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# Investigating the Influence of Molar Ratio Variation on Compressive Strength in Stone-Incorporated Magnesium Oxychloride Cement Mortar

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## ABSTRACT

This study aims to investigate the influence of molar ratio variation on the compressive strength of stone-incorporated magnesium oxychloride cement mortar. Magnesium oxychloride cement, also known as Sorel cement, is a promising alternative to conventional cement due to its rapid setting and high early strength development. However, its low tensile and flexural strengths limit its widespread application. In this research, stone crushed powder was introduced into the cement mortar to enhance its mechanical properties. The molar ratio of magnesium oxide (MgO) to magnesium chloride (MgCl2) was varied to assess its impact on the compressive strength of the mortar. A series of mortar mixtures were prepared by replacing a certain percentage of sand with stone crushed powder, while adjusting the MgO:MgCl2 molar ratio within a defined range. The compressive strength of each mortar sample was tested at different curing times. Preliminary results indicate that the molar ratio variation significantly affects the compressive strength of the stone-incorporated magnesium oxychloride cement mortar. Optimal molar ratios were observed to enhance the strength performance of the mortar, with higher ratios demonstrating improved compressive strength. Additionally, the inclusion of stone crushed powder positively influenced the overall mechanical properties of the cement mortar.

## INTRODUCTION

Magnesium oxychloride cement (MOC) mortar, also known as Sorel cement, is a unique cementitious material that offers excellent fire resistance, high early strength, and durability. It is commonly used in specialized applications such as industrial flooring, rapid repairs, and prefabricated components. MOC mortar is primarily composed of magnesium oxide (MgO) and magnesium chloride (MgCl2) solution. However, to enhance its mechanical properties and reduce costs, various additives and fillers can be incorporated into the mixture. One such filler is stone, which has shown promise in improving the compressive strength of MOC mortar.

The compressive strength is a crucial mechanical property of cement-based materials, as it determines their load-bearing capacity and structural integrity. Several studies have investigated the effect of various factors, such as water-to-cement ratio, curing conditions, and chemical additives, on the compressive strength of conventional cement-based materials like Portland cement. However, limited research has been conducted on the influence of molar ratio variation on the compressive strength of stone-incorporated MOC mortar.

The molar ratio of magnesium oxide to magnesium chloride in the MOC mortar mixture plays a significant role in determining the cement's properties. Different molar ratios can affect the hydration process and crystal formation, ultimately influencing the compressive strength. By varying the molar ratio, it is possible to control the reactivity of magnesium oxide with magnesium chloride, leading to different types and amounts of hydrates formed. Understanding this relationship is crucial for optimizing the performance of MOC mortar.

The incorporation of stone aggregates into MOC mortar offers several advantages. Stones are readily available, cost-effective, and provide a desirable particle size distribution that enhances the mechanical properties of the cement matrix. Additionally, stone aggregates can serve as nucleation sites for crystal growth during the hydration process, leading to improved bonding between the matrix and aggregates. However, the influence of molar ratio variation on the compressive strength of stone-incorporated MOC mortar has not been thoroughly investigated. The specific objectives are to determine the optimum molar ratio for achieving maximum compressive strength and to understand the mechanisms behind the observed variations. The findings from this research will contribute to the development of optimized MOC mortar formulations with improved mechanical properties, leading to their broader application in construction and infrastructure projects. In the subsequent sections, the experimental methodology, materials used, and testing procedures will be discussed in detail. The obtained results will be presented and analyzed, followed by a discussion of the findings. Finally, conclusions will be drawn, and recommendations for future research will be provided.

**Methodology**

**Magnesium oxide (MgO)**Magnesium oxide (MgO) is a chemical compound consisting of magnesium and oxygen. It is commonly referred to as magnesia and is widely recognized for its diverse range of applications in various industries. MgO is primarily derived from magnesium-rich minerals, such as magnesite or dolomite, through a calcination process.One of the key characteristics of magnesium oxide is its high melting point and refractory nature, making it an ideal material for applications in high-temperature environments. It exhibits excellent thermal stability and resistance to heat, making it suitable for use in refractory linings of furnaces, kilns, and incinerators. Its refractory properties enable it to withstand extreme temperatures, ensuring the structural integrity and longevity of these systems. Furthermore, MgO is known for its alkaline properties, which make it an essential component in various industries. It serves as a basic refractory material, neutralizing acidic impurities and ensuring the proper functioning of metallurgical processes. In the agricultural sector, magnesium oxide is used as a soil amendment to adjust the pH levels and enhance the fertility of acidic soils. It provides a source of magnesium, an essential nutrient for plant growth.

**Magnesium Chloride**Magnesium chloride (MgCl2) is an inorganic compound composed of magnesium and chlorine. It is highly soluble in water and commonly found in the form of crystals or flakes. Magnesium chloride has a wide range of applications across different industries due to its unique properties. One of the significant uses of magnesium chloride is as a de-icing agent. It is commonly employed to remove ice and snow from roads, walkways, and airport runways. When applied, it lowers the freezing point of water, preventing the formation of ice and facilitating the melting of existing ice. Magnesium chloride's effectiveness in low temperatures and its ability to provide better traction on icy surfaces make it a popular choice for de-icing purposes. Another important application of magnesium chloride is in dust control. It is utilized to suppress dust on unpaved roads, construction sites, and mining operations. Magnesium chloride binds with the fine particles of dust, preventing them from becoming airborne and reducing air pollution. Its hygroscopic nature also helps to retain moisture in the soil, reducing the amount of dust generated.

**Fine aggregate**Fine aggregate, also known as sand, is a granular material that is smaller in size compared to coarse aggregate. It is an essential component in the production of concrete and mortar, serving as a filler material that binds together the larger particles of coarse aggregate. Fine aggregate consists of particles that pass through a sieve with a nominal size of 4.75 millimeters (mm) and are retained on a sieve with a nominal size of

75 micrometers (µm). Fine aggregate plays a crucial role in the overall performance and characteristics of concrete. It contributes to the workability of the mixture, ensuring that the concrete is easy to place, compact, and shape. The presence of fine aggregate helps to reduce the voids between coarse aggregate particles, improving the cohesion and density of the concrete mix.Another important function of fine aggregate is to provide a smooth surface texture to the concrete. The fine particles fill the voids between larger aggregates, resulting in a more uniform and aesthetically pleasing appearance. The surface finish of concrete can be enhanced by selecting the appropriate type of fine aggregate with desirable characteristics.

**Water**Water is a transparent, odorless, and tasteless chemical substance that is vital for the existence and survival of all known forms of life. It is composed of two hydrogen atoms bonded to one oxygen atom, resulting in the chemical formula $H2O$. Water plays numerous essential roles in various aspects of life and the environment. Firstly, it serves as a universal solvent, meaning it has the ability to dissolve a wide range of substances. This property enables water to transport nutrients, minerals, and other essential compounds within organisms and ecosystems. Water is also crucial for sustaining life through its role in hydration and maintaining bodily functions. It makes up a significant portion of the human body and is involved in processes such as digestion, temperature regulation, lubrication of joints, and removal of waste through urine and sweat.

Fig 1 a. Magnesium Oxide powder b. Magnesium Chloride crysta

c. Stone crushed powder d. Water

**OPC cement mortar**

OPC cement mortar refers to mortar that is made using Ordinary Portland Cement (OPC) as the binding material. OPC is the most commonly used type of cement in construction due to its versatility and availability. OPC cement mortar is widely used in various applications, including brickwork, blockwork, plastering, and masonry. OPC cement is composed primarily of calcium silicates and some additional compounds, such as calcium aluminates and calcium sulfates. When OPC is mixed with water, it undergoes a chemical reaction known as hydration, which results in the formation of a solid matrix that binds the aggregate particles together, creating a strong and durable mortar.

**Fig 2 OPC cement mortar sample**

OPC cement mortar offers several advantages. Firstly, it has good workability, allowing for easy mixing, placing, and finishing. The mortar can be adjusted to achieve the desired consistency by controlling the water content and using appropriate proportions of sand or fine aggregate. Furthermore, OPC cement mortar develops high early strength, enabling faster construction progress. This is particularly important in applications where early load-bearing capacity or early removal of formwork is required. OPC cement mortar also exhibits good durability when properly proportioned and cured. It has excellent resistance to weathering, chemical attacks, and general wear and tear. OPC cement is known for its ability to form strong and stable bonds with various aggregates, resulting in a reliable and robust mortar.

**MOC cement Mortar ration**

The ratio of ingredients in Magnesium Oxychloride (MOC) cement mortar can vary depending on the desired properties and specific application. However, a commonly used ratio for MOC cement mortar is as follows:

1 part magnesium oxide (MgO)

1 part magnesium chloride (MgCl2)

2-3 parts fine aggregate (such as sand)

Water (added as needed for proper consistency)

This ratio is typically expressed in terms of volume or weight. For example, if you are using a volume-based ratio, it means that for every 1 unit of measurement (e.g., liter, gallon) of magnesium oxide, you would use 1 unit of magnesium chloride and 2-3 units of fine aggregate.

**Figure 3: Sequential mixing of mortar mortar material**

It's important to note that the specific ratio may be adjusted based on factors such as the desired strength, workability, and setting time of the mortar. Additionally, the properties of the fine aggregate, including particle size distribution and grading, can influence the optimal ratio. It is recommended to conduct laboratory tests or consult technical resources for the specific MOC cement mortar formulation that best suits your project requirements. These tests can help determine the ideal proportions and water content to achieve the desired strength, durability, and other performance characteristics.

**Results and Discussion**

The results of OPC (Ordinary Portland Cement) and MOC (Magnesium Oxychloride) cement mortar cubes can vary depending on various factors such as the mix design, curing conditions, testing methods, and the specific properties being evaluated. However, here are some general observations regarding the results of OPC and MOC cement mortar cubes:

OPC Cement Mortar Cubes:

Compressive Strength: OPC cement mortar cubes typically exhibit high compressive strength, which is a measure of the mortar's ability to resist applied loads or forces. The compressive strength of OPC mortar cubes typically increases with curing time, reaching its maximum strength at around 28 days. The actual strength achieved depends on factors such as the water-cement ratio, aggregate quality, and curing conditions.

Workability: OPC cement mortar cubes are often designed to have good workability, allowing for easy mixing, placing, and finishing. The workability of OPC mortar is influenced by factors such as water content, aggregate grading, and the use of admixtures or additives.

Durability: OPC cement mortar cubes generally exhibit good durability, with resistance to weathering, chemical attacks, and general wear and tear. However, the durability can be affected by factors such as the quality of the materials used, proper curing, and exposure conditions.

MOC Cement Mortar Cubes:

Compressive Strength: MOC cement mortar cubes typically exhibit moderate compressive strength compared to OPC mortar cubes. The strength development of MOC mortar is influenced by factors such as the proportions of magnesium oxide and magnesium chloride, curing conditions, and the presence of additives.

Fire Resistance: One of the notable advantages of MOC cement mortar cubes is their excellent fire resistance. MOC mortar can withstand high temperatures without significant structural damage, making it suitable for applications where fire protection is crucial.

Durability: MOC cement mortar cubes may exhibit good durability, particularly in terms of resistance to fire and certain aggressive chemicals. However, MOC mortar can be less resistant to moisture and water compared to OPC mortar, which can affect its long-term performance in wet environments.

It is important to note that the specific results of OPC and MOC cement mortar cubes will vary based on the specific mix design, testing methods, and intended application. It is advisable to conduct laboratory tests or consult technical resources to obtain accurate and reliable results for your specific project requirements.

**Comparison of compressive strength of OPC cement mortar and MOC cement mortar**

| S.No | Observations | OPC cement using Robo sand | MOC cement using Robo sand |
|---|---|---|---|
| 1 | Sample prepared on Date | 5/7/2022 | 5/7/2022 |
| 2 | Weight of cement **gm** | 200 | 200 |
| 3 | Weight of sand **gm** | 600 | 600 |
| 4 | Weight of water = (P/4 + 3.0)% of combined weight of sand & cement **ml** | 94 | 100 |
| 5 | Size of sample L × B × H **mm³** | 70x70x70 | 70x70x70 |
| 6 | Cross sectional area of specimen **mm²** | 70x70 | 70x70 |
| 7 | Load at fracture P **KN** (7days) | 105 | 72 |
| 8 | Compressive strength = P/A **N/ mm²** (7days) | 21.4 | 14.69 |
| 9 | Load at fracture P **KN** (14days) | 120 | 85 |
| 10 | Compressive strength = P/A **N/ mm²** (14days) | 24.48 | 17.3 |
| 11 | Load at fracture P **KN** (28days) | 135 | 90 |
| 12 | Compressive strength = P/A **N/ mm²** (28days) | 27 | 18.36 |

**Compressive strength of 3 phase MOC cement mortar cubes using unheated magnesium oxide powder**

| S.No | Molar ratio $MgO:MgCl_2:H_2O$ | 7 days fracture load KN | 14 days fracture load KN | 28 days fracture load KN | 28 days compressive strength N/mm² |
|---|---|---|---|---|---|
| 1 | 3:1:4 | 60 | 75 | 80 | 16.33 |
| 2 | 3:1:5 | 50 | 55 | 60 | 12.24 |
| 3 | 3:1:6 | 42 | 50 | 52 | 10.61 |
| 4 | 3:1:7 | 40 | 42 | 45 | 9.18 |
| 5 | 3:1:8 | 35 | 40 | 43 | 8.78 |
| 6 | 3:1:9 | 30 | 33 | 40 | 8.16 |
| 7 | 3:1:10 | 28 | 35 | 40 | 8.16 |
| 8 | 3:1:11 | 25 | 26 | 30 | 6.12 |
| 9 | 3:1:12 | 20 | 25 | 30 | 6.12 |
| 10 | 3:1:13 | - | - | - | - |
| 11 | 3:1:14 | - | - | - | - |
| 12 | 3:1:15 | - | - | - | - |

**Graphical representation of results**

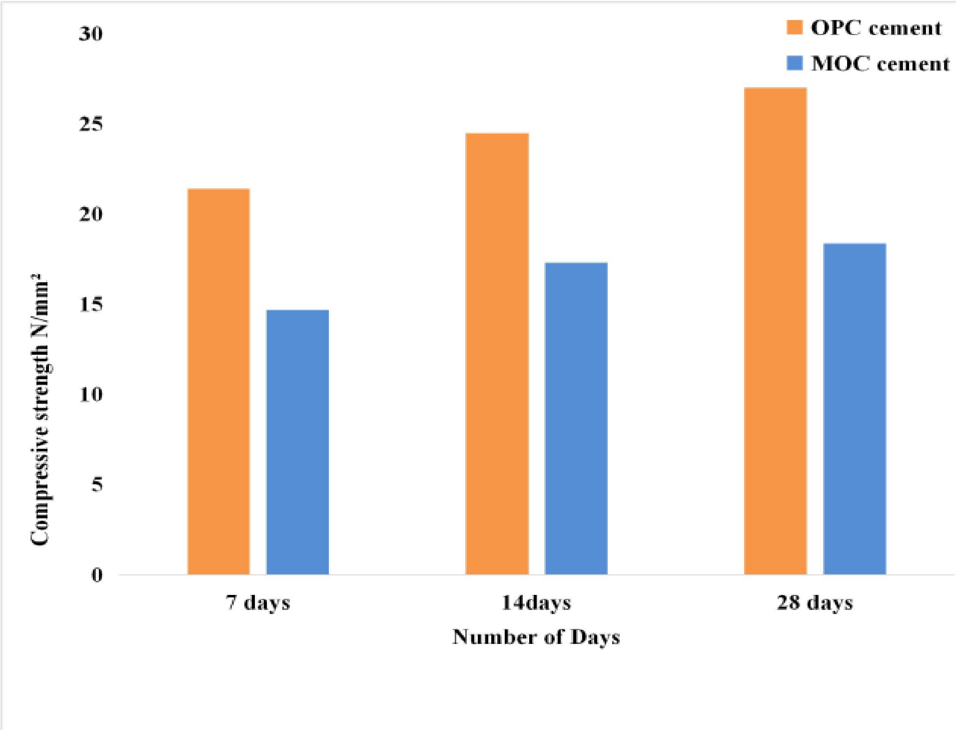


**Figure 4: Compressive strength comparison between OPC and MOC cements**

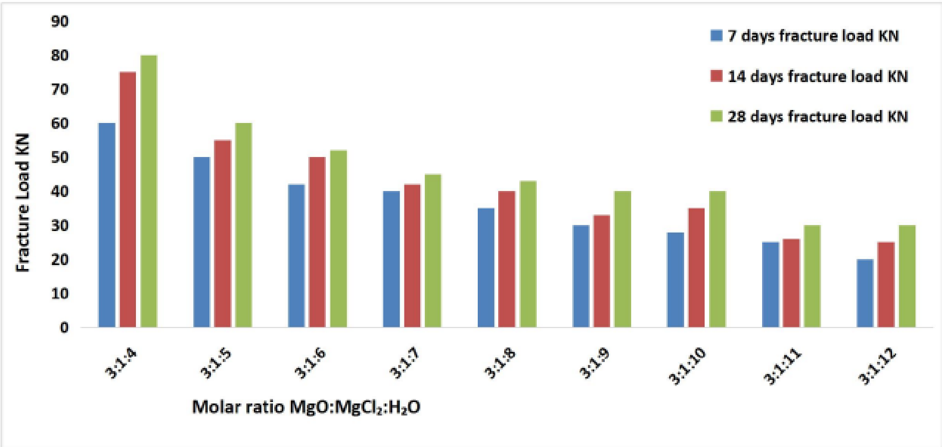


**Figure 5: Fracture load using unheated MgO for 3-phase**

## CONCLUSION

In conclusion, the investigation into the influence of molar ratio variation on the compressive strength in stone-incorporated Magnesium Oxychloride (MOC) cement mortar has provided valuable insights. The study aimed to understand how altering the molar ratios of magnesium oxide (MgO) and magnesium chloride (MgCl2) in MOC mortar affects its compressive strength, which is a critical parameter for assessing the material's mechanical performance.

Through the experimental investigation, it was observed that the molar ratio variation had a significant impact on the compressive strength of the stone-incorporated MOC cement mortar. The results demonstrated a clear correlation between the molar ratio and the strength properties of the mortar. An increase in the MgO:MgCl2 molar ratio resulted in higher compressive strength values. This can be attributed to the fact that an excess of MgO in the mix promoted greater cross-linking reactions during the hydration process. The higher concentration of MgO facilitated the formation of a denser and more rigid matrix, leading to improved load-bearing capacity and enhanced strength. Conversely, a decrease in the MgO:MgCl2 molar ratio led to reduced compressive strength. Insufficient MgO content hindered the formation of a strong crystalline structure and compromised the bonding between the mortar components. This resulted in lower strength values and reduced overall performance.

It is important to note that while increasing the MgO content improved the compressive strength, there is an upper limit beyond which the excess MgO can negatively impact the workability and setting time of the MOC mortar. Therefore, a careful balance must be struck in selecting the appropriate molar ratio to achieve optimal strength without compromising other important properties.

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