ANALYSIS OF MAGNESIUM OXYCHLORIDE CEMENT AS AN ALTERNATE BUILDING MATERIAL

A PROJECT

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"ANALYSIS OF MAGNESIUM OXYCHLORIDE AS AN ALTERNATE BUILDING MATERIAL"** in fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by NISHANT SHANDILYA (Enrolment no. 131633), JYOTI SHARMA (Enrolment no. 131671) and SHUBHAM SHARMA (Enrolment no. 131676),during a period from July 2016 to April 2017 **Mr. Saurav** (Assistant Professor) and **Mr. Abhilash Shukla** (Assistant Professor), Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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ABSTRACT

The recent development has provided us with various types of environmental friendly cementitious material, magnesium oxychloride cement is one of them. This cement can develop great strength with any of the treatments such as heat treatment or steam curing. This is because the bonding material that is responsible for the strength is easily achieved at normal conditions. MOC has drawn much Interest in the research in this area as the scientists are keen in finding new and ecofriendly ways of construction. Green cement and concrete is the need of the hour and this what MOC is offering energy saving and protection of environment. Magnesium phosphate cement is used for the repair purpose at the time of maintenance and mainly for repair purpose.

The preparation process of this cement can not only save a lot of energy but also emit comparatively or very less carbon dioxide into the environment. For magnesium Oxychloride cement, our research is will include the study of formulation of mixes, deciding optimal mix proportion, strength development and check, water resistance fire resistance of the cement. The influence of inert filler (Bagasse) The cement properties measured by standard consistency, setting time, moisture ingress compressive strength and soundness with magnesium oxide and magnesium chloride has been investigated. The compressive strength, moisture ingress soundness and the standard consistency of the sample gets receded with the treatment with the inert filler but more setting time was observed on increasing the quantity of the filler.

The most critical parameter to be considered while designing the molar ratio of $MgO/MgCl_2$ are the reactivity of the MgO powder.

LIST OF TABLES

LIST OF ACRONYMS

MOC	Magnesium Oxychloride Cement
R&D	Research and development
IST	Initial Setting Time
FST	Final Setting Time
MKPC	Magnesium Potassium Phosphate Cement
OPC	Ordinary Portland Cement
PPC	Pozzolanic Portland Cement
SC	Sorell Cement
GF	Granite Fragment

CHAPTER - 1

INTRODUCTION

1.1 General

On our planet Earth cement manufacturing is the second most intensive activity of carbon emission after the consumption of petroleum. Hence in order to save our mother Earth from the devastating effects of carbon emission and meeting the requirements of sustainable growth it is very important to switch to using alternate building material. We are proposing the use of Magnesium Oxychloride Cement which is a form of green cement aiming at mitigating the harmful effects of ordinary cement manufacturing and making use of the natural mineral resource which our country is blessed with.

MOC or Sorel cement has found its use in various architectural wonders since time immemorial – pyramids of Giza in Egypt, The Great Wall of China, The Forum in Rome and some stupas in India. Our way to make concrete greener along with providing adequate strength is by mixing supplementary materials like fly ash, sugarcane bagasse ash or by partial replacement with cement.

Its precedence over PPC can be illustrated owing to the following properties:

- High early strength
- Low alkalinity
- Light in weight
- High flame resistance
- Low thermal conductivity
- Good adhesion

A remarkable example of MOC cement is the grinding stone used for crushing pulses in homes in olden days.

MOC unlike normal Portland cement is capable of developing strength by dry or air curing It is utilized as a fast patching mortar for road & aircraft runways which can be operated in a span of 45 minutes. It naturally bonds with almost every organic material – wood chips, hemp, cotton cloth and other cheap filler materials. This is in disparity to Portland cement that repels cellulose and hence plastic binders are used for artificial adhesion in them. Additionally this cement can bond perfectly with brick, tile, wood & even steel MOC is super-stable in the form of Magnesium-Oxygen matrix because of the covalent bonds or molecular attraction between the double magnesium and oxygen molecules. MOC is used as a basic refractory material as well as a major ingredient in construction materials for fireproofing. It doesn't release any smoke and can be used as a flame resistant material.

It is also used as a soundproofing material and is used effectively in interior sound partitions like in encasing plumbing water pipes. As a result, water noise is effectively reduced.

While working with MgO products some construction workers reported that their cuts and wounds had healed quickly.

1.2 Background

The history of Magnesium oxide cement takes us to Addis Ababa, then a small town in Ethiopia. The Sub-Saharan Africa had long been a least urbanized and underdeveloped region of the world. Ethiopia was one of them. Hence the main objective of the government was a large scale construction within the given funds. Since the place was rich in mineral deposits hence an ecofriendly and low cost building material named Agrostone Panel which was later modifies to MOC was proposed which was a blend of magnesium oxide, magnesium chloride and diatomite fillers.

The major advantage was its low-cost production. That in turn contributed towards reducing the housing construction costs. Agrostone panel nearly reduced the cost of the wall constructions by half as compared to the conventional hollow concrete walls.

1.3 Principle:

In India, improvement through building is the second greatest money related development adjacent to agriculture. Improvement expect a basic part in budgetary advancement and has the distinctive effects on substitute divisions of the economy. The reliable climbing of bond era has realized honest to goodness consequences for imperatives resource, regular sullying. So there is a need of a coupling material which is more viable, more secure than standard method for improvement, predominant and usages the green advancement. Magnesium oxychloride cement is another coupling administrator having all the better properties over the customary Portland bond. It is an as of late introduced limiting administrator.

Only few researches has been done worldwide on MOC bond. We have to enhance the properties of MOC by using the additional substances with the objective that it can be feasibly used to supplant the OPC, having the particular central focuses. MOC is eco-obliging cement and does not require any glow, light or essentialness hotspot for its setting. The arranging system of MOC bonds save a significant measure of essentialness and in addition does not deliver carbon dioxide.

1.4 Objectives:

Our objectives in the project are:

1. Applying the mix design and fixing the proportioning of the constituents.
2. Analyzing the initial and final setting times of the MOC paste.
3. Analyzing the strength of the product formed from the MOC paste.
4. Analysis of enhancement of the properties of MOC with the addition of filler.
5. Analyzing the effect of cement replacement with MOC.
6. Nonstructural test on MOC which include water resistance, water absorption and fire resistance.
7. Cost Analysis of MOC casting.

CHAPTER - 2

LITERATURE REVIEW

2.1 General

In the search of finding new, ecofriendly and cleaner ways of construction the scientists have directed their focus to green cements. The cement production individually accounts to the 5% of human caused carbon dioxide emissions in the atmosphere. People all around the world are trying to find ways to improve the cement production process and look for new alternatives for cement as a binder, which will help us conserving our environment. Magnesium based cements are one of such binder. Many parallel researches are going on this material and many important discoveries have been made regarding the properties this type of cement.

There are various types of magnesium based cements. The popular ones are:

- Magnesium oxychloride cement
- Magnesium potassium phosphate cement
- Magnesium sulphate cement

Our project is concerned with the magnesium oxychloride cement and its past developments and future scope. Some research work done on MOC are given below.

2.2 Research and Studies

1 Introduction of Magnesium Oxychloride Cement

- In 1867, Sorell[1] a French researcher introduced a new binder and published the first exclusive and inclusive phase diagram for MOC binders, with formation of the 5 phase occurring in only a slim gap in the phase diagram of MOC. The MOC, thus formed breaks down to Magnesium chloride and magnesium hydroxide in the contact with water and change to hydromagnesite $[Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O]$ can likewise come about because of chloride draining. Unreacted $MgCl_2$ can relocate to the surface of a solid specimen, prompting unattractive white stores (blooming), and unreacted MgO can bring about dimensional stability issues, additionally influencing the toughness of these concretes.

- In 1980, Urwongse and Sorell[4] distributed a key article on the dissolvability of MgO in HCl arrangements at 23 °C that additionally refined the $MgO−MgCl_2−H_2O$ ternary graph for a fixed framework.

2. Material and Phases of Bonding :

- Zhou et al.[7] determined that the 3 phase is unstable in an answer with a Mg molality of less than 2.25 mol/kg, while the 5 phase is wobbly for Mg molalities of 1.47 mol/kg. Additionally, the landing of $MgCl_2$ is particularly unwelcome near any structures containing steel reinforcing in light of the threat of the chlorides making immense steel disintegration.

- The bonding phases formed depend on the temperature. More will be the temperature mare will be the bonding phases formed and more will be the strength theoretically. The arrangement of the higher-temperature stages was especially highlighted by Newman et al. (1964)[2], who concentrated the warmth era of MOCs utilizing a definition that was probably going to produce the 5 stage (anticipated that would be the most exothermic). But he found that at sample temperature of 147^0C, the strength of the sample was brutally affected. This discovering prompts an entangled circumstance where MOC monuments can encounter spatial varieties in stage collections as an element of the temperatures experienced amid curing as the high-temperature stages tend to hold on for quite a while at room temperature after cooling.

- Chau et al (2011) [17] based their studies on Magnesium potassium phosphate cement (MKPC). To enhance the properties of the magnesium based cement they decided to add potassium phosphate to the solution of magnesium chloride and water. This experiment leads them to the discovery that the problem of water degradation and corrosion can be improved by the addition of phosphates. The investigations demonstrated that the mechanical properties are being upgraded by the arrangement of magnesium potassium hex hydrate yet he likewise presumed that the mechanical quality is exceedingly reliant on the magnesia to phosphate proportion.

- Y. Li et al [14] concentrated the aftereffects of compressive quality of stone waste fly slag on MOC. He arranged different examples with various extents of fly cinder extending from 0% to 40% of magnesia by weight. On basis their strength found at 3, 7 and 28 days and with the help of X- ray diffraction he concluded that the filler enhanced the microstructure, results in the formation of dense phase-5 bonding which is responsible for strength and also improves the water resistance of the product. Hence the combination of the granite waste and fly ash as aggregate can improve the compressive strength of the MOC.

3. Proportion and Molar Ratio:

- Zongjin and Chau [12] in 2007 concentrated their work on the impact of molar proportions of $MgO/MgCl_2$. $H_2O/MgCl_2$ on the properties and quality of MOC. During the research they found that the most suitable molar ratio of $MgO/MgCl_2$ varied from 11-17 and $H_2O/MgCl_2$ varies from12-18. Further they likewise reasoned that the molar proportion of $H2O/MgCl_2$ is, however subject to the weight proportion of $MgO/MgCl_2$ to accomplish sought workability. Moreover, the molar ratio is also affected by the reactivity of the magnesium oxide used.

Durability of MOC:

- Zhu Ding and Zongjin [18] in 2007 worked on MOC and they suggested phosphate treatment with difference in the fine aggregates, along with different water content. The three sorts of fine aggregates were normal sand, dead consumed magnesia and alumina particles. Compressive quality of the specimens was conveyed at 3,7,28 days. They presumed that the compressive quality abatements with the increments of sand substance paying little heed to the sand sort.

  However, the strength reduction of MPSC mortar formed with magnesia and alumina was much smaller. The change of mechanical properties of the mortar is mainly controlled by increase of total porosity that was determined by the water content.

CHAPTER - 3

MATERIALS AND METHODOLOGY

3.1 General

3.1.1 Magnesium oxide

For commercial purpose Magnesium oxide is prepared by heating magnesite, which helps in driving off most of the CO_2. This material hence formed has good thermal conductivity and electrical resistively at elevated temperatures. Magnesium oxide in general is used as a basic refractory material for lining crucibles which is exposed to high temperatures. So we can say that magnesium oxide is a principal ingredient in construction materials used for fireproofing. It also finds its use as a reference white colour in colorimetry.

Magnesium Oxide occurs as a natural material, it is found in volcanic material and ejects, serpentine rocks and in contact with metamorphic limestone. Natural magnesium oxide gets converted to magnesium hydroxide in form of vapors in the atmosphere and does not form rocks and salt deposit. For industrial purpose a large amount of magnesium oxide is extracted from magnesite, seawater and natural and synthetic brine. Magnesite is a natural mineral which is composed of $MgCO_3$ and its composition is MgO (48%) and CO_2 (52%). Magnesium oxide is regarded as a refractory material i.e. a solid which is physically and chemically stable at high temperatures. It finds its use in various fields due to its inherent chemical resistance, high thermal conductivity, low electrical conductivity, high melting point and biological activity.

There are various technical grades of magnesium oxide such as magnesia sinter, dead burned magnesia and hard burned magnesium oxide which is used as a refractory material and in the steel industries. Nowadays large amount of calcined or decarbonated material known as caustic-calcined magnesia or caustic magnesia are used in agriculture and building industry. Talking about the production process, it occurs due to decomposition of the $MgCO_3$ to MgO and CO_2 (on application of heat) and hence CO_2 is released to the atmosphere in form of gas. All the processes involving calcination and having carbonate rock as input has the same phenomenon. The 85% of the material should pass through 150μm sieve so the final product is subjected to milling to achieve a size reduction. The magnesium oxide derived is a high-temperature product formed by the calcinations of magnesium carbonates. Though magnesite deposits are found in every state, but only very little portion is pure that is recovered for the purpose of industrial magnesium oxide manufacturing. For a rock to be classified as magnesite, it should contain at least of 50% magnesium carbonate.

When the rock contains only 30 to 45 % of magnesium carbonate, it is referred to as dolomite. Magnesium oxide is manufactured in various kinds of kilns by one of the following reactions:

$$MgCO_3 + heat \longrightarrow CO_2 + MgO$$

3.1.2 Production of Magnesium Oxide from Brine:

The source of magnesium oxide is magnesite which is extracted by mining, while one another important source is obtained from processing seawater, underground deposits of brine which has magnesium chloride. The extraction process from seawater is the same but it differs in the concentration of magnesium that the seawater has within it. The seawater has low concentration of magnesium in it.

Brine is a salt solution in water, in this case, water has magnesium chloride, calcium chloride in it. As mentioned above that the concentration of magnesium is low in brine solution, so justifying that magnesium is about 9%i.e. 0.5 kg of magnesium oxide can be produced from 10 liters of seawater.

In this process of extraction of magnesium oxide form brine, one another compound is needed. Basically, this compound is quick lime or calcium oxide (CaO) which has its origin from a mineral source, dolomite limestone [$CaMg(CO_3)_2$] is one of the example. When it is given heat treatment the product that is left after the escape of carbon dioxide is calcined dolomite. First, the brine solution is mixed with both water and calcined dolomite to form an aqueous suspension that contains combination of magnesium hydroxide and calcium chloride:

$$MgCl_2 + CaCl_2 + H_2O + (CaO.MgO) + 2H_2O \longrightarrow 2Mg(OH)_2 + 2CaCl_2 + H_2O$$

The calcium chloride and magnesium hydroxide which are produced from the reaction exist together in the solution but they have two distinct physical states. Magnesium hydroxide are the solid particles while the liquid phase is the calcium chloride which is present in the dissolved phase. Further the mixture of both these compounds is commonly referred as slurry.

Our aim here is to separate the magnesium compound from the slurry, this is done by gravity separation. Since magnesium hydroxide is heavier than water the solid phase of the slurry gets separated with the help of gravity. This is how magnesium hydroxide is extracted which is also called milk of magnesia.

The solids at the bottom are separated and the water is removed to get the solids and also remove the residual chloride content in the solution. This results in a damp filter cake which is then treated with heat to get the magnesium oxide by driving the water traces in the solids.

$$2Mg(OH)_2 + heat \longrightarrow 2MgO + 2H_2O(steam)$$

Originally magnesium hydroxide particle is usually described as large and loosely bonded particles. With the exposure to the heat treatment the particle alters its structure and becomes more round while the porous structure starts to fill up. Thermal treatment also affects the reactivity of magnesium oxide due to the fact that less pores and less surface area is left in the structure thus reducing the reactivity with other compounds.

Various types of kilns can be used in the calcination process of magnesium hydroxide. The calcination process not only converts magnesium hydroxide to magnesium oxide, but plays a very important role in deciding the quality of the final product i.e. magnesium oxide. Depending on these various factors there are various grades of magnesium oxide.

Depending on the reactivity of the and the degree of heat treatment provided the magnesium oxide has three basic types or grades. Various types of kilns used for calcination now come to use in getting the desired final product by varying the degree of heat treatment given to the sample. These three grade are discussed below.

Dead burned magnesium oxide (Sintered magnesia):

Most of the magnesium hydroxide or magnesite (85%) is converted to form sintered magnesia or dead burnt magnesia. Dead burnt MgO has low reactivity and its quality not only depends on chemical composition but its low reactivity and high bulk density imparts desired properties in the product. Depending upon the percent of magnesium present there are 10 grades of dead burned MgO. The reactivity of sintering capability decreases by increasing purity, making it difficult to achieve high density product. Temperatures used in the kiln while carrying out the calcination process ranges form 1500^{o}C-2000^{o}C and the magnesium oxide thus formed is referred to as "dead-burned" since the reactivity has been decreased. It is used as a refractory material in the production of bricks. It is also used for lining purpose in the steel industries where a specific part is exposed to varying heat and extreme heat. This dead-burned magnesia in the form of granular size is suitable for refractory purposes.

Hard burned magnesium oxide:

This is the second type of magnesium oxide which has low reactivity and which is formed by calcination of magnesite at temperature range of 1000ºC – 1500ºC. This product has low bulk density of 1200kg/m^3. It has a very narrow range of reactivity due to which it is used where slow degradation or slow chemical reactions are desired to be achieved such as animal feeds and fertilizers.

Light burnt Magnesium Oxide:

It is the third grade of MgO which is produced by calcining of magnesite at temperatures ranging from 700°C - 1000°C. Light burnt magnesium oxide is also known as caustic magnesia. It is the most reactive grade of magnesium oxide. Due to its wide range of reactivity, it has various industrial applications that includes processing of plastics, rubber, paper and pulp, steel boiler additives, adhesives and many more.

Caustic magnesia is a very reactive, this is achieved by exposing the product to a heat treatment such that finely crystalline material is produced by burning magnesium hydroxide or magnesite slightly above the decomposition temperature. Caustic magnesia in past was produced only from the crypto crystals of magnesite with a low iron content but now it is also obtained from all types of magnesite and magnesium hydroxide.

In the case of magnesium hydroxide that is extracted from the sea water, a multistage hearth kiln is used to dewatered filter cakes and carry out the calcination of the cakes in lump form at about 9500^{o}C. Each hearth is provided with four burners in the vertical cylindrical shape kiln wall and these kilns contain ten hearths, one above the other.

The material to be calcined is feed continuously from the top of the kiln and its retention time can be adjusted with the help of rake that moves above each hearth. The uncontrolled burning of magnesite or the magnesium hydroxide results in excess growth of the reactive MgO crystals which futher lowers the activity of the final product (MgO) so the burning conditions of the kiln should be carefully adapted to avoid any contamination it the feed.

When heated from 700°C to 1000°C, magnesium carbonate thermally decomposes to produce magnesium oxide and carbon dioxide:

$$MgCO_3 + heat \longrightarrow MgO + CO_2 \text{ (gas)}$$

3.1.3 Magnesium Chloride

Magnesium chloride is another important material used for making MOC cement. This material should be in crystalline form $MgCl_2(H_2O)_x$. The bonding phase that forms with the reaction with the MgO requires the magnesium chloride to be in crystal for having water of crystallization in them. These salts are ionic halides which are highly soluble in water. Many salt lakes and natural brines are the primary source of magnesium chloride. Sea salt contains about 17 % of $MgCl_2$.

While $MgCl_2$ can also be extracted from mineral salt deposits which contains minerals like canalite, bischofite and occasionally the double salt anhydrites in which the magnesium chloride is present in combined state with calcium chloride ($CaCl_2.2MgCl_2.12H_2O$). Magnesium chloride. The reactivity of the amorphous form of magnesium chloride does not form the desired bonding with magnesium oxide and thus the strength of the sample gets reduced. $MgCl_2$ crystallizes to form cadmium chloride, in which the structure of magnesium is octahedral in shape. There are various variety of hydrates which can be easily represented by the formula $MgCl_2(H_2O)_{x.}$ So with the increase in the temperature the water present in the magnesium chloride reduces. As magnesium chloride has a tendency to form octahedral complexes, especially when anhydrous, acts as a weak Lewis acid.

The most favorable form of magnesium chloride that guarantees the development of strength is its hexahydrate form. In past various ways have been established for the production of magnesium chloride hexahydrate. Among them one of the most common techniques used is evaporation of sea water and natural brines. But this technique is economical only where the dilute solutions containing $MgCl_2$ can be preconcentrated by solar evaporation. The sample of solution is first subjected to solar evaporation which is followed by subjecting the solution to vacuum evaporation until the 6-hydrated form of $MgCl_2$ and $MgSO_4$ gets precipitated.

The precipitated crystals are then heated to a temperature range of 120 -150^oC to dissolve the $MgCl_2.6H_2O$ into the solution that will allow easy removal of magnesium sulphate as they are still in the solid state at this temperature. So finally the $MgCl_2.6H_2O$ can then be crystallized out of the solution.

The only problem with the process of extracting magnesium chloride with evaporative processes is the high energy input required and thus the costs associated with the production of $MgCl_2.6H_2O$. By far the most significant expense associated with production of magnesium chloride is the cost of brine dehydration. Some alternate methods of production of magnesium chloride is in the form of by-product of the potash industry or by performing chlorination of magnesium oxide in the presence of any reducing agent. However, these alternate methods are even much more expensive than the production by evaporation of brines.

To summarize the points mentioned above is that the best way which is the most economical process in the production of magnesium chloride from seawater or brines is evaporation by the use of solar energy. In this process the dilute solutions are pre concentrated by solar evaporations. But when the sea water cannot be pre concentrated with the help of solar energy Dows process is used for the production of magnesium chloride. Through Dows process large scale of $MgCl_2$ is produced by precipitation as magnesium hydroxide, that is followed by conversion to magnesium chloride with hydrogen chloride. Magnesium chloride is regenerated from magnesium hydroxide using hydrochloric acid:

$$Mg(OH)_2(s) + 2HCl \rightarrow MgCl_2(aq) + 2H_2O(l).$$

3.1.4 Bagasse:

Bagasse which is also called “megass”, is the fiber residue that remains after the extraction of the juice from sugarcane to get sugar. Bagasse has various uses like it can be burned to supply heat to the sugar refining operation and it is also used as a source of cellulose for preparing animal fees. In recent years it has found its use in various fields, some part of the bagasse is used into various board products. The bagasse fiber is thick walled and relatively long having length in the range of 1-4mm. Bagasse is also used as composites, the main fibers are obtained mostly from the rind, but the interior is also fully packed with these fibro vascular bundles.

Bagasse is available wherever sugarcane is grown. As such, almost no harvesting problems exist, and large volumes are available at sugar mills. Bagasse as such cannot be used as a filler in the making of magnesium oxychloride cement. This fibrous bagasse has to be burnt and converted into ash before it can be used as a filler. The ash also should have some specific properties be it particle size, carbon content or texture. Bagasse in the ash form is added in the MOC paste to as it enhances the properties of the material and also adds new and desired properties such as light weight mix, insulation, water resistance and fire resistance.

3.2 Materials Used

MOC paste can be formed by mixing magnesium oxide with magnesium chloride. The strength of the material is responsible for the formation of bonding phases that form with the interaction of magnesium oxide with magnesium chloride. So these two ingredients are crucial for the formation of the MOC paste. Further the fine aggregate can be added to the paste in form of bagasse, dolomite or pumice powder. These are the few preferred fine aggregates that are with MOC paste. Different fillers when added to the paste enhances and improves different properties of the mix.

Here in our project we have used bagasse as our filler material along with the magnesium oxide and magnesium chloride. Table 3.1 shows material specifications while Table 3.2 shows the specific gravity of the material.

Table 3.1 – Material Specifications

S.NO.	Material	Specification
1	Magnesium Oxide	Industrial Grade
2	Magnesium Chloride	70 % pure

Table 3.2 – specific gravity of MgO and $MgCl_2$

S.NO.	Material	Specific Gravity
1	Magnesium Oxide	3.58
2	Magnesium Chloride	1.56

The material that we have used are not pure as the pure samples are available in small packages and are very costly in the Indian markets. Therefore, using the purest materials would have made the project unfeasible. So we have used industrial grade magnesium oxide which is most common in Indian markets. This grade of magnesium is slightly calcined and is cost effective. While the magnesium chloride we used is 70 percent pure. The composition of industrial grade of magnesium is given in Table 3.3

Table 3.3 – Composition of MgO used

COMPONENTS	WEIGHT PERCENTAGE
MgO	87%
CaO	5.4%
SiO	3.6%
Fe_2O_3	0.6%
Al_2O_3	0.5%
SO_3	2.9%

3.3 Design mix

Mix design is the process of choosing the suitable ingredients of building materials and defining their quantities within the purpose of achieving a material of the desired strength which is economic and has certain minimum properties which is workability, durability. It must be explained that design in the exact sense is not possible, the material used are variables as quantitatively many of their properties cannot be assessed accurately. The area of study that we have chosen is new and in India not much work is done on it, therefore, in order to obtain a satisfactory mix, we must check the estimated proportions of the mix by making trial mixes. Various design mixes are proposed for preparing such type of mix but due to variation in the raw material available and the quality of magnesium products available the mix may vary from place to place. So appropriate adjustment to the proportions of material is done until a satisfactory consistence mix is obtained.

We have adopted the mix design of the magnesium oxychloride cement and filler paste as a reference from the consistency of the Production Center mix proportion and for determination of the working consistency is based on IS: 4031 and also British standards. Based on the working consistency of magnesium oxychloride cement mix proportion paste, the workability and consistency of the other paste with bagasse ash filler and mix ratio was established and the mix showing desired consistency along with the appropriate strength is selected.

3.4 Methodology.

3.4.1 Flow of the Work:

1. Obtained the magnesium oxide and magnesium chloride from Delhi.
2. Obtained the Sugarcane Bagasse from the sugar factory from nearby Himachal. The bagasse was in ash form which was black in colour.
3. Various Mix design were prepared and then performed to obtain the desired results. After getting the optimal mix proportions we performed various test on the mix to test properties such as compressive strength, initial and final setting time, soundness and durability on the sample.
4. Then the next step is to bring it the bagasse in the form of partial replacement with magnesium oxide at the interval of 5% is done.
5. Cubes are casted for finding the mechanical properties of the MOC.
6. After air curing for 7, 14 and 28 days the specimens are tested for the mechanical properties.
7. Then the cubes formed are tested for water resistance, water absorption and fire resistance.
8. Now to see that this alternate material is economical or not we performed a cost analysis on a wall and compared the results with the cement concrete construction.

3.4.2 Burning of the Bagasse

The Bagasse that is obtained after the extraction of sugar juice from the sugarcane cannot be used in the MOC mix. It has to be burned to convert it into ash form. The bagasse ash we bought had black colour that meant that the ash contained a large amount of the carbon content so we had to decrease the carbon content so as to achieve the required properties by burning it with the help of kerosene. After burning the ash should achieve gray colour. We first decided to burnt the sugarcane residue with the help of kerosene but this was a very long process and also the ash we got was very less. For proper burning we required temperature of 200-250^{0}C which could not be achieved in the open atmosphere burning. The standard procedure to burn bagasse is through a furnace which can achieve very high temperature. The burning and heating here is in closed environment and thus can be controlled.

So to burn the ash we went to the ongoing welding and metal cutting work near the civil department. There with the help of gas cutter be burnt are ash for about half an hour and kept the hot ashes and the other black one piled up for 4 - 5 hours. Doing this achieved the desired colour and specifications of the ash. The temperature of the gas cutter ranges from 2500^0C to 3000^0C. now this gray colour ash can be used in the project with partial replacement with magnesium oxide in the mix that is prepared. The Figure 3.1 shows the gas cutter ash the bagasse ash.

There are various advantages of adding the bagasse ash into the magnesium oxychloride cement paste. The MOC samples has a problem when it comes in contact with water and further the cubes show corrosion when they come in contact with metal. With partial replacement with bagasse ash that water resistance and water absorption can be reduced. It also helps in reducing the corrosion that was seen earlier in the cubes.

Fig3.1-Burning of bagasse

3.4.3 Mixing:

The mixing of the ingredients should be done properly so that the paste formed is homogenous and the strength is uniform throughout the sample. Magnesium oxide is a white powdered material while Magnesium Chloride is in form of crystals. Magnesium Chloride if firstly dissolved in water to make a solution before mixing it with the Magnesium oxide powder. This solution is then kept still overnight so as to remove the impurities in the crystals of magnesium chloride. Then the next day to form the Magnesium chloride solution is filtered and the settled residue is removed. For the basic mix white powder of magnesium oxide is mixed with the gauged magnesium chloride solution in a given range of molar ratio.

The amount of material required is based on the molar ratios of the 3 materials i.e $MgO/MgCl_2$ and $H_2O/MgCl_2$. The mix that we used is according to the molar ratio between $MgO/MgCl_2$ and $H_2O/MgCl_2$ that was $MgO/MgCl_2$ – 11 and $H_2O/MgCl_2$ – 12. Varying the molar ratio will vary the properties of the mix and the final product.

The sequence of work done in preparing the mix of MOC is as follows.

- First the magnesium oxide solution is prepared. The crystals of magnesium chloride are mixed in water and is continuous stirred up to 10 minutes. Then this solution is left as such overnight so that the impurities can settle down. The settled impurities are removed and the concentrated solution of the magnesium chloride is prepared.
- The white magnesium oxide powder is then mixed with the concentrated solution of magnesium chloride. The mixing is done with the help of mechanical mixture for about 5 to 10 minutes but due to lack of the equipment we had to mix the constituents by hand mixing. This mixing is wet mix and ensures homogeneity of the paste thus formed as shown in Figure 3.2.
- Then the cubes of size 7.06X7.06X7.06 cm^3 are casted.
- After 24 hours the cubes are demoulded and kept for curing. As the mixing performned while making the mix is we so there is no need for wet curing. Further the MOC cubes are very prone to degrade in presence of water. The cubes are kept in rooms having no moisture.

Fig 3.2 -Mixing of the MOC paste

- Further when filler is introduced in the MOC paste the ratios of $MgO/MgCl_2$ and $MgCl_2/H_2O$ is altered. The bagasse ash is added with partial replacement with MgO. This means that the for a given volume of MOC paste to be made the quantity of MgO will reduce and accordingly the molar ratios and the quantity of $MgCl_2$ and water to be used to make the mix will vary.

- Then to test the compressive strength of the cubes and comparing the results the quantity of the filler is varied.

- Then we also tried to improve the water resistance and long term strength of the MOC by partial replacement with cement with the magnesium oxide.

Here we have the flow chart (Figure – 3.5) that demonstrates the procedure that we followed while preparing the magnesium oxychloride cement paste.

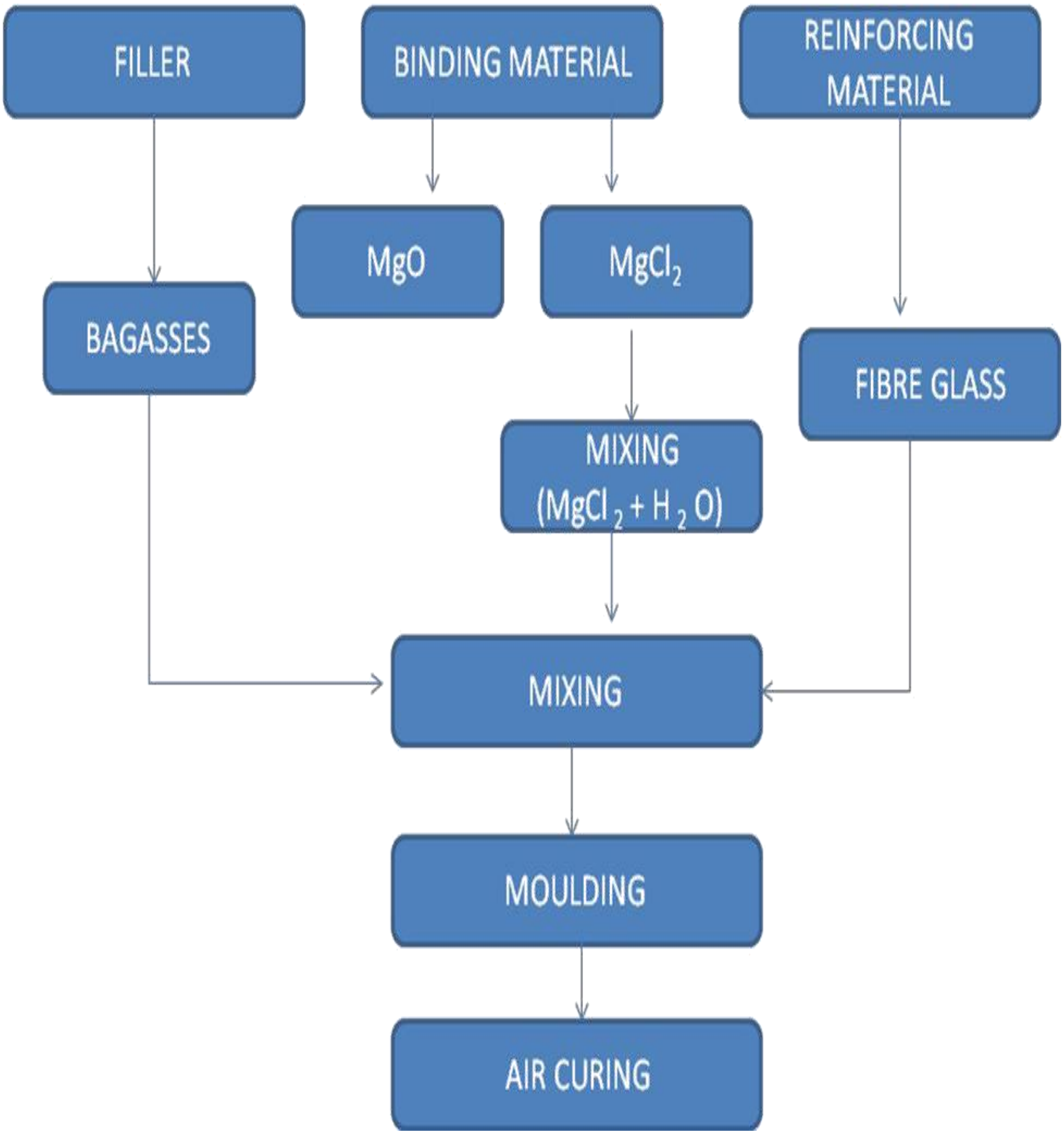

Fig 3.5 - Sampling Process Chart

CHAPTER - 4

RESULTS AND DISCUSSION

4.1 General:

We started our test with basic testing with the normal cement finding its characteristic values by conducting various test such as specific gravity of cement, finding the IST and FST of the cement paste with the help of the Vicat's apparatus, finding its percentage fineness, soundness and lastly finding its compressive strength by casting of the cubes of size $70.6X70.6X70.6mm^3$ and testing them with the help of Compression testing machine.

Then after testing the cement and getting the reference values for our tests we moved on to our main aim or material of choice MOC. Our vision was to do the testing for cement and then make the MOC paste and perform same test on cubes formed form MOC and then compare the results of the test. These tests will help us compare the properties of cement with magnesium oxychloride cement and help us determine that can it replace cement and act as alternate building material, thus justifying quality and economy considerations.

We started off by performing some basic tests on the raw materials (MgO and $MgCl_2$ and bagasse) such as specific gravity and their fineness. Then we performed our calculations and designed our mix according to the molar ratios and percentage weight of the mix. After having the initial calculations made we started making the mix with different mix proportions and side by side performed the tests to find out the initial and final setting time and found the appropriate mix that was $MgO/MgCl_2$ – 11 and $H_2O/MgCl_2$ – 12. After making the paste and finding its IST and FST, we moved on to finding it's the compressive strength of the paste formed. We made three -five different samples with different proportion with the filler and also with the partial replacement with cement as the material we used did not show any particular strength. Now after checking the structural properties of MOC, we started testing the non-structural properties of MOC. We performed three test to check water resistance, water absorption, fire resistance and insulated properties of the material. At the end to we performed a costing of a wall to check that the MOC construction is economical that old cement practices or not.

4.2 Results:

The results pertaining to the tests that were performed on the material are summarized as below:

4.2.1 Determining the Specific Gravity:

With the help of density bottle specific gravity was determined.

Table 4.1 Specific Gravity of Cement

MATERIAL	SPECIFIC GRAVITY
Cement	2.98

Table4.2 Specific Gravity of MgO

MATERIAL	SPECIFIC GRAVITY
Magnesium Oxide	3.27

However, compared to standards the specific gravities of MgO and $MgCl_2$ are 3.58 and2.7 respectively. From Table 4.1 and Table 4.2 we can conclude that magnesium will fill the voids better as it is finer than the cement.

4.2.2 Percentage Fineness test:

Percentage Fineness of Cement:

Cement manufacturer: - Ambuja

Type of cement: - PPC (part - 1)

Table 4.3 - Percentage fineness of cement

S.No.	Weight of Cement in (gms)	Weight of Cement retained on 90 µ. Sieve	% of Fineness	Remarks
1	200	12	94	Not less than 90%
2	200	11.3	94.5	

Percentage Fineness of MOC:

Table4.4 - Percentage fineness of MgO

MgO	Weight of MgO in (gms)	Weight of MgO passing 150 µ. Sieve	% of Fineness
1	200	182	91
2	200	180	90

Finer the binding material more will be its reactivity and hence more will be its bonding action. Usually the MgO powder should be finer than cement. From Table – 4.3 and Table 4.4 the MgO we used is less finer than cement and hence theoretically the bonding action of cement will be greater than the Mgo as a binder. In other journals the greater fineness has justified the greater reactivity of MgO but due to limited budget of the project we had to use industrial grade of magnesium oxide.

Percentage Fineness of Bagasse:

Table 4.5 - Bagasse Fineness

Bagasse Ash	Cement Weight (gms)	Cement Weight Passing 150 µ.	% of Fineness
1	100	86.5	86.5
2	100	85	85

The filler that we used (bagasse ash) has fineness through 150 µ sieve as 86.5 and 85 % which is coarser than the MgO which justifies that the voids of the bagasse ash will be filed with MOC as is clear from Table 4.5. The bagasse just like any other filler like sand imparts its inherit material strength to the cubes.

4.2.3 Initial Setting Time and Final Setting Time:

Table 4.6 – Setting times of cement

Sample	IST	FST	IST not less than 30min FST not less than 10 hrs
Cement	62 mins	6hr 42 mins	

The cement used was exposed to air and lumps were formed thus the FST came more but still it is less than the 10hrs which is the limit.

Table 4.7 - Setting times of MOC

Sample	**IST**	**FST**
Pure MgO and MgCl2 (1:1)	142min	8hr54min
Partial replacement by cement (10% by weight of MgO)	105min	7hr20min
Partial replacement by cement (15% by weight of MgO)	74min	6hr48min
Partial replacement by cement (25% by weight of MgO)	50min	6hr20min
Partial addition of sugarcane bagasse	74min	7hr42min

From the results in Table 4.6 and Table 4.7 we can see that the setting time decreases, this happens due to the fact that the rate of exothermic reaction is very high reason being gauging solution's high temperature. Setting time of various dry mix compositions depends upon the crystalline phases in the cementing paste.

Fig 4.1 - IST and FST by Vicat Apparatus

The relationship between the setting time of magnesium oxychloride cement and the inert filler added to the dry mix is direct whereas the setting time is inversely proportional to the temperature of the gauging solution. The Figure 4.1 depicts the samples of pure MOC that we casted and checked for IST and FST.

Optimum cementing properties are obtained for MOC when the composition for dry mix is 1:1 As mentioned earlier that the grade of the MgO used is of the industrial based so the purity is 60% so due to the impurities present in it the FST is not achieved much earlier that might be expected from the results of this type of mix. The mix was just life like a jelly after it achieved the IST. In our few trials the paste didn't even set within the period of 10 hrs. This problem was countered by reducing the water and increasing the MgO content of the mix.

The late FST of the mix may also signify that the phases that are responsible for the strength are not formed, this might be due to the less mixing or proper mixing of the mix or may even be due to the grade of the MgO we are working with.

Compared to Portland Cement the setting time was more and it may be due to the following reasons:

- Interaction among these new ingredients
- Temperature effects as the experiment were carried out in the beginning of winters.
- MOC cement paste not attaining the desired consistency

4.2.4 Compressive Strength:

Compressive Strength of Cement:

The compressive strength of the MOC is found by casting cubes of size 70.6 X 70.6X70.6 mm^3 and then testing the cubes after 7, 14 and 28 days for compressive strength. The results we got for various samples are as follows:

Table 4.8 – Strength of cement

Test number	7days strength (MPa)	14 days strength (MPa)	28 days strength (MPa)
1	4.8	12.2	22.9
2	5.3	12.8	23
3	5.6	13	23.1

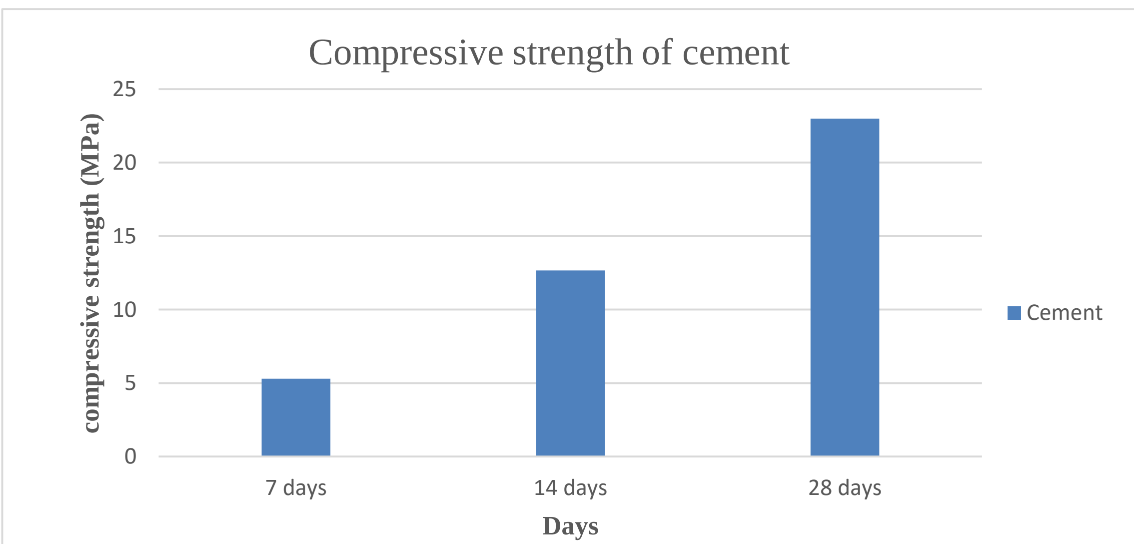

Figure 4.2 – Compressive strength of cement

The compressive strength of cement depends on the type of cement and curing method used Under normal curing conditions the cubes achieve two third of its strength (66%) in 7 days and about 90% of its strength in 28 days.

Compressive strength of MOC:

The compressive strength test of MOC is done with various samples. We started by testing of MOC having the dry ratio of 1:0, which means that the MgO to filler (Bagasse ash) ratio is 1:0. Then we performed test on cubes having dry mix of 1:1. Further to check and study the long-term strength of the material prepared we performed the compressive strength test on cubes having partial replacement of MgO by cement (i.e) 10%, 15% and 25% replacement.

Table 4.9 - Strength of MOC with dry ratio (1:0)

Material	Magnesium oxide(gm)	Magnesium Chloride (gm)	Water (ml)	7 Days Strength (MPa)	14 Days Strength (MPa)	28 Days Strength (MPa)
Sample 1	340	61.2	200	5.5	9.2	12.3
Sample 2	330	60	170	5.6	9.5	12.8
Sample 3	330	60	200	5.4	9.3	12.5

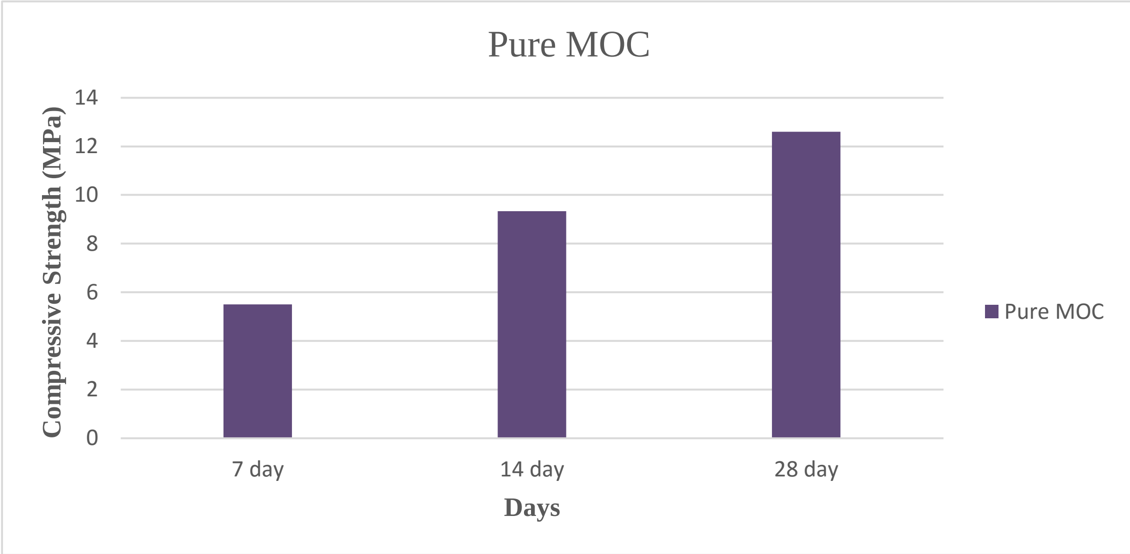

Figure 4.3 – Compressive strength of MOC

Figure 4.3 depicts more strength than Figure 4.4 that signifies that cement has more strength.

We casted three samples and altered their molar ratio of Mgo/$MgCl_2$ and $MgCl_2$/H_2O. Through these tests we found that the strength of the cubes depends on the molar ratio and the reactivity of magnesium oxide used. The main bonding phase that are responsible for adhesion of filler and MOC is phase 3 and phase 5. The formation of these phases can be ensured by keeping the MgO/$MgCl_2$ ratio higher than $MgCl_2$/H_2O ratio and by adding excess of MgO in the mix. Here with the help of table we can see that when we reduced the $MgCl_2$/H_2O ratio the compressive strength increased relatively but when this ratio is increased in the third sample by keeping the MgO/$MgCl_2$ ratio constant then the compressive strength is observed to fall.

Table 4.10 - Using Bagasse Filler with (1:1) ratio

Material	Magnesium oxide(gm)	Bagasse Ash(gm)	Magnesium Chloride (gm)	Water (ml)	7 Days Strength (MPa)	14 Days Strength (MPa)	28 Days Strength (MPa)
Quantity	165	165	29.7	193.8	7.6	12.2	17.1

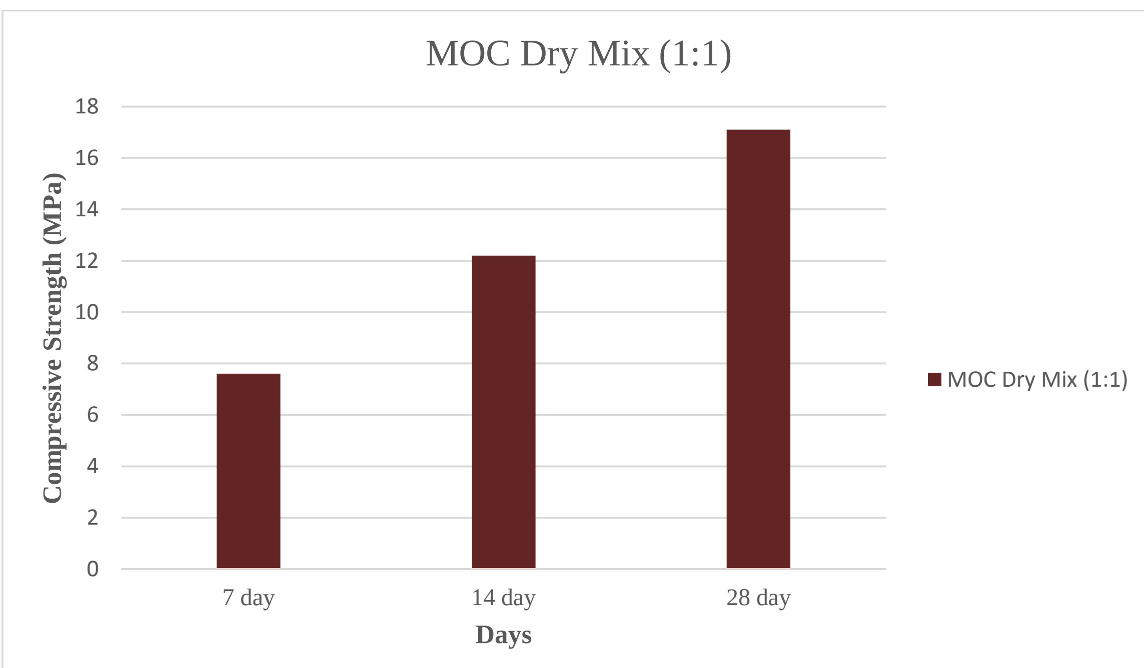

Figure 4.4 – Compressive strength of MOC with Dry mix (1:1)

This sample is made by partial replacement of MgO by bagasse ash filler. The main advantage of adding this filler is that it improves water resistance by the improvement of pore structure of magnesium oxychloride cement sample thus formed. The sample prepared has a dry mix of 1:1, which indicates that the quantity of MgO and filler used is the same. Here we can observe that the strength in Table 4.10 has improved if we compare the results with the results in Table 4.9.

Though the MOC product shows high early strength but it is not observed in our results. Our observation indicates that the strength gain is linear with no signs of high early strength. Besides, the long-term strength tends to degrade, so we decided to perform test on sample having partial replacement by cement.

Table 4.11-Strength of MOC with 10 % replacement with cement

Material	Magnesium oxide(gm)	Cement (gm)	Magnesium chloride(gm)	Water (ml)	7 Days Strength (MPa)	14 Days Strength (MPa)	28 Days Strength (MPa)
Quantity	300	30	54	133.5	6.5	9.4	12.6

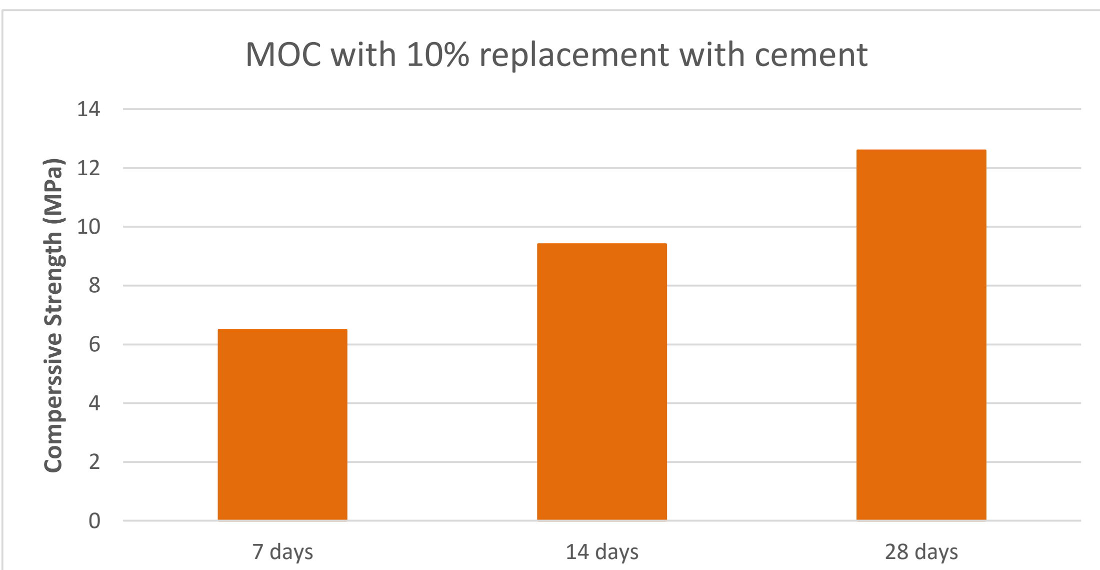

Figure 4.5 – Compressive strength of MOC with 10% replacement with cement

From Table 4.11 it is clear that with 10% partial replacement of Magnesium Oxide with cement the early strength of 7 days and 14 days have increased but the later strength has no prominent change. Furthermore, when compared with the mix with dry mix of 1:1, the strength is still less than what we obtained from the mix with filler as partial replacement.

The strength at the later stage is still less and no visible change is noticed, so we increased the percentage of cement replacement.

Table 4.12 – Strength of MOC with 15 % replacement with cement

Material	Magnesium oxide(gm)	Cement (gm)	Magnesium chloride(gm)	Water (ml)	7 Days Strength (MPa)	14 Days Strength (MPa)	28 Days Strength (MPa)
Quantity	561	99	90.2	270	7.1	10.8	14.2

The 15% replacement of magnesium oxide with cement showed some improvement in the strength at later stage as is seen visually in the graph (Figure 4.6), but it fails to achieve the strength that is needed for structural use and to ensure safety of the structure. Besides the strength at the early age is much or less the same as in case of pure MOC product.

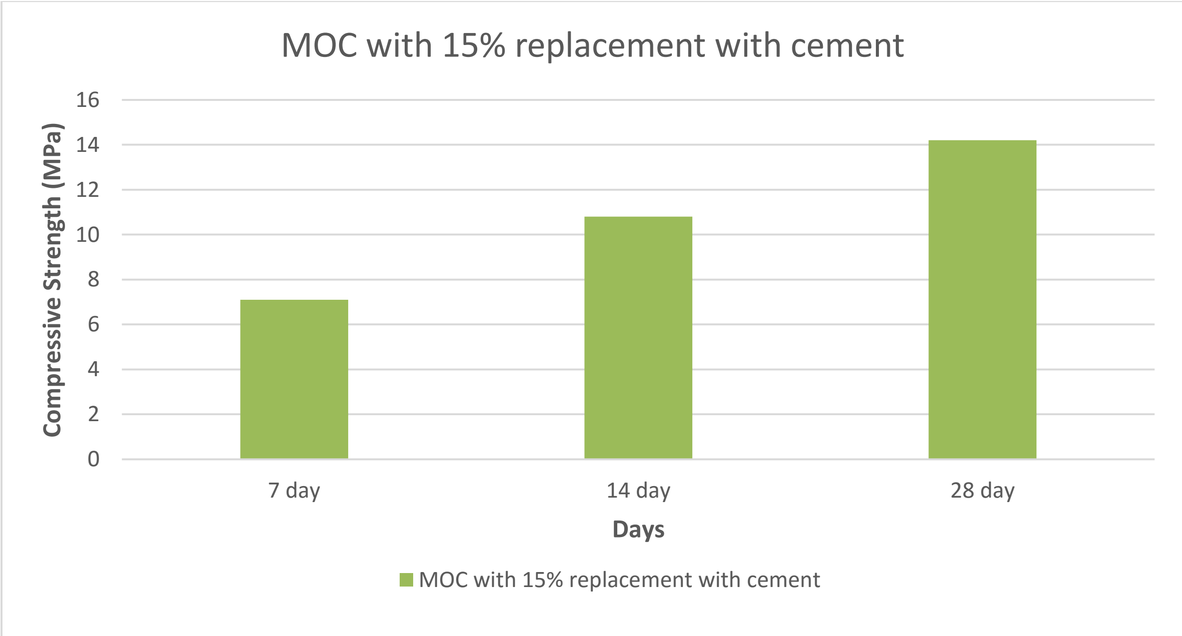

Figure 4.6 – Compressive strength of MOC with 15% replacement with cement

In hope to get the desired results of attaining structurally accepted strength we performed last compression test on the sample having 25% partial replacement with cement.

Table 4.13 - Strength of MOC with 25 % Cement replacement

Material	Magnesium oxide(gm)	Cement (gm)	Magnesium Chloride (gm)	Water (ml)	7 Days Strength (MPa)	14 Days Strength (MPa)	28 Days Strength (MPa)
Quantity	495	165	89.1	272	8.5	12.2	15.5

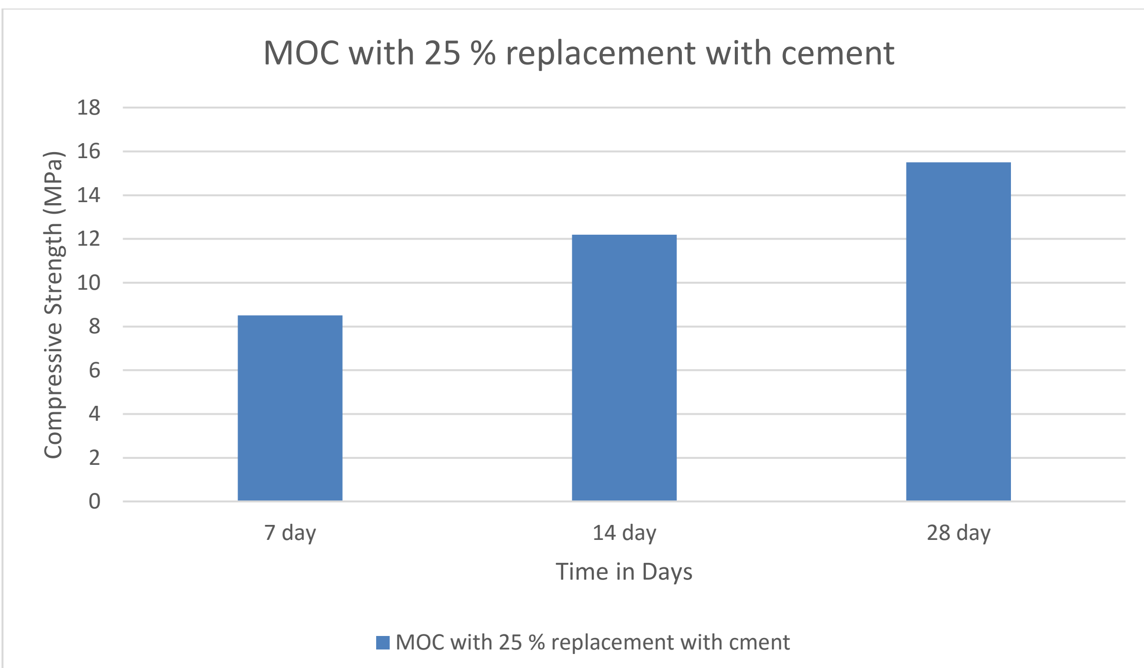

Figure 4.7 – Compressive strength of MOC with 25% replacement with cement

4.2.5 Graphical Comparison:

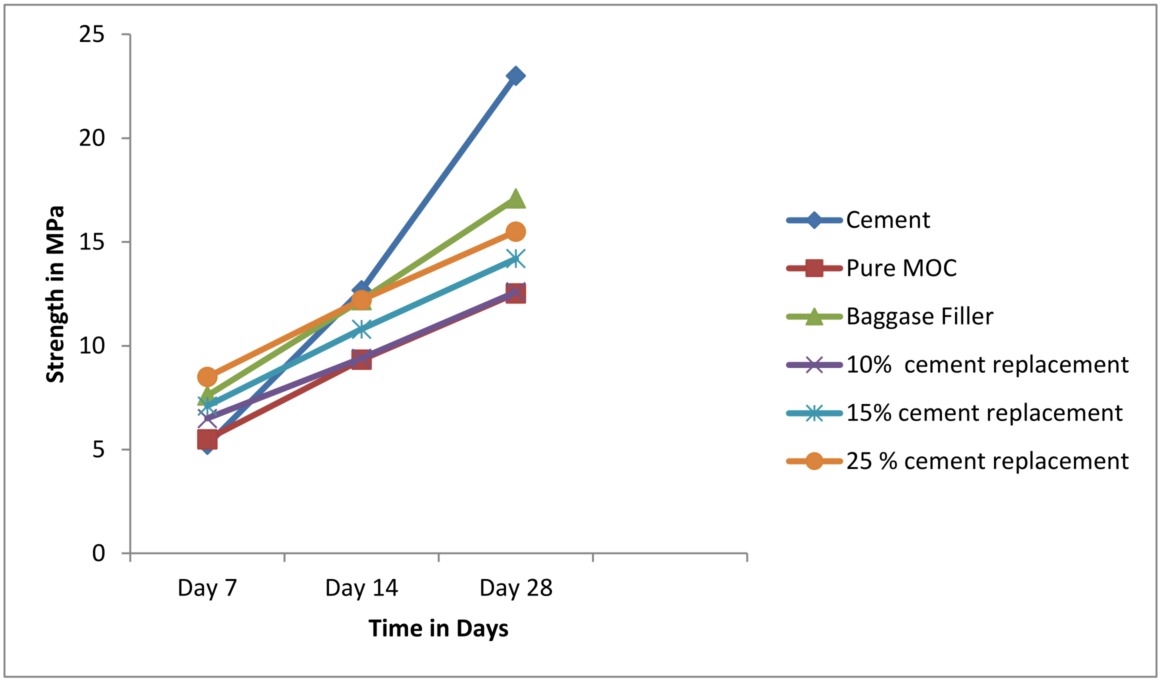

Figure 4.8 – Strength comparison graph

Therefore, from Figure 4.8 we observed that the pure Magnesium Oxychloride Cement and the products that we obtained through the partial replacement of cement do not possess high final strengths.

Thus we tested the material further for nonstructural properties.

Non Structural tests:

4.2.6 Water Absorption Test

Water absorption test is done to check the moisture absorption tendency of the samples. Water absorption test is carried out by immersing the samples in water at normal temperature. After immersion samples were weighted at regular intervals. The percentage water absorption (W%) was then calculated Table 4.14 and Table 4.15 shows the results of water absorption tests.

Table 4.14 – Water absorption test on pure MOC

PURE MOC	SAMPLE 1	SAMPLE 2	SAMPLE 3
Dry Weight(gm)	495.6	501	503
Surface Saturated weight(gm)	854	859	850
Water Absorption(gm)	72.3	71.45	68.98

Table 4.15 – Water absorption test on dry MOC mix of 1:1

MOC with Bagasse replacement	SAMPLE 1	SAMPLE 2	SAMPLE 3
Dry Weight(gm)	405.8	401.5	410.01
Surface Saturated weight(gm)	603.05	611	598
Water Absorption(gm)	48.6	52.17	45.35

- Water absorption is a drawback of MOC binder.
- Water absorption of the pure MOC cubes is 70% which makes it less reliable as an alternate material.
- Partial replacement of MgO with sugarcane ash can reduce the water absorption
- This is the most economical way to improve the water resistance of the cubes.
- While working with MOC in highly humid environments the surface of the products of magnesium oxychloride cement produce a white material called “white frost”.

4.2.7 Water resistance test:

Moisture and water resistance is the main short coming of the MOC product. In presence of water the MOC paste loses its strength and its bonding ability. So this the reason why use of MOC is restricted to hot regions around the world. This test is performed by visual inspection, the cubes are immersed in the water for 24 hours and then the cubes are visually inspected for any weathering on the surface.

Pure MOC sample:

Figure 4.9 – Weathering of pure MOC

- Pure MOC cube when immersed in water for 24 hours it showed weathering of the cube due to loss of the binding action. The edges and the corner of the cubes are mostly got weathered.
- The weathering of the cube as seen in Figure 4.9 is due to the instability of the phase-5 of the MOC sample which is responsible for the bonding of the constituents of the sample with the exposure of the sample to water for long time.
- This test shows that MOC has poor water resistance.
- Along with the weathering due to water there are clear signs of corrosion form the mould which indicate that this paste of MOC is not suitable for use in any type of work with the reinforcements. Being susceptible to corrosion this problem need a solution which is provided by addition of filler the paste of MOC.

Sample with bagasse filler:

Figure 4.10 – water resistance on filler based MOC cube

- the filler based cube when immersed in water for 24 hours shows far better water resistance then the pure MOC cube.
- By varying the quantity of filler in the MOC cube the water resistance of the cubes can be improved as visible in Figure 4.10 but the quantity of the filler should we optimized so that the strength of the sample remains unaltered.

4.2.8 FIRE RESISTANCE TEST

Fire resistance and insulation properties of MOC is one of the desirable properties in any building material. Tests were conducted with the help of a gas cutter having the temperature of flames ranging from 1000-1200^{0}C. the samples were cut with the help of saw into a thickness of 3 cm and then exposed to the flames. For testing the fire resistance of the material we took three different samples:

- Pure MOC sample
- Pure cement sample
- MOC sample partially replaced with bagasse.

Pure MOC Sample:

Figure 4.11 – Fire resistance test on pure MOC cubes

Filler based sample:

Figure 4.12 – Fire resistance test on filler based MOC cube

The sample was exposed to the flames for about 10 to 15 minutes. The sample with partial replacement with bagasse also shows good fire resistance and insulation as the heat from the gas cutter was not felt on my palm as depicted in Figure 4.11 and Figure 4.12.

Whereas the other samples which consisted of the pure cement sample and samples in which partial replacement has been done showed much higher degree of heat transfer as compared to that of pure MOC samples. Figure 4.12 shows fire resistance test on cement cube.

Figure 4.12 – Fire resistance test on cement cube

4.3 Cost Analysis:

For a building material to be regarded as alternate building material it should satisfy various criteria of strength, non-structural properties and cost effectiveness. Today world is more aware about the environment and the people are constantly searching for greener ways of construction. MOC products are such products that help reduce the carbon dioxide emissions in the environment and has proved to be a good alternate building material. Though the journals and various patents claim that this material has high early strength but we were not able to achieve that much high early strength so we suggested to use this material in not structural purpose or for non-load bearing walls and partition walls. This product shows good insulation and fire resistance properties and has also shown improvement in the water resistance capacity. So in order to replace the presently used cement the MOC should also be economical.

For the cost analysis of the MOC product various variables has to be considered.

The cost depends on the production cost along with some general expenses.

The manufacturing cost as follows:

1. Fixed costs:
   These are expenses which do not vary with changes in casting and production and practically remain constant from year to year. These are the bills that have to be paid whatsoever the quantity of the product produced. The items of the fixed operating costs are:

   - Operating labor
   - Laboratory cost
   - Supervision
   - Plant overhead
   - Depreciation
   - Local taxes

2. Variable costs:
   It includes expenditures which depend upon manufacturing operations directly and they rely on the quantity of material casting done.

The variable costs are:

- Raw material cost
- Cost of Utilities

Assumptions:

Costing in a real project is a very intricate process as the variables that has to be considered while summarizing the cost are huge. So to just check the economic feasibility of the material the assumptions had to be made. Some of the assumptions considered are:

- The fixed cost is assumed to be the same for concrete and need not to be considered. As it doesn't vary with the type of work.
- The raw materials are locally available. The utilities and the transportation cost can be reduced but assuming that the construction site is near to the raw materials.
- To make the costing easy the estimation is done on 1 m3 wall. This wall is assumed as non-load bearing wall.

Rate Analysis of 1 Cum M20 Grade in 1:1.5:3 Proportions

Dry mortar required to make 1 cum of cement concrete = 1.54 cum

Therefore

a) Cement Bags required = $\frac{1*1.54*28.8}{5.5}$ = 8.07 Bags

b) Sand required = $\frac{1.5*1.54}{5.5}$ = 0.42 m^3

c) Aggregates required = $\frac{3*1.54}{5.5}$ = 0 .84 m^3

Table 4.15 – Cost analysis of concrete

Description	**Quantity** (m^3)	**Rate (₹)**	**Amount(₹)**
Cement Bags	8	320	2560
Sand required	0.42	600	252
Coarse Aggregate(20mm)	0.56m^3	700	392
Coarse Aggregate(10mm)	0.28	700	196
Total			₹3400

Rate Analysis of 1 Cum of MOC:

Table 4.15 – Cost analysis of MOC

Description	**Quantity**	**Rate(₹/Kg)**	**Amount(₹)**
MgO	470	3.5	1645
$MgCl_2$	84.61	4	338.44
Bagasse	470	0.75	352.5
Total			₹2336

The comparison of cost of casting1 m^3 of concrete and MOC shows as shown in Table 4.14 and Table 4.15 justify that if the materials are locally available and all other expenses are fixed then MOC is economical than concrete. Thus being economical than concrete construction this can be used as an alternate building material. Further as the strength of MOC is not much, it is desirable to use this material for the construction of partition wall and non-load bearing walls.

CHAPTER - 5

CONCLUSION

Anything new that is produced should be assessed from cradle to grave before it has been produced and brought into practical use. The understanding of a material and its behavior is of utmost importance such that it does not get vitiated by the passage of time and the environmental agencies. MOC or Sorel Cement as it is commonly known exhibited marvelous properties of high early strength, fire resistance, low thermal conductivity, light weight, low alkalinity and a good bondage or adhesion. It was found to be advantageous over OPC or PPC because of its self-efficiency in dry curing. Hence it is highly recommended to be used in hot, dry regions where moist curing cannot be provided and early setting owing to speeded hydration occurs thereby making it fit for being used in immediate repairs like rapidly patching mortar for runways and roads.

Hence, overall if we see the utilization of MOC as an alternate building material yields positive results if it is used for nonstructural purposes. The only main drawback of this new binder encountered was its poor performance with water. Hence more endeavor by means of intensive research and experimentation using various ecofriendly and cost effective fillers followed by regular examining in this field needs to be done so that this binder can be used in fluctuating environment too and it won’t be long when the building industry would be driven towards “green cement” production.

Present Status and future scope:

In the field of MOC various research is required to improve the water resistance and long term strength. The future of the MOC is bright as an alternate building material but it requires more research in the following fields:

Chlorine ion capture agent:

The poor water resistance of the MOC is due to the formation of leaching out of the residual chlorine. Cao Ming-li (2010) [10] put forward this view. Water susceptibility of MOC can be improved with the help of chlorine ion capture agent as it enhances its stability in damp environment**.**

Addition of inert fillers:

Fillers like Low temperature rice husk ash, fly ash and dolomite which increased the water resistance property along with additional properties such as fire proofing and good insulation. Different filler enhance different properties of the mix makes the other properties of the product to suffer. More research is needed to improve and optimize the fillers to be added.

Surface coating and dip:

It is also proposed that Coating of a resin (generally epoxy resin) on MOC products form a water repellent layer on the surface of MOC, making it water resistant.

These are various areas to be worked on and making a greener way of construction that would help us to save conserve our earth and also pace with the need of construction and housing in the future.

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