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A Study on Compressive Strength and Micro Structural Properties of Magnesium Oxychloride Cement Concrete Under Varying Temperatures of Magnesium Oxide

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Abstract: Construction is a huge consumer of natural resources and a considerable contribution in terms of CO_2 emissions. Manufacturing cement and construction materials was shown t be source of the most greenhouse gas emissions. This study looks at whether magnesium oxychloride cement (MOC) may be used as a concrete alternative to standard Portland cement to lessen the environmental effect of the building sector. The research process involves a thorough review of the literature, an experimental investigation, and an internal structural analysis based on the optimal molar ratio. In this investigation, MOC cement concrete was mixed with magnesium powder at varied temperatures. The use of heated magnesium oxide powder produces the first set of results.

Finally, a change was made to increase compressive strength of MOC cement concrete. To stimulate the reaction or gel formation, heat was applied to MgO powder at various temperatures and added to the manufacturing of MOC cement to improve the compressive strength. The molar ratio is chosen from the journal for optimum mixing and simple casting of concrete cubes. SEM and EDAX are utilized to analyze the microstructure of the various raised temperature samples. The MgO, phases 3 and 5, are apparent as double and triple ribbons with shared boundaries with water molecules and chloride anions in the SEM images, showing that the strength has increased due to these phases. EDAX shows the proportion of elemental weight in the sample.

Keywords: Magnesium Oxide (MgO), OPC, MOC, Molarity, Compressive strength. Magnesium chloride ($MgCl_2$), SEM, and EDAX.

I. INTRODUCTION

A. General

Since the 1800s, plain Portland cement concrete has been widely used. According to study, each tonne of cement required releases around 0.9 tonne of CO2 into the environment, both directly during decomposition and indirectly as a result of the energy required during manufacturing. Currently, cement is estimated to contribute between 5% and 8% of worldwide CO2 emissions; 4.2 billion tonnes are produced each year, with a 2.5% annual increase rate.

Figure 1.1: CO_2 emission from factory

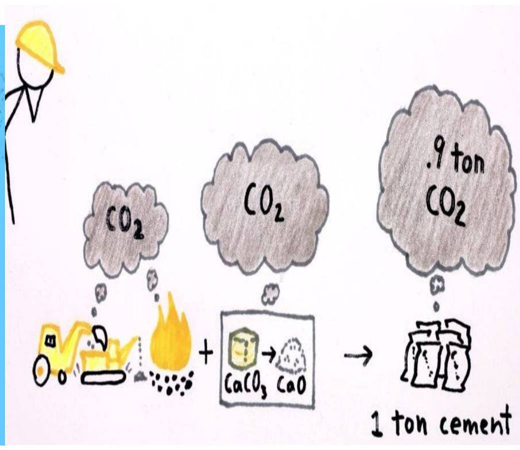

Figure 1.2: CO_2 emission from construction

To lower the carbon impact of ordinary Portland cement (OPC). Concurrently, byproducts of other industries such as flyash, silica fumes, magnesium oxide, and magnesium chloride have been employed as admixtures to replace the CO_2-free cement component. Strength is one of the advantages that arise. However, the presence of cement is required for the cementitious matrices to react and produce the binding material in concrete. Magnesium oxychloride is used to "activate" the unaccompanied cementitious matrix and restrict the cement's capacity to react.

Table 1.1: Comparing the chemical components of OPC and MOC

Components	MOC percentage (%)	OPC percentage (%)
Magnesium (MgO)	94.37	0.83
Lime (CaO)	1.09	61.85
Silica (SiO_2)	2.95	20.07
Iron oxide (Fe_2O_3)	0.34	4.62
Alumina (Al_2O_3)	0.28	5.32
Sulfuric anhydrate (SO_3)	-	2.50
Chloride content	-	0.0028
Factor of lime saturation	-	0.91
Ratio of alumina / Iron oxide	-	1.18
Ignition loss	0.97	2.7172

OPC chemicals taken as per IS code 12269-1987 recommendations

B. Magnesium Oxychloride

Magnesium oxychloride cement (MOC), one of the low-carbon cement alternatives, has a high probability of replacing Portland cement due to its superior qualities, such as reduced CO2 emissions and lack of sticky drying. Low alkalinity, quick setting time, and great mechanical strength are further qualities that set MOC apart.

Sorel developed magnesium oxychloride (MOC) cement in 1867. It is an air-solidified gel composed of water (H2O), magnesium chloride (MgCl2), and magnesium oxide (MgO) that has been mildly burned.

1) Magnesium chloride ($MgCl_2$) sources and occurrence

For every ton of potassium chloride generated, 8-10 tons of magnesium chloride are produced as a byproduct. The materials were obtained from Sreshtavi Enterprise in Jeedimetla and shipped from Mayuri Chemicals in Gujarat.

2) Magnesium oxide (MgO) sources and occurrence

Dolomite (CaMg(CO3)2) is a valuable calcium and magnesium resource on Earth. Dolomite is a raw material that can be used to make magnesium cement. It was shipped from Tanmag in Tamil Nadu, and I obtained magnesium oxide from Sreshtavi Enterprise in Jeedimetla.

C. Objective of work

The major purpose of this research is to measure the compressive strength of magnesium oxychloride cement concrete for m_{20} grade concrete by altering the temperatures of magnesium powder. Which temperature produces the most strength compared to standard Portland cement, and to examine the interior structure of the cube using SEM and EDAX.

As a result, in order to fulfill the goal, the work was completed in the steps listed below:

1) The molar ratio of MgO: $MgCl_2$:H_2O used in the study determined by Wen Jing et al.(2013).
2) Cubes measuring 150x150x150 mm3 were cast in sufficient quantities during the second phase and allowed to cure outside for 7, 14, and 28 days.
3) During the third stage, the cubes had tested using a compressive testing machine to see if there were any problems or changes that needed to be made, and experimental work was carried out appropriately.
4) If the compressive strength of MOC cement concrete is less than that of OPC cement concrete in the fourth phase, the method is repeated and the temperature is raised until the compressive strength of MOC cement concrete is more than that of OPC cement concrete.

5) Finally, the internal structure of the examined specimen is evaluated for 28 days samples using SEM and EDAX.

D. Organization of Thesis

There are five chapters in the thesis. The present thesis project's aims and parameters are briefly discussed in the first chapter. This includes an introduction to MOC cement concrete, the source of, material origin and extraction, the scope of the current effort, gaps discovered in the literature, and the work's purpose.

The second chapter presents a literature review organized into three divisions, including a review of literature on comprehensive studies and a review of literature on experimental work.

The third chapter outlines the many types of materials utilized, their qualities, and the physical tests performed on the materials to let us handle them with ease. The sequential process for filling gaps detection in the literature review, which includes experimental work done to achieve the study aim, is provided in fourth chapter.

The fifth chapter explains the state of the work done and discusses the outcomes of the experimental work done by performing several physical tests on concrete. In chapter six, microstructure analysis is done to analyze the shape of concrete specimens, damage produced, and factors responsible for the strength of MOC cement concrete using SEM and EDAX methods.

The seventh chapter deals with the paper's concluding results, which provide a thorough summary of the current study based on the experimental work done. The last chapter contains references for drawing the aim and completing the thesis work efficiently.

II. LITERATURE REVIEW

A. Introduction

The research publications on the issue have been classified into three categories: literature on experiment study, literature on experimental work, i.e. thorough studies of MOC cement concrete using SEM and EDAX analysis, and literature on magnesium cement kinds utilizing analysis. Each study is briefly described in the next section.

B. Literature on experimental studies

The first group of literature reviews involves experimental studies conducted by different researchers on the magnesium oxychloride cement in concrete, and its various application and properties have been studied.

A K Misra et al., (2007) The flexural and compressive strengths of magnesium oxychloride (MOC) cement, which is used in concrete projects, were examined in this study. A variety of metrics, including scratch resistance, compressive strength, and flexural strength, were studied for different MOC cement concrete compositions with varying strengths that contribute to good placement and finishing attributes. The study also assessed the MOC concrete compositions' resilience to high temperature variations, freezing and thawing, wetting and drying, and salt deposition. With a compressive-flexural strength range of 6-8, the results showed that MOC concrete has a high flexural-to-compressive strength ratio.

Hongxia Qiao et al., (2014) have presented a comprehensive study on the applications of magnesium oxychloride cement due to its flaws, which include ease of building and poor water resistance, as well as its high strength, light weight, and strong abrasion resistance. But also describes the state of domestic research on magnesium oxychloride cement and its promising future development.

Hao Sun et al., (2018) has investigated the characteristics of magnesium oxychloride cement experimentally. This teaches us the MOC cement is superior to OPC concrete in terms of strength and folding pressure. It also adds an organic solution to provide design and processing guidelines for future MOC cement component design.

C. Literature On Experimental Work

The second group of literature reviews includes experimental work on magnesium oxychloride cement conducted by various researchers. The experimental work was carried out by substituting magnesium oxychloride cement for normal cement and investigating its strength, durability, workability, and mechanical properties.

Chenggong Chang et al., (2018) have presented an experimental study using magnesium slag and hydrochloric acid to prepare magnesium oxychloride cement. The compressive test for MOC cement is performed after 3days, 7days, and 28days. MOC may have a high early strength if its hydrochloric acid content is high. The composition and activity of magnesium slag calcined at various temperatures were investigated using XRD and hydration methods.

Qing Huang et al., (2022) have presented a comprehensive investigation of replacing magnesium sulphate with magnesium chloride in magnesium oxychloride cement. The effects of replacing magnesium sulphate water with magnesium chloride on the setting time, compressive strength, and water resistance of MOC cement.

Prior to replacing magnesium chloride with 5Mg (OH)2.MgCl2.8H2O, the addition of sulphate reduces the magnesium concentration of the water phase by 30%. After replacing with magnesium sulphate, the phase becomes 5Mg (OH)2.MgS O4.7H20. Mixing varying mass fractions of magnesium sulphate solution with MOC resulted in a composite gelling system composed of magnesium thioxide and chlorine. The phase composition and micromorphology of the hydration products in the mixed system of magnesium thioxide and chlorine, which was created by combining various mass fractions of magnesium sulphate solution with MOC, were investigated using XRD and SEM.

Michel Lojka et al., (2021) Composite materials were developed and assessed with additions such as multi-walled carbon nanotubes (MWCNTs) and magnesium oxychloride cement (MOC). The composites containing 0.5 and 1% MWCNTs were compared to pure MOC phase 5 references. Several analytical techniques were employed to determine the phase and chemical composition, morphology, and thermal behaviour of the composites. After 14 days, the composites' fundamental structural properties, pore size distribution, mechanical strength, stiffness, and hygrothermal performance were all evaluated. MWCNT-doped composites have high compactness, higher mechanical resistance, stiffness, and water resistance, all of which are critical for their use in the building industry as well as the future design and development of substitute building materials.

Amal Brichini et al., (2016) Several parameters were tested to see how they affected magnesium oxychloride-containing cement. It has been demonstrated that using experimental design to determine the ideal experimental conditions is extremely advantageous in the development of a superior cement mix. The operational parameters were predicted and optimised based on stirring speed, mixing time, mass ratio of magnesium chloride/magnesium oxide, percentage of silica glass powder (SGP), and SGP partial size. Responses were tested using compressive strength and setting time. Scanning electron microscopy was utilised to assess morphological aspects, x-ray diffractograms to assess MOC phase compositions, and differential thermal analysis of thermogravimetric analysis to analyse phase decomposition. It was demonstrated that using SGP can boost MOC's water resistance by forming forsterite, which can decrease the decomposition of phase 5 and prevent the synthesis of brucite in water.

Milena Pavlikova et al., (2022) The project aims to create lightweight composites with moderate strength and improved thermal performance. The composites' properties were assessed as part of the experimental study, which also included the usage of magnesium oxychloride and increased wood chip ash. Foamed glass was used as a lightweight aggregate to create materials with high porosity and mechanical strength, moderate water absorption, low thermal conductivity, and large heat storage capacity. Wood chip ash was added to the composites to improve mechanical strength and provide construction materials with less negative environmental impact. When environmentally friendly and sustainable construction materials are required, these composites could be an intriguing alternative to Portland cement-based composites.

Chuanlin hu et al., (2015) has examined the phase 5 reaction product's micromechanical characteristics experimentally in the magnesium oxychloride (MOC) cement system. Researchers used scanning electron microscopy methods and nanoindentation to determine that phase 5 (5MgOH2.MgCl2.8H2O) had an average indentation modulus of 32.5 ± 4.2 Gpa and an average hardness of 1.03 ± 0.19 Gpa. The study also found a relationship between the MOC cement paste's elastic modulus on the micro-and micro-scales, which may be used to estimate the material's macroscopic elastic modulus.

Anna-marie lauermannova et al., (2021) Conducted the research on magnesium oxychloride cement, which is environmentally friendly and has good mechanical properties. The diatomite composite is investigated in this work. Three phases were created using various approaches and tested with different quantities of diatomite. Along with structural, mechanical, hydrophilic, and thermal properties, the study investigated phase, chemical composition, morphology, and thermal behaviour. This environmentally friendly material has remarkable mechanical properties, making it suitable for demanding conditions and with exciting application possibilities.

N.Clament Sagaya Selvam et al., (2011) has done an excellent job with his experiments on producing MGO using microwave-assisted burning. Next, the finished product was placed next to MGO, which was created in the traditional way. A comprehensive research using XRD, FT-IR, HR-SEM, TEM, EDX, DRS, and PL spectroscopy was conducted, yielding findings and results. The FT-IT method was utilised to investigate how water and CO2 adhered to the MGO surface and confirmed the formation of the MGO phase. The XRD results confirmed the formation of cubic-phase MGO. The formation of MGO microcubes and nanosheets was demonstrated, and HR-SEM and TEM were utilised to explain how they could develop. Scientists utilised DRS and PL spectroscopy to determine how much light was absorbed and emitted by the grid.

Wen Jing's et al., (2013) To strengthen TDMOC cement and make the maximum use of salt lakh's magnesium supply, researchers investigated how citric acid affected the hydration process and mechanical qualities of the cement. Citric acid was observed to slow down the second peak of TDMOC, reduce heat release, and produce more $5Mg(OH)_2.MgCl_2.8H_2O$ and less $Mg(OH)_2$ during the hydration process. The microstructure revealed tiny, perfect crystals.

Pan Liu et al., (2021) was examined for the characteristics of magnesium residue at various temperatures during calcination. Rather than using light magnesium oxide, magnesium residue from salt lakhs can be used to make magnesium oxychloride cement (MOC). Different magnesium chloride solutions and calcination temperatures were used to create MOC specimens. MOC cement is strengthened by utilising a high concentration of magnesium chloride solutions. Magnesium oxychloride cement has the potential to be a long-term alternative for Portland cement materials, lowering pollution levels and mitigating the construction industry's negative environmental effects.

Chenggong chang et al., (2022) It is beneficial for both the environment and the economy to investigate the usage of magnesium chloride resources in the form of magnesium oxychloride cement. However, the specific impact of high temperatures on cement is uncertain. The study sought to evaluate the effects of calcination temperature on the phase composition, microstructure, and mechanical properties of cement. Flexural strength decreased by 57.07% after calcination at 1000°C, whereas compressive strength remained constant. The MOC cement retained its high compressive strength (67.7 Mpa) after calcination at 400^0C. However, the cement totally lost its compressive and flexural strengths when the calcination temperature was raised to 450^0C.

D. Literature On Types Of Magnesium Analysis

Yuanji chen et al., (2018) The effect of Portland cement on magnesium oxysulfate (MOC) cement was investigated using an experimental approach. We used parameters such as setting time, compressive strength, cement mortar flexibility, x-ray diffraction, scanning electron microscopy, and the rate at which the cement hydrates and releases heat. The results showed that the mechanical strength of MOC cement is significantly reduced when Portland cement is added. However, adding a small amount of portland cement might decrease the setting time while maintaining maximum compressive strength.

Xiangchao Zeng et al., Magnesium sulphate cement is a lightweight, quick-setting, long-lasting, and wear-resistant magnesium-based cementitious material that has undergone laboratory testing. It could be used for building insulation as well as groundwork. BMS offers 2.5 times the flexural strength of Portland cement in the same strength class, as well as comparable durability and reinforcement protection. This essay examines how BMS is formed and hydrates, as well as how various factors might alter its microstructure and properties.

Baki Aykut Bilginer et al., has conducted studies to examine the advantages of magnesium potassium phosphate cement (MKPC) over regular Portland cement, including strength gain and quick setting. Although the effects of mixture proportioning on MKPC paste have been studied, there are conflicting reports on how magnesia calcination, parameters such as the magnesium-to-phosphate ratio (m/p) and water-to-binder ratio (w/b), added materials such as fly ash and borax, and sand addition influence mineralogy and properties such as setting and strength. The factors are evaluated on paste samples using scanning electron microscopy, thermogravimetric analysis, and X-ray diffraction over a relevant range of values. The increase of strength can be measured using both pastes and mortars. Calcination of magnesia produces some forsterite with impurity SiO_2, which may be related to reactivity decrease. As W/B increases, the setting rises.

E. Summary of Literature Review

The majority of studies show that utilising light-burned magnesium powder instead of conventional Portland cement increases the compressive strength of magnesium oxychloride cement concrete at various molar ratios. However, there is little written about the subject. So, the purpose of this research is to determine the strength of magnesium powder by varying the temperature and utilising it instead of M20-grade OPC cement concrete.

III. MATERIAL PROPERTIES

A. Introduction

This chapter describes the many materials utilized and the various tests are done to facilitate the process. This will help us understand the qualities and applications of materials.

B. Materials

1) Magnesium Oxide: Magnesium oxide is a solid white mineral that forms naturally as periclase. It is an artificial magnesium salt that can dissolve in water. The general formula for it is made up of oxygen and magnesium ions.

2) Magnesium Chloride: Magnesium chloride, also known as $MgCl_2$, is a type of inorganic chemical. When mixed with water, it forms hydrates of $MgCl_2.nH_2O$, where the value of n can range from 1 to 12. These compounds are colorless or white solids that dissolve easily in water. They have a wide range of practical applications due to their natural occurrence.
3) Fine aggregate: Fine sand or crushed stones are usually used for making fine aggregates. These particles are usually small enough to pass through a less than 4.75 mm sieve.
4) Coarse aggregate: Coarse aggregate are the big chunks of material we use in construction and concrete. They can be anywhere from 0.075 mm or 75 microns to 80mm, but usually they are between 4.75 and 10mm. most of the time, we use gravel for the coarse aggregate, but sometimes we use crushed stone.
5) Water: The chemical name for water is H2O. Water is clear, odourless, tasteless, and almost colourless.


a. Magnesium oxide powder b. Magnesium chloride crystals


c. coarse aggregate d. fine aggregate

e. water

Figure 3.1: Materials used.

C. Properties Of Materials

The physical characteristics of several materials utilized in the study are determined and reported here.

1) Physical Properties

a) Properties of Magnesium Oxide (MgO)

Magnesium oxide, represented by the chemical formula MgO, exhibits several important characteristics that define its properties and uses. With a molecular mass of 40.30 g/mol, it consists of one magnesium atom (Mg) and one oxygen atom (O). This composition gives it a density of 3.59 g/cm³, indicating a tightly packed atomic structure within the substance. Magnesium oxide has a melting point of 714°C, which signifies the temperature at which it transitions from a solid to a liquid state. Furthermore, its boiling point is at 1090°C, marking the temperature at which it transforms from a liquid to a gaseous state. These properties make magnesium oxide valuable in applications such as a refractory material in high-temperature processes and as a component in various ceramics, where its stability and physical properties play crucial roles.

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b) Properties of Magnesium Chloride ($MgCl_2$)

Magnesium chloride (MgCl2) is a chemical compound with a molar mass of 95 g/mol, composed of one magnesium (Mg) atom and two chlorine (Cl) atoms. It exhibits a density of 2.32 grams per cubic centimeter (g/cm³), indicative of its relatively close atomic packing in a given volume. The boiling point of magnesium chloride is notably high, reaching 1411 degrees Celsius (°C), and it undergoes a phase change from solid to liquid at this temperature. Conversely, the melting point occurs at 714°C, marking the transition from a solid to a liquid state. These distinct properties make magnesium chloride valuable in various applications, including as a de-icing agent to melt snow and ice on roads, in the pharmaceutical industry for medicinal purposes, and in the production of magnesium metal through chemical processes.

c) Fine Aggregate

- Density of fine aggregate 1450 - 2082 kg/m^3
- Specific gravity- 2.6
- Water absorption less than 3%
- Moisture content is 0-5%

d) Coarse Aggregate

- Density of coarse aggregate is 1450 - 2082 kg/m^3
- Specific gravity – 2.68
- Water absorption – 0.5 - 1%
- Moisture content - 0.2 - 4%

e) Water (H_2O)

Water (H2O) is a remarkable and ubiquitous substance with a wide range of unique properties. One of its most distinctive features is its ability to form hydrogen bonds between its molecules. These bonds arise from the partial positive charge on hydrogen atoms and the partial negative charge on oxygen atoms, resulting in strong intermolecular forces that give water its exceptional properties. Water's melting point at 0°C and boiling point at 100°C, under standard atmospheric pressure, are defining characteristics that allow it to exist in three primary states: solid, liquid, and gas. In the solid state, water forms ice, typically at temperatures below 0°C. In its liquid form, water is the most common state we encounter, with its temperature usually ranging from 0°C to 100°C. When heated above its boiling point, water transforms into a gaseous state, known as water vapor.

f) Portland cement

- Density of OPC is
- Specific gravity of cement – 2.84
- Normal consistency of cement is 29%
- Initial setting time – 30 min
- Fineness of cement is 6.66%

D. Mix Design Calculations

- MOC cement molar ratio is 5:1:8, which means for 5 times magnesium oxide, 1 time magnesium chloride, and 8 times water. This ratio holds on to the different temperatures of magnesium powder used in MOC cement. The molar ratio shown above is from Win Jing's (2013) publication.
- We used the M_{20} concrete grade in a 1:1.5:3 ratio, where: 1 part OPC cement, 1.5 parts fine aggregate, 3 parts coarse aggregate.
- For M_{20} grade concrete, MOC cement completely replaces OPC cement.

1) Sample calculation

- ➢ The MOC cement concrete is prepared with mix proportion 1:1.5:3 which is same as M_{20} grade concrete.
- ➢ Where '1' represent MOC cement, '1.5' represents Fine Aggregates, '3' represents Coarse Aggregate.
- ➢ To get MOC cement , as it is prepared from magnesia, $MgCl_2$ and water the following proportions are used 5:1:8 which is obtained from Win Jing's (2013) publication.

2) Quantity of material required for one cube of size 150mm x 150mm x 150mm

- Quantity of Magnesium Oxide (MgO)
- The magnesia quantity will be obtained from mix proportion of 5:1:8
- From where, 5 part of MgO can be obtained from = weight of MOC cement required for one cube / 5+1+8 = 1.05/14 = 0.075 x 5 parts of MgO = 0.375 kg
- But,

Weight of MOC cement required for one cube will be obtained from mix proportion of M_{20} (1:1.5:3) as = volume of cube/5.5 x ratio of cement = 0.00337 / 5.5 x1 = 0.006 x density of MOC cement = 0.0006 x 1750 = 1.05 kgs

- Here,

"0.00337" is the volume of one cube in m^3.
"1750" is the density of MOC cement in kg/m^3.

3) Quantity of Magnesium Chloride ($MgCl_2$)

- One part of $MgCl_2$ = weight of MOC cement required for one cube / 14 x 1 = 1.05 / 14 x 1 = 0.075 kg

4) Quantity of Water (H_2O)

- 8 parts of H_2O = weight of MOC cement required for one cube / 14 x 8 = 1.05 / 14 x 8 = 0.6 liter

5) Fine aggregate:

- Density of fine aggregate = 1800
- Volume of one cube = 0.0033 cum
- Volume of fine aggregate in one cube = 0.0033/5.5*1.5*density of fine aggregate (1800) = 1.62 kg

6) Coarse aggregate:

- Density of coarse aggregate = 1850
- Volume of cube = 0.0033 cum
- Volume of coarse aggregate in one cube = 0.0033/5.5*3*density of coarse aggregate (1850) = 3.33 Kg

7) From above calculations the quantity required for 1 MOC concrete cube

- Magnesium oxide (MgO) = 375g
- Magnesium chloride ($MgCl_2$) = 75g
- Water (H_2O) = 0.6 lit
- Fine aggregate = 1620g
- Coarse aggregate = 3330g

8) Sample calculations for 12 cubes

- Mgo = 375*12 = 4500g
- $MgCl_2$ = 75*12 = 900g
- Water = 0.6*12 = 7.2 lit
- Fine aggregate = 1620*12 = 19440g (19.44) kg
- Coarse aggregate = 3330*12 = 39960g (39.96) kg

9) Ratio of OPC cement: 1:1.5:3

- Density of Ordinary Portland Cement (OPC) =1440 kg/m^3
- Volume of one cube = 0.15*0.15*0.15 = 0.0033 m^3
- Quantity of cement required for one cube = volume of cube (0.0033)/1+1.5+3*1 = 0.0006* density of OPC cement (1440) = 0.864 kg for one cube
- Fine aggregate = 1.62kg
- Coarse aggregate = 3.33kg

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IV. CASTING AND CURING

A. Introduction

This chapter discusses the process of batching materials based on the concrete ratio obtained from the journal. The stage involved in achieving this goal include determining the physical parameters of magnesium oxide and casting the concrete, following by curing the concrete cubes and evaluating them for their compressive strength.

B. Methodology

STEPS INVOLVED: Compressive strength of MOC cement concrete comparing with M_{20} grade OPC cement concrete cubes.

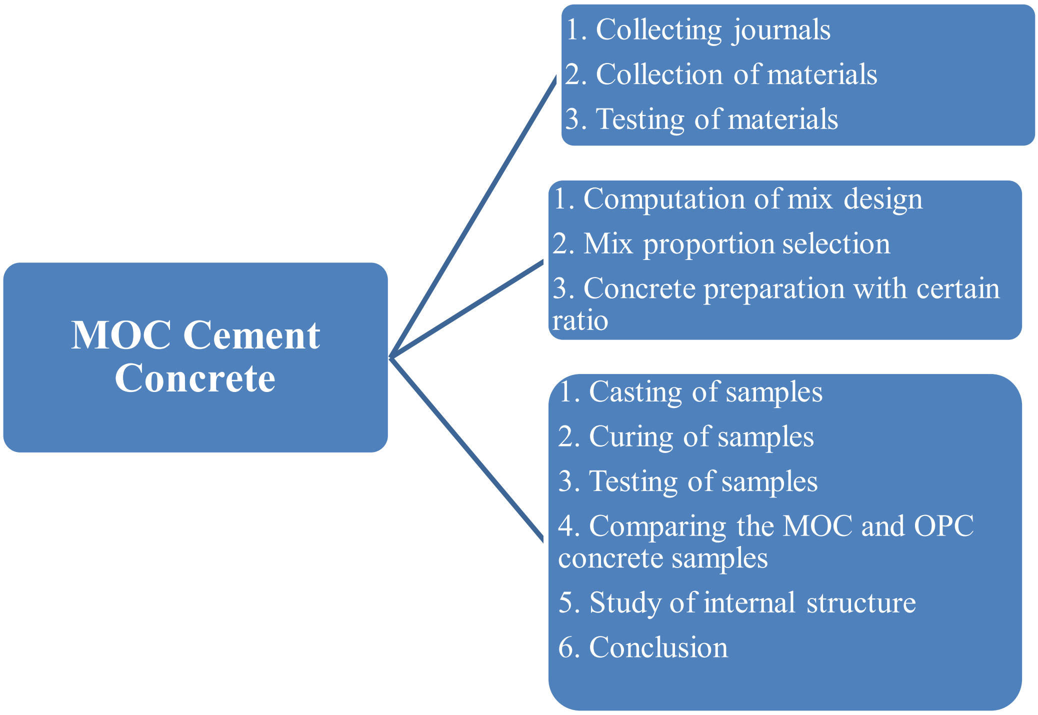

Figure 4.1: Methodology

C. Ordinary Portland cement concrete ratio

OPC Cement: Fine Aggregate : Coarse Aggregate =1:1.5:3. Compressive tests were performed on 9 OPC cement concrete samples for 3, 7, and 28 days, and the results were compared to MOC cement concrete.

Figure 4.2: OPC concrete cubes

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D. Magnesium Oxychloride Cement concrete ratio

Magnesium oxychloride: Fine Aggregate: Coarse aggregate = 1:1.5:3. Initially, temperature adjustments were performed on magnesium powder, and casted the MOC concrete cubes. The twelve cubes were cast for compressive testing over 3, 7, and 28 days.

Figure 4.3: Material mixing sequence in concrete

The concrete mixture was machine-mixed and poured into concrete cubes, making a total of 12 cubes. The mixture was initially made by heating magnesia powder for two hours at a steady temperature, after which the magnesium chloride crystals were slowly poured into water and stirred until the crystals dissolved and the water had a homogeneous texture. It was next put aside for 24 hours at room temperature.

1) Heated MgO

- 3 MOC concrete cubes individually were casted by heating magnesium powder at a various temperatures of 100^0C, 150^0C, 200^0C, 250^0C for 2 hours.
- Without heating the magnesium powder, the strength is reduced. To avoid this, we heat the magnesium powder to boost the strength.

Figure 4.4: Heated MgO powder

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2) Mixing of heated MgO

- The ratio used for magnesium oxychloride cement is 5:1:8 = heated magnesium powder: magnesium chloride (crystal added in water): water.
- The M_{20} grade is used for the concrete i.e. 1:1.5:3.
- In this concrete ratio the cement is replaced with MOC cement.
- The ratio 5:1:8 is for MOC Cement and the grade used for concrete is M_{20} grade i.e. 1:1.5:3 ratio is for MOC Concrete.

Figure 4.5: Mixing of MOC concrete

- 12 MOC cement concrete cubes were cast at various temperatures with a 1:1.5:3 ratio.
- After pouring concrete into mould, the cubes are left to set for 24 hours before being removed from the molds and exposed to ambient curing for 3, 7, and 28 days. Finally, a compressive strength test is performed.

Figure 4.6: MOC concrete cubes exposed to air

E. Test on Concrete blocks

To determine the strength of concrete, one effective method is to conduct a compressive test on cubes.

1) Compressive strength

The determination of the compressive strength of concrete was carried out through the applications of a loading mechanism on the concrete specimens, which were then subjected to a compression testing machine (CTM). This process was performed after 7, 14, and 28 days of curing, with the aim of identifying the strength achieved in 28 days of concrete. The results of this approach provide valuable insights into the long-term durability and stability of the concrete structures, which are important aspects of the construction industry.

Figure 4.7: Compressive Testing Machine

V. RESULTS AND DISCUSSIONS

A. Introduction

This chapter presents the results of tests conducted on MOC concrete, which determined the project's objectives.

B. The physical characteristics of OPC and MOC cement

This module compares the results of OPC and MOC cement tests.

1) Fineness results of magnesium oxide and OPC cement

The 90 microns sieve is used for fineness of cement and magnesium oxide powder.

- Fineness results of magnesium oxide

Table 5.1: The values obtained on fineness of magnesium oxide

S.NO	MgO at different elevated temperatures	Weight of the sample in (gm)	Weight of magnesium oxide retained on sieve (gm)	Percentage weight retained on sieve (%)
1	250^{0}C	100	79	79
2	200^{0}C	100	82	82
3	150^{0}C	100	83	83
4	100^{0}C	100	87	87

- % Weight of MgO retained on sieve = {weight of samples retained/total weight of sample}*10
- Mean weight of MgO retained on sieve = 82.75 gm
- The percentage fineness of MgO = [82.75/100]*100 = 82.75%

- Fineness results of OPC cement

Table 5.2 The values obtained on fineness of cement

S.NO	Observations	Sample-1	Sample-2	Sample-3
1	Weight of cement (W) gm	100	100	100
2	I.S sieve size microns	90	90	90

3	Sieving time(min)	15	15	15
4	Weight retained on sieve (W_1) gm	6	5	9
5	Weight retained on sieve (W_1/W_2)*100(%)	6	5	9

- Mean percentage retained on sieve = 6.66%

The fineness findings of MOC and OPC are shown in table 5.1 and 5.2. The MOC has an 82.75% and the OPC has a 6.66%.

2) Experimental values for normal consistency and initial setting time

The Vicat needle test, which determines the initial and ultimate setting durations of cement, is used as a quality control method for cement characterization.

Table 5.3 Normal consistency and initial setting time of MOC and OPC

S.NO	Observations	Normal consistency (%)	Initial setting time (min)
1	OPC	29	30
2	MGO at 250^{0}C	51	20
3	MGO at 200^{0}C	52	18
4	MGO at 150^{0}C	52	17
5	MGO at 100^{0}C	54	16

3) The specific gravity of MOC cement and OPC cement

The specific gravity of a substance tells you how heavy or light it is compared to another substance.

Table 5.4 The specific gravity values of ordinary Portland cement (OPC) and Magnesium oxychloride cement (MOC)

S.NO	observations	OPC	MGO at 250^{0}C	MGO at 200^{0}C	MGO at 150^{0}C	MGO at 100^{0}C
1	Wt. of empty bottle (W_1) gm	25	25	25	25	25
2	Wt. of bottle + cement (1/3) (W_2) gm	49	52	51	52	53
3	Wt. of bottle + cement (1/3) + kerosine (W_3) gm	87	85	87	84	85
4	Wt. of bottle + kerosine (full) (W_4) gm	70	67	65	67	68
5	Wt. of bottle + water (full) (W_5) gm	80	75	75	74	76
6	Sp. Gr. Of kerosine (Sr)	0.818	0.82	0.81	0.82	0.82
7	Sp.gr. of OPC and MOC cements	2.84	2.46	2.52	2.31	2.08

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C. Mechanical properties of OPC and MOC concrete

Table 5.5 Comparison of compressive strength of OPC cement concrete and MOC cement concrete

Category	Compressive strength at 7 days (N/mm^2)	Compressive strength at 14 days (N/mm^2)	Compressive strength at 28 days (N/mm^2)
OPC concrete	14.2	18.23	21.78
MOC concrete at 100^0C	3.55	6.67	8
MOC concrete at 150^0C	10.6	11.12	12
MOC concrete at 200^0C	9.3	12.89	14.22
MOC concrete at 250^0C	15.11	22.6	23.11

Table 5.5 presents a comparison between MOC and OPC cement concrete, indicating that the 250^0C MOC concrete exhibits high strength. As the temperature increases in magnesium powder, the strength of concrete increases.

D. Graphical representation of results

The results obtained are represented in graphical manner

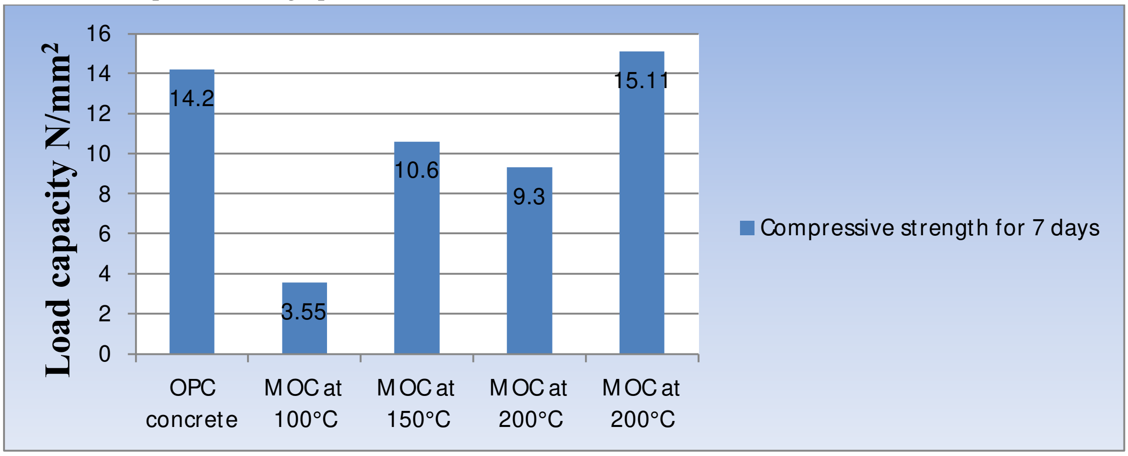

Figure 5.1 Compressive strength of OPC and MOC cement concrete for 7 days

Figure 5.1 shows the graphical representation of OPC and MOC cement concrete. The MOC at 250^0C has high strength than OPC cement concrete, MOC at 200^0C has decreased the strength.

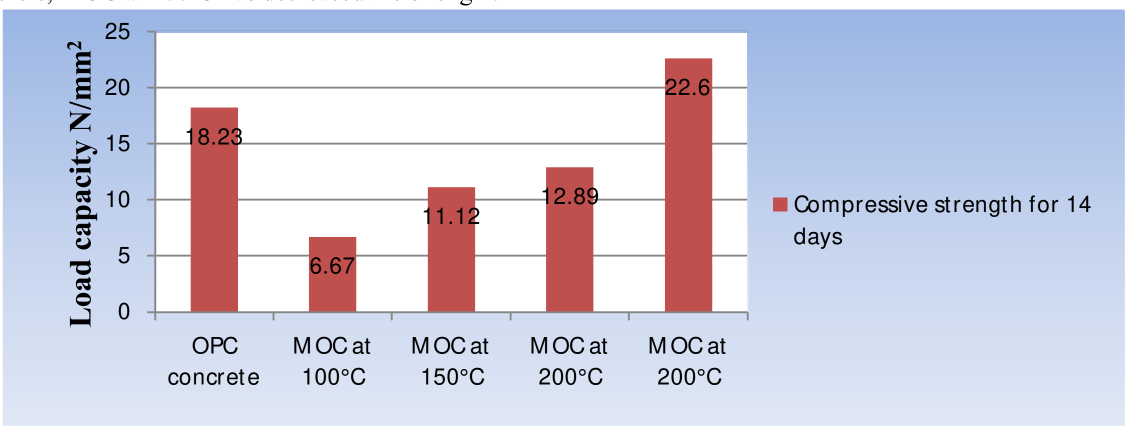

Figure 5.2 Displays the compressive strength of Ordinary Portland Cement (OPC) and Magnesium Oxide Cement (MOC) concrete after 14 days of curing

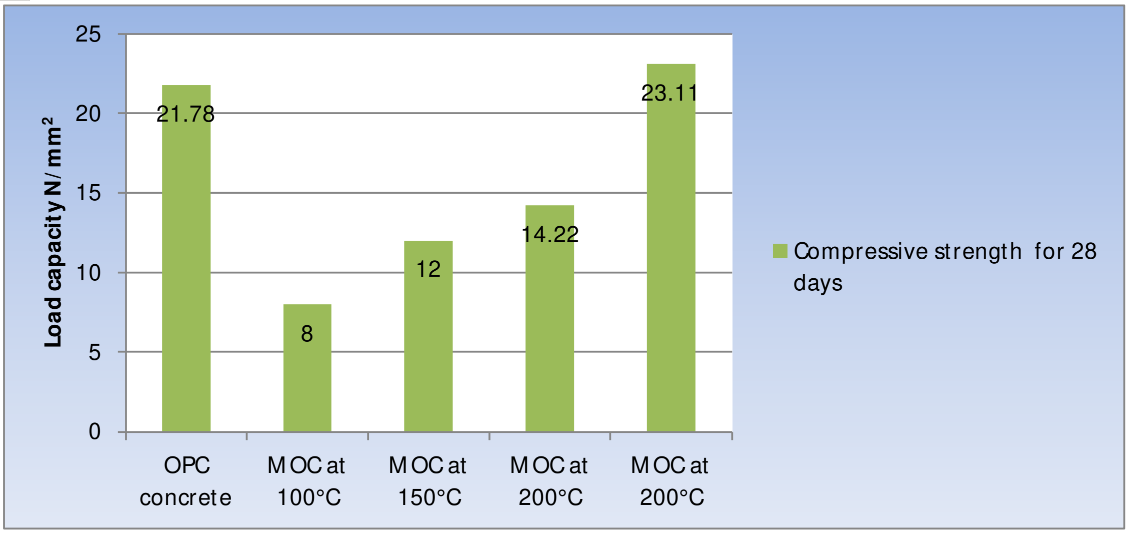

Figure 5.3 shows the compressive strength of MOC and OPC after 28 days

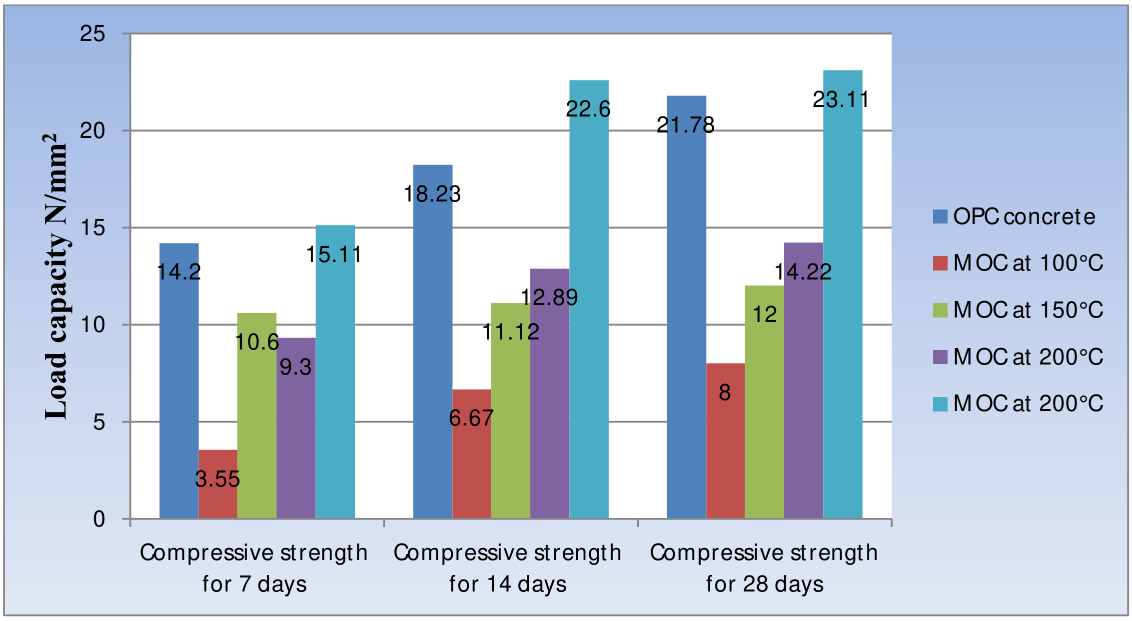

Figure 5.4 Depicts the combination of compressive strength of five samples over 7, 14, and 28 days

The graphical representation shown in figure 5.4 illustrates the compressive load of MOC cement concrete cubes after 7, 14, and 28 days, which were made using heated magnesium oxide powder at different temperatures. The comparison was made with OPC cement concrete. It was observed that the compressive load increased with the increase in temperature of magnesium oxide powder. At a temperature of 250^0C, the MOC cement concrete showed greater strength than the OPC cement concrete.

E. Summary of Results

This module contains a detailed account of the results obtained from the experimental work. The task at hand involved a series of producers, including casting and curing of concrete cubic specimens, followed by mechanical testing using varying temperatures of magnesium oxide powder. The samples were prepared in accordance with the M_{20} grade, which entailed using a ratio of 1:1.5:3 = 5MgO : $MgCl_2$: $8H_2O$. It is worth noting that by replacing OPC cement with MOC cement at a temperature of 250^0C, the grade M_{20} can be significantly strengthened. The findings of this experiment are critical in the field of construction and will aid in developing more robust and long- lasting structures.

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VI. MICROSTRUCTURE ANALYSIS

A. Introduction

Microstructure analysis is a method of examining the internal composition of an object through microscopic examination. The microstructure of a solid material is determined by the size, shape, and distribution of its various phases. Structures that are visible to be naked eye fall under the macrostructure category, while those that are smaller than 200µm are classified as microstructures. Microstructure analysis is a microscopic study used to determine the internal structure of a specimen. The electron microscope, which has a capacity of up to ten times magnification and potentially more, can be used to identify morphology, internal processes, and tiny particles such as voids, pores, and internal cracks present in the specimen. It is useful in determining any structural damage to the structure. Several techniques such as Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD), Energy Dispersive X-Ray Spectroscopy (EDAX), Fourier Transform Infrared Analysis (FTIR), White Light Interferometry (WLI), are used to analyze microstructures. In this study, microstructure investigation was carried out using SEM and EDAX methods.

B. Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy (SEM) is a high resolution imaging technique used to analyze the microstructure of a sample. A sample is exposed to a stream of highly charged electrons, which eject secondary electrons. These secondary electrons are gathered using a detector that surrounds the sample and converted into a signal that can be processed by a computer. SEM products highly detailed images that can reveal the structure of a sample at a very high resolution, making it a powerful tool in materials science, engineering, nanotechnology, biology, and other fields.

The images displayed below showcase various sizes, shapes, and structures, each representing different characteristics. These SEM images depict the microstructure of MOC cement concrete, where the ideal molar ratio of MgO: $MgCl_2$: H_2O is 5:1:8. The concrete has been subjected to temperature variation, where heated (250^{0}C) magnesium oxide powder is used, resulting in high compressive strength.

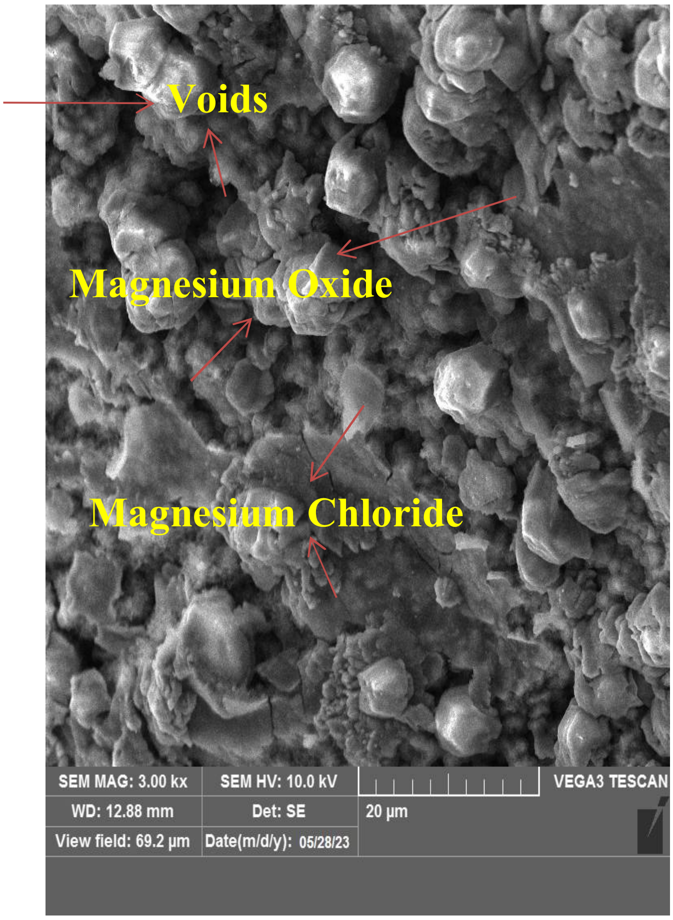

Figure 6.1: Displays the internal structure of MOC concrete that has been heated to 100^{0}C with MgO

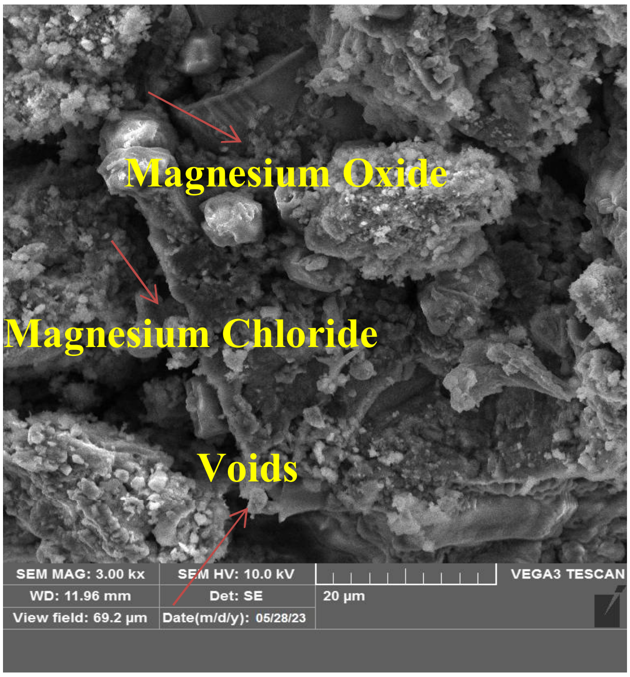

Figure 6.2: Shows the internal structure of MOC concrete that has been heated 150^{0}C using MgO

The magnesium reacts with hydroxides and chlorides to form foam slurry when heated magnesium oxide, fine aggregate, coarse aggregate, and water are combined to form a binder. In the beginning, the fluid quickly solidifies into a slurry. A few minutes after hydration, interactions between the magnesium, hydroxide, and chloride ions cause needle-shaped crystals to start to form.

Figures 6.1 and 6.2 show that there are a lot of empty spaces in the MOC cement concrete, which makes it weaker Basically, these gaps are messing with the strength of the concrete, so we need to do something about it.

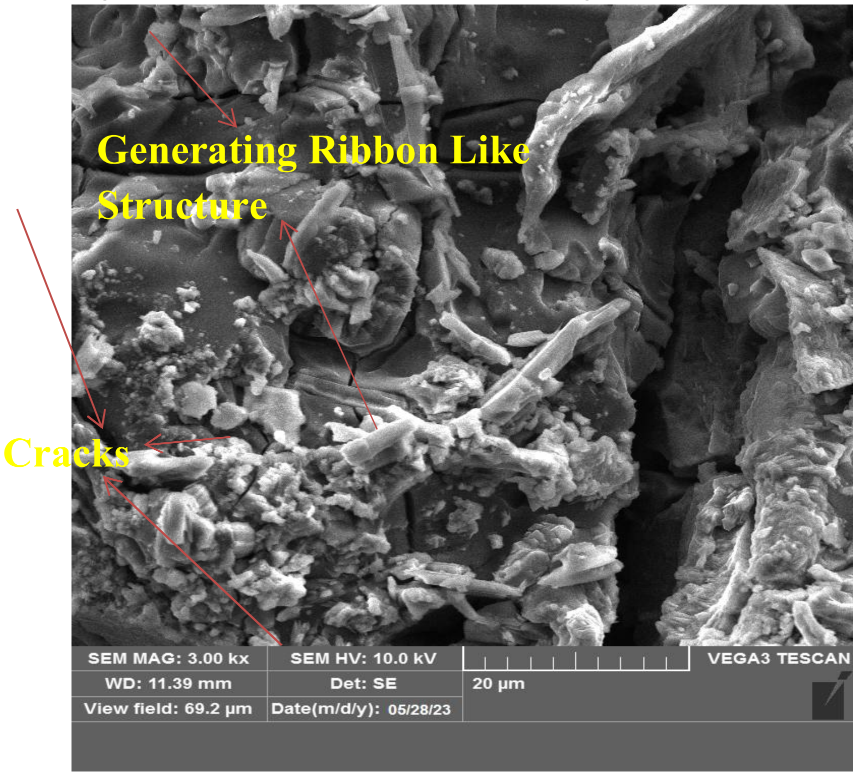

Figure 6.3: Displays the internal structure of MgO heated MOC concrete at 150^{0}C

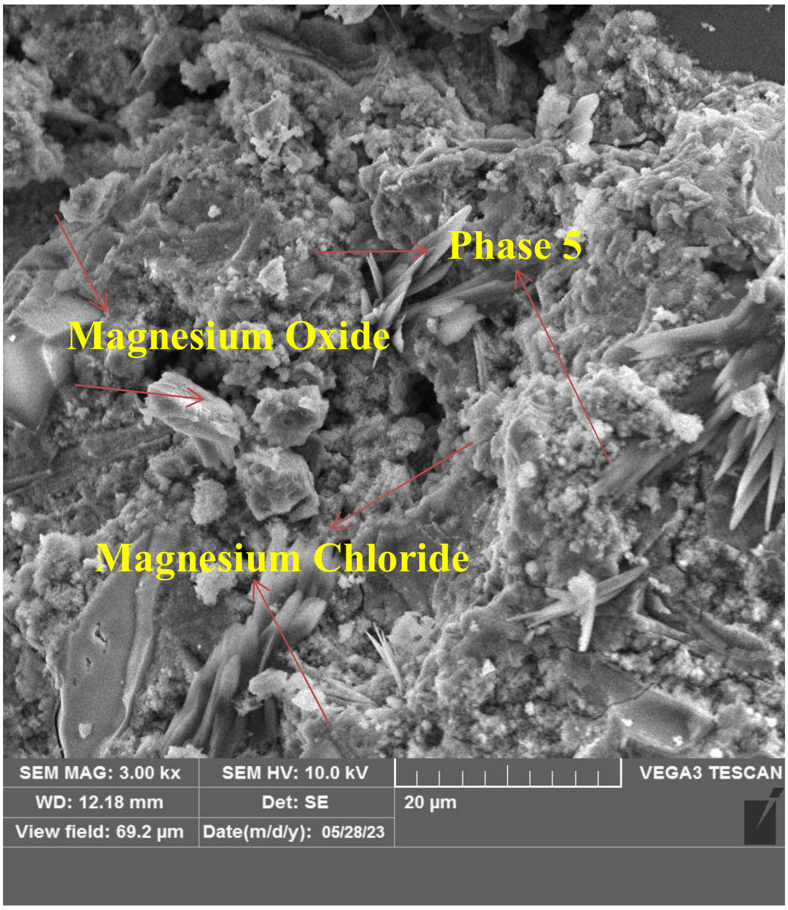

Figure 6.4: shows the internal structure of MOC concrete that has been heated to 250^0C using MgO

Thus, voids have been reduced in Figure 6.3, but cracks-like structure has been identified, and the generating ribbon-like structures. Figure 6.4 shows the formation of phase 3 and phase 5 by increasing the quantity of the ribbon-like structure, and this phase is in charge of the strength of MOC concrete.

C. Energy Dispersive X-Ray Spectroscopy (EDAX)

Energy Dispersal X-Ray Analysis (EDAX) serves as a valuable tool for identifying the weight and atomic composition of elements in a sample. During this study, an X-ray detector precisely detects the wavelengths of the electrons emitted. This makes it easy to determine the precise elemental proportions. This technique clarifies the elemental constitution of samples, allowing us to learn more about how they are chemically formed.

Table 6.1: Percentage of weight of element in 100^0C MOC concrete

Element	CK	OK	MgK	AlK	SiK	KK	CaK
Weight %	4.15	45.37	0.55	5.71	12.50	1.04	30.69

Table 6.1 displays the percentages of weight of the different parts that make up MOC cement concrete at 1000C for magnesium oxide powder with a molar ratio of 5:1:8 MgO: MgCl2: H2O. This mixture was found to have the lowest compressive strength after 28 days of drying in the air at room temperature. The total weight of the elemental composition in MOC cement concrete is gradually reduced by these percentages of weight.

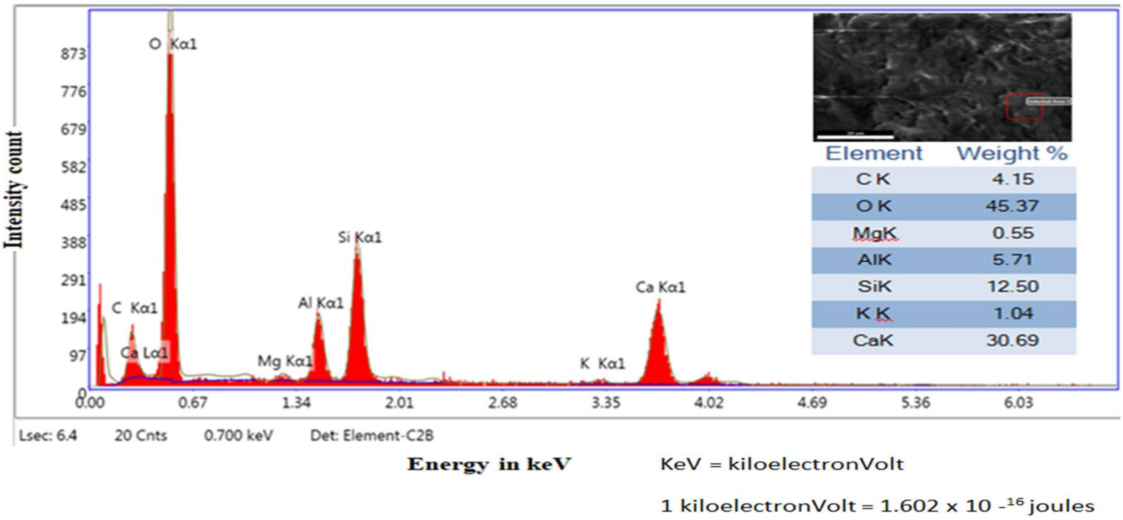

Figure 6.5: EDAX pattern showing elemental composition of 100^{0}C MOC concrete

Figure 6.5 shows the elemental composition of the cubic specimen. The percentage of each element present in the specimen represents the elemental composition of the specimen, totaling 100%. In the figure, the oxygen element, which is required to promote the formation of oxides with other elements, has the most significant percentage. Furthermore, calcium makes a significant contribution by increasing cement hydration and shortening setting time, particularly in concrete applications where it interacts with other constituents.

Table 6.2 Percentage of weight of elements in 150^{0}C MOC concrete

Element	CK	OK	MgK	AlK	SiK	KK	CaK
Weight %	5.27	49.79	0.32	3.86	8.54	0.80	31.43

Table 6.2 provides data on the weight percentage of magnesium oxide powder present in MOC cement concrete when exposed to a temperature of 150°C. This specific composition adheres to the molar ratio of MgO: MgCl2: H2O-5:1:8 and has been confirmed to yield the lowest compressive strength after a 28-day period of air curing at room temperature. Within the context of MOC cement concrete, these weight percentages represent a progressive reduction from the overall weight of the elemental constituents.

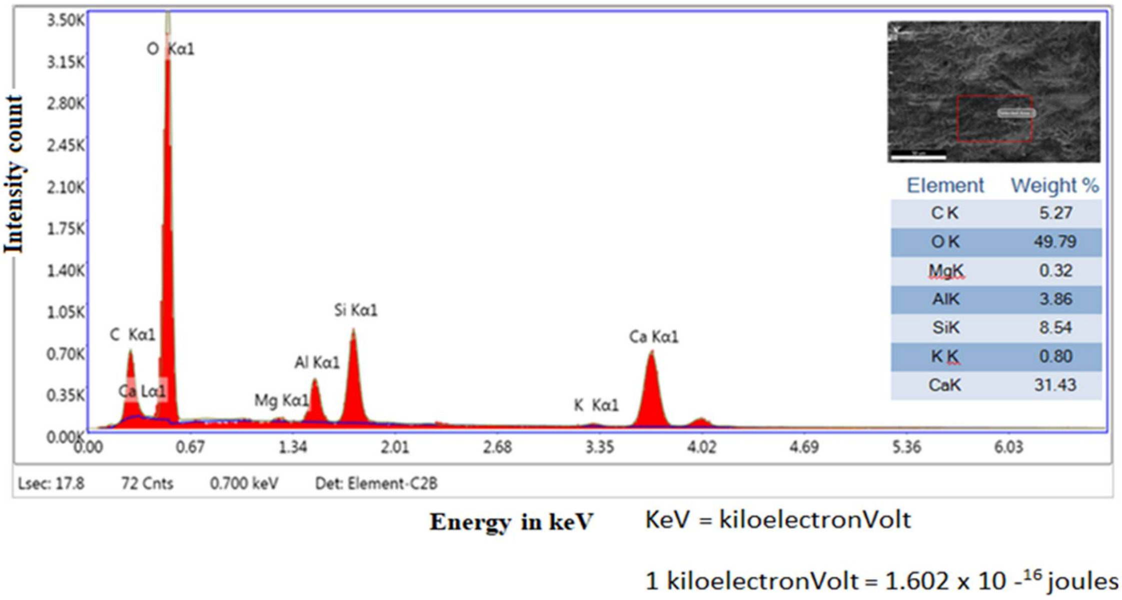

Figure 6.6: EDAX pattern showing elemental composition of 150^{0}C MOC concrete

Figure 6.6 depicts the elemental composition of the cubic specimen. The proportion of each element present in the specimen out of a total elemental makeup of 100% is known. Both the calcium element, which aids in expediting cement hydration and reducing set time for concrete applications including other elements, and the oxygen element, which aids in the formation of oxides for other elements, have the highest quantities in the figure. Because the levels of calcium and oxygen increased, the strength increased more significantly than in the previous sample.

Table 6.3 Percentage of weight of elements in 200^{0}C MOC concrete

Element	CK	OK	MgK	AlK	SiK	KK	CaK
Weight %	3.19	45.56	1.12	5.93	7.33	1.29	35.58

Table 6.3 displays the weight percentages of magnesium oxide powder within MOC cement concrete when subjected to a temperature of 200 degrees Celsius. This particular composition adheres to the molar ratio of MgO: MgCl2: H2O-5:1:8, which, notably, has been identified as optimal but results in the lowest compressive strength after a 28-day period of air curing at room temperature. These weight percentages represent the gradual removal of magnesium oxide powder from the total weight of the constituent elements comprising the MOC cement concrete mixture.

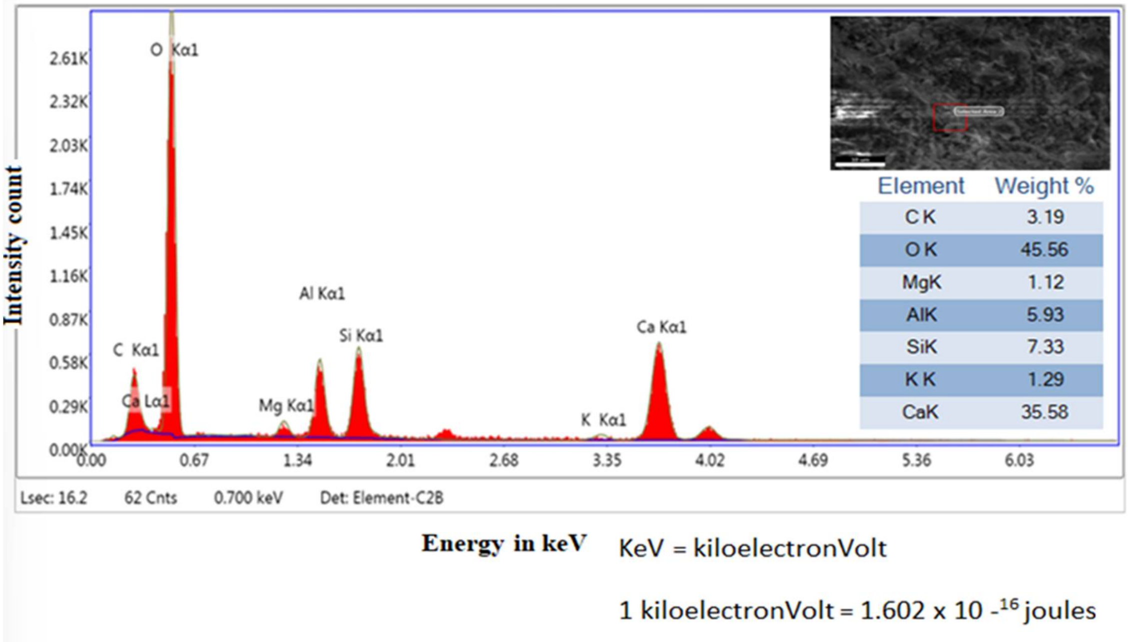

Figure 6.7 EDAX pattern showing elemental composition of 200^{0}C MOC concrete

Figure 6.7 depicts the elemental makeup of the cubic specimen. The oxygen percentage is reduced in this sample compared to the previous sample, and the calcium is raised, resulting in an small amount of improvement in strength and reduction in the setting time of cement concrete were particularly used in cold weather.

Table 6.4 Percentage of weight of elements in 250^{0}C MOC concrete

Element	NaK	MgK	AlK	SiK	KK	CaK	Oxygen
Weight %	6.83	0.71	14.36	27.68	1.54	1.01	47.87

Table 6.4 shows the weight percentages of the ingredients of MOC cement concrete at a temperature of 250° Celsius. Following 28 days of air curing at room temperature, the molar ratio of MgO:MgCl2:H2O-5:1:8 magnesium powder utilised in this composition was found to be optimal for achieving maximum compressive strength. These percentages represent the steady weight reduction of the component portions of the MOC cement concrete mixture.

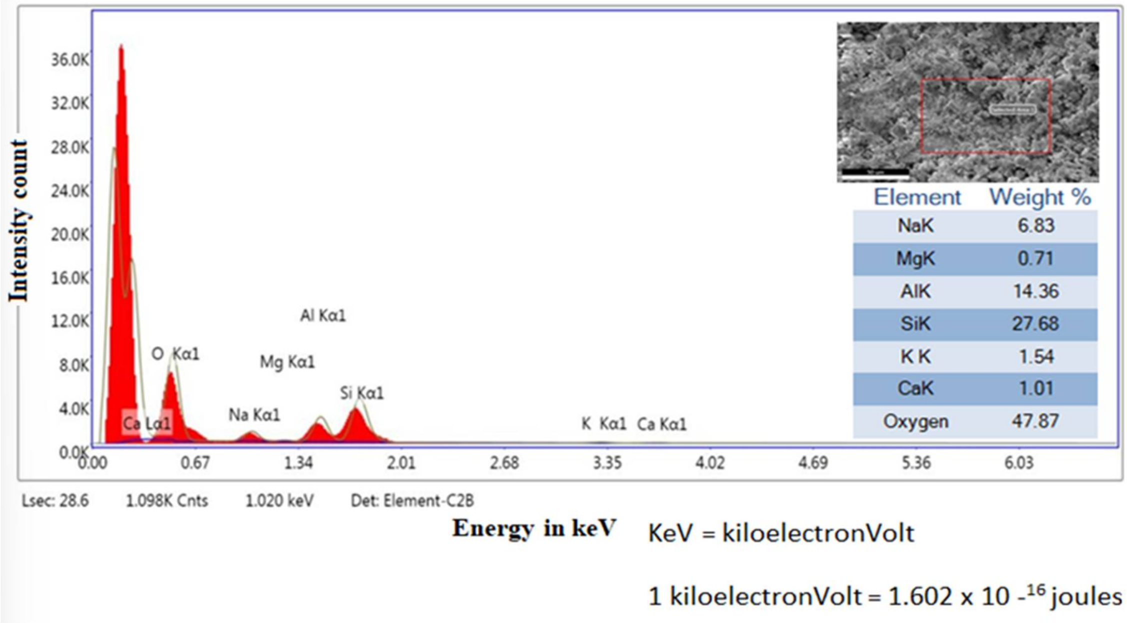

Figure 6.8 EDAX pattern showing elemental composition of 250^0C MOC concrete

Figure 6.8 clearly show the cube's elemental composition. This representation depicts the fraction of each element contained in the specimen, which account for 100% of its elemental composition. The figure shows oxygen as the most prevalent element. It plays an important role in the production of oxides for other elements. Silicon is also vital for improving the object's qualities, particularly in terms of compressive strength, bond strength, and abrasion resistance, as well as for connecting to other elements.

D. Summary Of Work

To investigate the microstructure, Scanning Electron Microscopy (SEM) was employed, allowing for a comprehensive analysis. To enhance the quality of the results, SEM images were captured at multiple scales. These images were instrumental in documenting the various morphological structures that contribute to both the positive and negative effects on MOC cement concrete. Specifically, the SEM images were obtained at different temperatures during the heating process of magnesium oxide powder, which is a key component in 5-phase molar ratio MgO: MgCl2: H2O-5:1:8 MOC concrete. Additionally, the composition of elements and their respective proportions were graphically presented through Energy Dispersive X-Ray Analysis (EDAX).

VII. CONCLUSIONS

A. Summary Of Work

Following testing, some MgO oxide powder was heated at a temperature of 1000C for two hours before using it to cast the specimens. The specimens with the highest compressive strength at 2500C temperature, as well as the internal microstructure, were analyzed using SEM and EDAX. The following discoveries are the result of additional work.

B. Conclusions

1) It is concluded that, for the preparation of MOC cement concrete magnesia powder has to be calcined to get good strength.
2) Calcination of MgO is been done at different elevated temperatures like 100, 150, 200 and 250 degree centigrade.
3) The mix proportions of the MOC concrete is taken as 1:1.5:3 and it is compared with OPC concrete.
4) The optimum MOC concrete is considered for an elevated temperature of 250 degree centigrade who's compressive strength is more than that of OPC concrete.
5) The increase in strength of air dried MOC concrete which is heated at 250 degrees centigrade is analyzed using SEM and EDAX studies which says that the formation of phase-3, phase-5 long needle like crystal structures and in EDAX we observe the percentage of oxygen and silicon which leads to increase the strength.

The current investigation found that magnesium oxychloride cement performed better than cement at a particular temperature. The final sample demonstrates the great compressive strength of OPC cement concrete at M_{20} grade. We can expect that heating MgO at higher temperatures will enhance its compressive strength.

C. Future Scope

Experimental data clearly reveal that subjecting magnesium oxide powder to higher temperatures during heating can greatly boost its strength qualities. However, the vulnerability of MOC cement to prolonged exposure to humid climatic conditions is a fundamental restriction that must be recognized. To reach its full potential in the construction business, it must overcome this barrier. Future research may look into the usage of reducers and super plasticizers as potential cures. Furthermore, due to its amazing resistance to high temperatures, MOC cement has a promising future in plasterboard construction, allowing a versatile application beyond its current limitations.

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