International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 3, No. 2, April, 2014

Research Paper

EFFECTS ON SETTING, STRENGTH AND WATER RESISTANCE OF SOREL CEMENT ON MIXING FLY ASH AS AN ADDITIVE

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Magnesium oxychloride cement (MOC, Magnesia / Sorel's Cement), discovered by Sorel S.T. in 1867 and has versatile cementing characteristics. It is prepared by the reaction of magnesium chloride with magnesia in aqueous solution. Various fillers are used as to improve the setting time, compressive strength, water tightness of oxychloride cement. Additives play an important role to modify the properties of Sorel's cement. In this work we have used fly ash along with magnesium oxychloride (MOC) cement, an energy efficient and environmentally friendly cementitous material which can be used for civil, structural and industrial applications. We have found that the compressive strength of Sorel's cement increases with the increase in quantities of the additive (20%, 40%,60%). It is also found that the incorporation of fly ash improves the water resistance, decreases the workability or fluidity, retard the setting time of the final cement.

Keywords: Compressive strength, Fly ash, Magnesium oxychloride cement, Setting time, Water resistance

INTRODUCTION

Magnesium oxychloride (MOC) cement was developed shortly after the invention of Portland cement, as a magnesia-based cementing material that sets in air curing when compared to portland cement which requires water for curing (Brady G S,2002 and Sorel S T). With a through solution reaction at ambient temperature, the MOC system is a typical ternary system with magnesium oxide, magnesium chloride and water the three major reaction components. The two main chemical composition phases produced in the ternary system are 3Mg(OH)2. MgCl2. 8H2O (phase 3) and 5Mg(OH)2. MgCl2. 8H2O (phase 5). The well crystallized needle-like structure of phase 5 of chemically bonded MOC has been described as scroll-tubular whiskers. The mechanical interlocking and unique fibrous microstructure resulting from the intergrowth of the crystals is a major source for the strength development of MOC cement. Therefore, the physical properties of MOC

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cement depend largely on the phases formation and subsequently on the appropriate proportions of the starting materials.

It is well known that MOC cement has many properties superior to the ordinary Portland cement (Y Karimi & A Monshi, 2012; Z Juhasz, 1977). Because of its elastic and acoustic properties, and attractive marble-like appearance which comes from the use of different fillers, MOC cement is used for rendering wall insulation panels, interior plasters and exterior stuccos, and decorative panels. Some other commercial and industrial applications of MOC cement are industrial flooring, fire protection, grinding wheels and light weight concrete. The excellent performance of MOC cement including rapid setting and hardening, good resistance to abrasion and chemicals, as well as remarkable bonding ability to large amounts of different inert fillers makes it an attractive candidate of binding materials for repair mortar.

Moreover, MOC cement draws much research interests recently due to the energy saving consideration as it can be used as a Portland cement replacement on many occasions. The production of light burnt MgO used in MOC requires a much lower calcinations temperature compared to that for Portland cement, thus reducing vast amount of energy consumption and favorite for the sustainable development of the building industry. Besides, generated during the combustion of coal for energy production, fly ash is one of the major industrial by-products and being utilized in the construction industry for decades. By incorporation of fly ash into MOC cement, an energy saving and environmentally friendly construction material can be formed for industrial applications[5]. In addition, water resistance of MOC system is a key issue in the research before MOC related products could be utilized in the industry. To that end, the effects of the fly ash on MOC cement including flow property, setting time, strength development, water resistance have been investigated.

RAW MATERIALS

A. Magnesium oxide

Magnesium oxide is used in this study was obtained from TANMAG, Salem that was produced by the calcination of magnesium carbonate . It is produced by sintering raw magnesite shaft kiln at a controlled temperature around 1000 C by using furnace oil. The chemical analysis of the magnesium oxide is given below.

Table 1: Chemical Composition of the Magnesium Oxide

Ingredients	Percentage (%)
Magnesium Oxide	87
Calcium Oxide	1.5
Ferric oxide	0.2
Silica	8.5
Alumina	0.25
Loss on Ignition	2.5

B. Magnesium Chloride

Magnesium chloride is the name for the chemical compounds with the formulas MgCl2 and its various hydrates MgCl2 (H2O)x. These salts are typical ionic halides, being highly soluble in water. The hydrated magnesium chloride can be extracted from brine or sea water. Mixed with hydrated magnesium oxide, magnesium chloride forms hard material called Sorel cement.

C. Fly Ash

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash.

Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite). (Ying Li *et al*. 2013).

1. Class F fly ash

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 5% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds.

Table 2: Class F Fly Ash Chemical Composition

Property	ASTM C618 Requirements %
SiO_2 + Al_2O_3 + Fe_2O_3, min	70
SO_3, max	5
Moisture content, max	3
Loss on Ignition, max	6

2. Class C fly ash

Class C fly ash is produced from the burning of lignite or sub bituminous coal. In addition to having pozzolanic properties, it also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO4) contents are generally higher in Class C fly ashes.

Table 3: Class C Fly Ash Chemical Composition

Property	Requirements (ASTM C618), %
SiO_2 + Al_2O_3 + Fe_2O_3, min	50
SO_3, max	5
Moisture content, max	3
Loss on Ignition, max	6

Table 4: List of Proportion (by Weight %)

SAMPLE NAME	MgO	MgCl2	Fly ash
F1	40%	40%	20% (class F)
F2	30%	30%	40% (class F)
F3	20%	20%	60% (class F)
C1	40%	40%	20% (class C)
C2	30%	30%	40% (class C)
C3	20%	20%	60% (class C)

EXPERIMENTAL PROCEDURE

Magnesium oxychloride cement is prepared by mixing the raw materials, magnesia (MgO) of Salem origin, Magnesium chloride and Fly Ash (as an inert filler). To study the effects of admixing fly ash as an additive, following tests have been carried out by taking fly ash in different proportions in the dry mix on some properties of magnesium Oxychloride cement. All experiments were carried out according to IS specifications (Indian Standard et al. (1982; 1977; 1760; 1982).

In order to study the effect of fly ash on the strength and water resistance 70 mm X 70 mm cubes were casted by mixing preweighed amount of magnesium chloride in water and this solution was mixed with preweighed amount of magnesia and fly ash. This dry powder was mixed with solution for about 3 minutes until a smooth pourable slurry was formed and poured into cubes for measuring the compressive strength and water resistance. Nine cubes were casted for each composition. The cubes were taken out and kept at room temperature for further curing. After one week of air curing one cube in each composition was taken and weighed and immersed in preweighed amount of water. The results of compressive strength, setting time and water resistance are discussed below.

RESULTS AND DISCUSSION

A. Compressive Strength

From the table it can be seen that the compressive strength increases steadily with age which is typical with all the cementitous materials. It can also noted that the strength increases as the fly ash loading increases which is a very good from the sustainability point of view because one will be able to use more amount of fly ash which will be otherwise land filled. From the table it can be seen that the loading of fly ash can be as high as 60% and still attains strength of 43 Mpa which is not at all possible with Portland cement. The industry practice has been 25% loading of fly ash in Portland cement. The strength development of the Oxychloride cement remains independent on the type of fly ash used as filler.

Table 5: Effect of Fly Ash on Compressive Strength of Oxycholride Cement

Compression Strength N/mm^2			
Class F	**1st day**	**3rd day**	**27th day**
F1	11.19	15.44	18.63
F2	21.73	26.59	30.09
F3	27.82	34.19	42.38

Chart 1: Comparison of Fly Ash on Compressive Strength

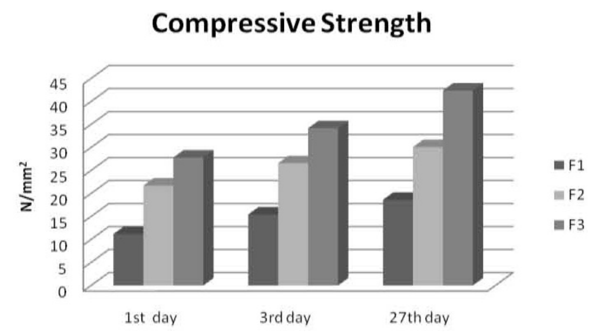
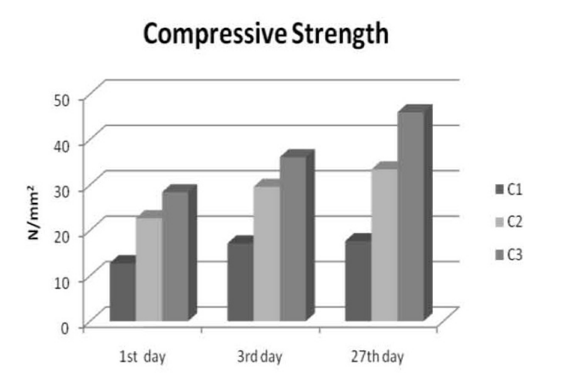


Table 6: Effect of Fly Ash on Compressive Strength of Oxycholride

Compression Strength N/mm^2			
Class F	**1st day**	**3rd day**	**27th day**
C1	12.75	17.12	17.62
C2	22.66	29.58	33.40
C3	28.38	36.11	45.99

Chart 2: Comparison of Fly Ash on Compressive Strength



B. Setting Time

The effect of fly ash on setting characteristics of magnesium oxychloride cement was studied by admixing the additive in the dry mix in varying proportions. The dry mix was mixed with predetermined amount of water until a smooth slurry is formed and tested for Initial and Final setting time. From the table it can be seen that the setting time increases with increasing amount of fly ash. The initial and final setting time can be controlled by using various proportions of fly ash

Table 7: Effect of Fly Ash on Setting Time of Oxycholride Cement

Setting Time	Initial (min)	Final (min)
F1	120	320
F2	130	360
F3	150	400
C1	115	310
C2	120	355
C3	140	405

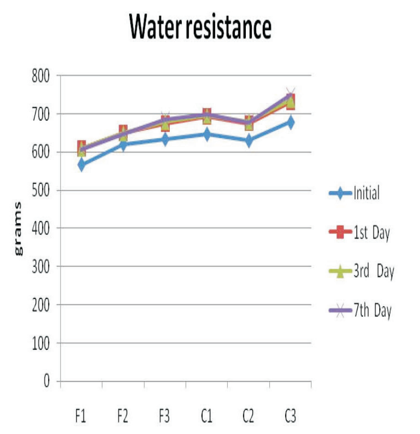
C. Water Resistance

The result of the water soaking tests as plotted in chart 3 exhibits that the water resistance of the MOC would be dramatically boosted when appropriate amount of fly ash is utilized. From the table it can be seen that for class F samples the weight of the cube increases initially and then decreases, but for class C1 sample the weight goes on increasing. The sample C2 broke due to expansion. This shows that there is a clear interaction between the binding phase of cement and oxides in fly ash which needs to be analysed further.

Table 8: Effect of Fly Ash on Water Resistance of Oxycholride Cement

	Water resistance (grams)			
Proportion	Initial	1st Day	3rd Day	7th Day
F1	566.5	609.5	608.5	607.5
F2	620.5	650.0	649.0	648.5
F3	634.0	675.0	678.0	685.0
C1	647.0	693.5	695.0	697.0
C2	630.0	675.5	678.5	678.0
C3	678.5	731.5	736.0	749.0

Chart 3: Comparison of Fly Ash on Water Resistance



CONCLUSION

The influences of class C and class F fly ash on the properties of MOC cement are investigated in this study. By incorporating fly ash up to 60% by weight, the workability or fluidity is enhanced, the setting time retarded, and more importantly the water resistance improved and the compressive strength is increased. The improvement of water resistance of the MOC incorporated with a fly ash may be attributed to the interaction between the binding phases of cement and the oxides in the fly ash which needs to be analysed further.

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