Effect of Xanthan Gum and Sodium Silicate Admixture on Setting Time, Moisture Resistance, and Compressive Strength of Magnesium Oxychloride

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Abstract:

The construction sector is responsible for the majority of global development. Cement is an essential component of all construction materials. In 1867, Frenchman Stanislas Sorel discovered magnesium oxychloride cement (MOC). It has several advantages over ordinary Portland cement, such as high strength, great bonding, and a rapid setting time. It does not require any type of energy, such as heat or light for its preparation. It does not require humid curing. It's a durable, stone-like, fireproof material. Poor water resistance is the fundamental downside of MOC, which limits its large-scale industrial application. In this research work, xanthan gum and Sodium silicate admixture are added to the cementing formula in various amounts to improve the compressive strength, water resistance, and bonding qualities of MOC. Xanthan gum and Sodium silicate are added to the cementing mixture at various percentages, including 0.5%, 1.0%, 1.5%, and 2.0%. This admixture effect on MOC is increased compressive strength, and water resistance. It was found that a 0.5% of admixture of xanthan gum and Sodium silicate produces superior outcomes.

Keyword: Compressive strength, Magnesium oxychloride, Setting time, Sodium silicate, Water resistance, Xanthan gum etc.

Introduction

Binder material refers to compounds that harden and bond with other solid materials, providing cohesion and adaptability to the system. Binders can agglomerate or combine solids on their contact surfaces. This term refers to many construction materials with unique qualities, applications, and economic significance (1). Chemical binders, whether liquid or solid, organic or inorganic, can operate as a filler, bridge, or catalyst for chemical reactions (2). Chemical binders form a robust agglomeration that can resist storage, handling, packaging, and shipment. Binding behaviour is caused by polymerization or interlocking crystals.

Stanislas Sorel, a Frenchman, discovered magnesium oxychloride (MOC) cement, sometimes known as Sorel's cement, in 1867. Magnesium oxychloride cement is becoming a popular alternative binder due to its excellent characteristics. Magnesium oxychloride is created by mildly calcining magnesium oxide with a concentrated solution of magnesium chloride. The exothermic process produces heat, causing fissures in the cement, reducing its strength, moisture resistance, and making the product unsound. To address this issue, an inert filler is included in the matrix.

The inert filler absorbs heat by a three-body collision process, rather than participating in the cementing reaction. In this study, dolomite powder was employed as an inert filler to decrease thermal shocks in cement.

Magnesium oxychloride has multiple benefits over ordinary Portland cement(OPC), including light weight, high strength, quick hardening, low thermal conductivity, excellent fire-proofing, wear resistance, mechanical strength, volume stability, and high cohesiveness in lightweight panels. Magnesia cement is known for its hardness, high bonding, short setting time, humidity-free curing, and compatibility with many materials. MOC manufacture emits less CO_2 than OPC manufacturing. After manufacture, it absorbs CO_2 from the environment and emits no heat, making it an excellent alternative to OPC.

The MOC cement in $MgO\text{-}MgCl_2\text{-}H_2O$ ternary systems is formed through a reaction between reactive magnesia and magnesium chloride solution9. The reaction yields the following hydration products: 5 $Mg(OH)_2$. $MgCl_2.8H_2O$ [phase 5]; 3 $Mg(OH)_2$. $MgCl_2.8H_2O$ (phase 3), 2 $Mg(OH)_2$. $MgCl_2.8H_2O$ [phase 2], $9Mg(OH)_2 \bullet MgCl_2 \bullet H_2O$ (phase 9). At ambient temperature, phases 5 and 3 are prevalent. The hydrate phase composition is mostly determined by the $MgO/MgCl_2$ molar ratio.

Formation reactions of some main phases in MOC :

$$5MgO + MgCl_2 + 13H_2O \longrightarrow 5Mg(OH)_2.MgCl_2.8H_2O$$

$$5Mgo + MgCl_2 + 12H_2O \longrightarrow 5Mg(OH)_2.MgCl_2.7H_2O$$

$$MgO + MgCl_2.6H_2O \longrightarrow 3Mg(OH)_2.MgCl_2.8H_2O$$

Dolomite powder was employed as an inert filler in this study since it is inexpensive and readily available. MOC has two major drawbacks: low early strength and poor water resistance, which limit its economic application in construction. Many researches have worked in the topic of MOC to improve its features. Some examples are as follows:

Y Guo et al. investigated the production of magnesium oxychloride cement with improved water resistance by incorporating silica fume and a hybrid fly ash-silica fume. Y. Guo et al. investigated the effects of sodium monofluorophosphate (MFP) and phosphates on the mechanical characteristics and water resistance of magnesium oxychloride cement. A. Pivak et al. examined magnesium oxychloride cement composites including silica filler and coal fly ash (FA). T Huang et al. studied the effect of phosphoric acid on the strength of Magnesium oxychloride cement pastes with high molar ratios of $H_2O/MgCl_2$. X Luo et al. investigated the influence of hydroxy acetic acid (HA) on the water resistance of magnesium oxychloride cement.

In this study, Na_2SiO_3 and xanthan gum were utilized to improve the properties of MOC, and to develop a novel building material with improved performance that can be extensively applied.

Materials & method

The study's raw materials included mildly calcined Magnesite (Magnesia), technical grade magnesium chloride, and dolomite powder (inert filler).

- **Magnesium oxide (MgO):** Commercial grade Magnesia used in the study was of Salem origin, and the chemical composition of MgO is: MgO = 84.70%, SiO_2 = 8.53%, CaO = 3.19%, Fe_2O_3 0.22%, Al_2O_3 = 0.07%, Loss on Ignition (LOI) = 4.79%.
- **Magnesium chloride (MgCl2)** : The Magnesium chloride ($MgCl_2.6H_2O$) used was Indian Standard (IS 254-1973) grade 3 with the following characteristics: colourless, crystalline, hygroscopic crystals; highly soluble in water; magnesium chloride minimum 93%; magnesium sulfate, calcium sulfate and alkali chloride content are less than 5.5%.
- **Dolomite($CaCO_3.MgCO_3$)**: Waste material from Dolomite mines (Dolomite dust produced during cutting and shaping etc.) was used as an inert filler. It was collected from Matasya Industrial Area, Alwar, Rajasthan. The chemical composition of Dolomite is: SiO_2 = 4.85%, CaO = 30.42%, MgO =18.60%, Fe_2O_3 = 0.62%, Al_2O_3 = 0.43%, LOI = 45.19%, $CaCO_3$ = 54.08%, $MgCO_3$ = 43.52%, Brightness = 92.00%, Whiteness = 96.35%.
- **Sodium silicate (Na_2SiO_3) & xanthan gum**: Sodium silicate and xanthan gum is collected from the local market of Jaipur, Rajasthan, India

Methods

- **Preparation of gauging solution**: Technical-grade Magnesium chloride was dissolved in lukewarm water to make a saturated solution. This solution is allowed to stand overnight so that insoluble impurities settle down at the bottom of the container. The supernatant-saturated solution is filtered with the help of a vacuum pump. This solution is known as the gauging solution for oxychloride cement. The concentration of the gauging solution is determined in terms of degree on the Baume scale; the higher the concentration, the higher the density of the gauging solution.
- **Preparation of dry-mixes**: Dry-mixes were prepared by mixing lightly calcined Magnesium oxide and Dolomite in the ratio1:1 and a mixture of xanthan gum and Sodium silicate (Xanthan gum : Sodium silicate is 1:1) is used as an additive in 0.5% (XSS1), 1.0% (XSS2), 1.1% (XSS3), 2.0% (XSS4) weight ratio of MgO.

- **Preparation of the wet mix**: Gauging solution was added to the dry mix to form a wet mix of workable consistency.

All trials were carried out under the same temperature (about 30°C) and humidity (over 90%). The following studies were carried out to determine the influence of magnesium chloride concentration and dry-mix composition on the strength and water resistance of magnesium oxychloride cement. Each experimental method was performed in triplicate, and the average is provided.

Result & discussion

Fig. 1-3, summarise the effect of additive composition on the cementing characteristics (compressive strength setting time, moisture ingress resistance, and) of magnesium oxychloride cement.

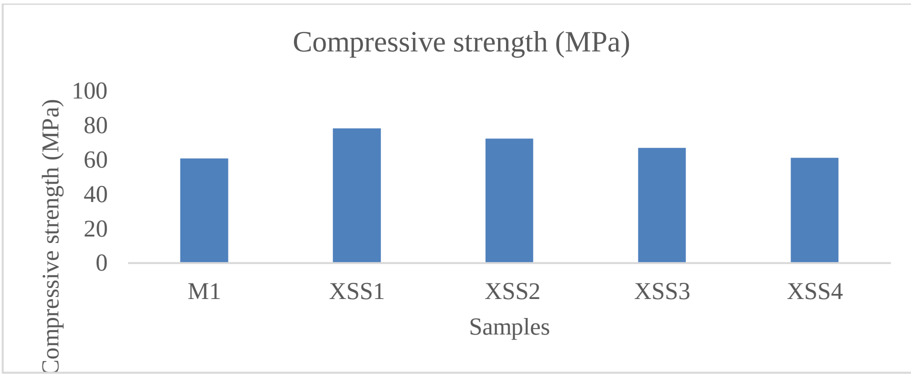

Fig. – 1 Compressive strength of reference sample and modified Magnesium oxychloride cement samples.

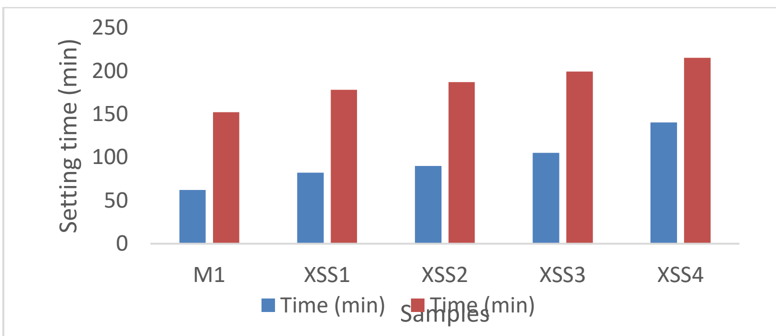

Fig. - 2 Effect of additive on setting properties of different Magnesium oxychloride samples

Fig. 3 - Effect of additive on moisture resistance property of Magnesium oxychloride cement.

Table 1 - Effect of Xanthan gum and Sodium silicate on water resistance property of Magnesium oxychloride cement

Sample	Amount of additive (Sodium silicate and xanthan gum) (%)	Dry-mix composition (MgO: Dolomite)	Trial blocks were kept in boiling water for					
			0-5 hrs.	5-10 hrs.	10-15 hrs.	15-20 hrs.	20-25 hrs.	25-30 hrs.
M1	0	1:1	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
XSS1	0.5	1:1	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
XSS2	1.0	1:1	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
XSS3	1.5	1:1	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
XSS4	2.0	1:1	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.

Fig. 1 represents the compressive strength of different compositions of Magnesia cement (with reference to varying concentrations of additive). After 28 days of air curing, the strength of various MOC samples was measured. M1 samples had the lowest strength, while the XSS1 cementing composition had the highest compressive strength. Xanthan gum, a natural polysaccharide polymer with strong hydrogen bonding properties, reacted with MOC and formed interlacing/crossing crystals and gelatinous structure. There is also H-bonding between xanthan gum and MOC, and Sodium silicate also increases the strength of Phase-5, which having 3-D network structure these factor responsible for the improvement in compressive strength of cement blocks. However, an excess quantity is not useful in terms of increasing MOC strength.

Fig. 2 depicts the initial and eventual setting times of several types of MOCs. The reaction between MgO and the gauging solution $MgCl_2$ is exothermic. This heat is also responsible for the quick setting of concrete blocks. In these results, some of the heat absorbed by dolomite which is responsible for increasing setting time, and the additives xanthan gum and Sodium silicate produce a gel-like amorphous phase which also takes time in setting, so after adding additive setting time (both initial and final) increases.

Fig. 3 shows the results of water resistance. After adding additives water resistance of MOC increases because Sodium silicate forms chemical bonds with MOC to prevent phase 5 hydrolysis and enhance moisture ingress resistance xanthan gum make interlocking with MOC so pore size decrease effect of this interlocking water molecules does not penetrate.

Conclusion

- Effect of additive on MOC shows all results are positive, It was found that a 0.5% admixture of xanthan gum and Sodium silicate produces better results.
- Setting-time investigations reveal that minimum setting time is observed for the XSS4 sample.
- Water resistance investigation reveals the additive increases the water resistance of MOC because Sodium silicate forms chemical bonds with MOC and Sodium silicate has a bulky structure that repels water molecules.
- Compressive strength of MOC increases because both xanthan gum and Sodium silicate form an amorphous structure.

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