976, pp.18. | [25] M.P.S. Chandrawat, R.N. Yadav & R. Mathur, (1994) Effect of disodiumhydrogen phosphate on some properties of magnesia cement, Res. and Ind., 39:18-21. | [26] Y.K. Gupta, M.P.S. Chandrawat & R.N. Yadav, (1994) Effect of magnesium sulphate in setting, strength & moisture resistance of oxychloride cement, Proc. NASIA 64(A)II :199-204. | [27] M.P.S. Chandrawat (1976) Technical Problems in oxychloride Mill Stone, Industries in India, their solution and specifications for good quality products, Ph.D. Thesis, University of Rajasthan, Jaipur, Rajasthan. | [28] ASTM (2008) -Designation C109 / C109M: Standard test method for compressive strength of hydraulic cement mortars (Using 2-in. or [50-mm] cube specimens. V. 04.01, USA. | [29] C. James, The Development of Magnesium Oxychloride Cement As Reparing Materials, M.Phil. Thesis, University of Science and Technology, Hong Kong, 2006. |