

The Concrete Incorporated With Zeolite for Reducing Atmospheric Carbon Dioxide

Hanusha Durisetty, Kiranmai Palcham, K. Prasad Babu

Abstract: *The Intergovernmental Panel on climate changes have concluded that- Most paths to halting global temperature increases at 2 degrees and every way to decrease it to 1.5 degrees depend on adopting methods of sucking CO₂ from the sky. "CO₂ removal has gone from a moral hazard to a moral imperative," says Julio Fried Mann senior research scholar at the Center for Global Energy Policy at Columbia University. There are many industries emitting the flue gases which include steam, sulphur dioxide, nitrogen dioxide, carbon dioxide. One such industry which emits carbon dioxide is cement industry. A single cement industry accounts for around 5 percent of global carbon dioxide emissions. Concrete is the second most widely used material on earth after the water. Concrete is used for wide range of applications like construct buildings, bridges, roads, runways, sidewalks, and dams. So, here's the concrete with zeolite powder and zeolite sand that captures the carbon dioxide from the ambient air and reduces the atmospheric carbon dioxide making it eco-friendly. Also addition of zeolite to the concrete improves the mechanical strength of the concrete. It is more durable than the ordinary Portland cement. In this review paper, we will discuss the performance and properties of concrete incorporated with zeolite.*

Keywords: Zeolite, Concrete, Carbon dioxide, eco-friendly

I. INTRODUCTION

According to IPCC report, the carbon dioxide concentration in atmosphere has increased from 0.03% to 0.04164% since 1800's. Concrete which acted as the building block for the modern world is now accountable for more nearly 7% of global carbon emission, standing second to iron and steel industry, according to International Energy Agency [8]. Cement is man-made material which is used in manufacture of concrete along with sand, aggregates and water. Cement is produced by heating clay, silica, limestone at high temperatures (around 1500°C) of which limestone is the cause for CO₂ emission, resulting from decomposition of calcium carbonate. More than 50% carbon dioxide emissions in construction sector come from cement production. Depending on the technique nearly 0.73 to 0.99 tons of

CO₂ is released per 1 ton of cement[]. Hence, the concrete production industries are focused on reducing their carbon footprint by various methods such as replacing cement with supplementary cementitious materials (SCM's), using carbon capture and storage techniques etc., to achieve the goal of 2°C temperature change. The manufacture of Portland cement was patented nearly 200 years ago, since then it hasn't seen much difference in the process which makes it a challenge in climate change action[8].

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But, research from past few decades have shown a possibility of replacing cement with zeolite powder or zeolite sand for absorbing carbon dioxide without decreasing the strength of concrete. In fact, incorporating concrete with zeolite increases its mechanical properties and other properties like resistance to sulfates and chlorine attacks.

II. 2. ZEOLITE

Zeolites are volcano polo zones mostly available as sedimentary rocks near volcano's or water bodies.

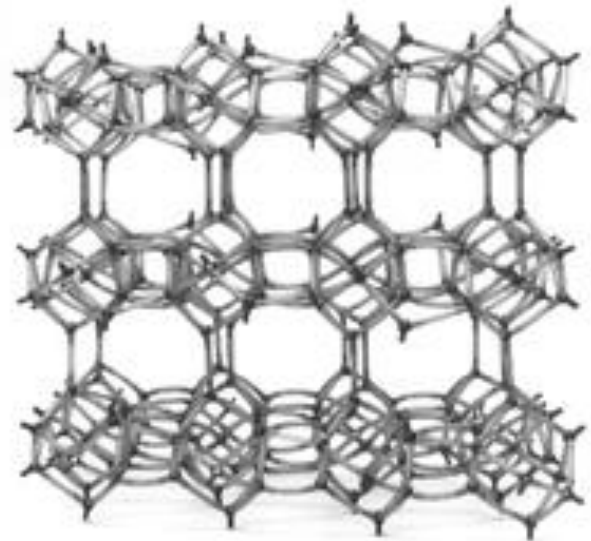


Fig 1: Structure of Zeolite

$M_{2n}O \cdot Al_2O_3 \cdot xSiO_2 \cdot yH_2O$.

M can be any of metals, including sodium, lithium, potassium, calcium and magnesium. The variable "n" stands for the valence of the metal cation, and "y" for the number of water molecules in the structure of zeolite

They crystallize in post-depositional environment over periods ranging from thousands to million years in sea basins[2] They are characterized by honeycomb structures with extremely small pores and channels up to 3×10^4 [2]. Zeolites are aluminosilicates of alkaline and alkaline earth metals like sodium, calcium, magnesium with tetrahedral structure with cavities occupied by water or cations. They are featured by open channels, are capable of cation exchange and accommodating water molecules. Zeolite can be available in nature directly or also can be synthesized. Nearly 50 types of natural zeolites and 150 above types of zeolites are used in industries [3]. They are used in many general applications such as ion-exchangers in purification, as catalysts, for removal of H₂O, CO₂, SO₂ etc.,[3].

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The structure and formula of zeolite are shown below. Because of their abundance and porous structure zeolites can be used as admixture in concrete and mortars. Research has been going on effect and change in properties of concrete after replacing various concentrations of cement ranging from 5%, 10%, 20%, 25% to nearly 40% by zeolites. It is found that incorporating zeolites increases the stability of the cement mixture in concrete. The compressive strength of concrete with zeolite was found to be greater with aging when compared to that of concrete with ordinary Portland cement. Therefore, it can be used in place of cement. Zeolite has improved surface hardness, strength, durability of concrete by pore refinement. Zeolite in concrete and mortar decrease permeability and impedes harmful reactions like alkali-silica and alkali carbonate reactions which cause cracking of concrete [4]. Concrete blocks with zeolites are capable of absorbing carbon dioxide significantly greater when compared to normal concrete, absorbing nearly 60% of carbon dioxide released from manufacturing process. This makes concrete with zeolite eco-friendly. Zeolite incorporated concrete can be potentially used in construction of buildings, concrete roads, structures for absorbing atmospheric carbon dioxide thereby contributing to decrease in global warming.

III. PROPERTIES

Zeolites are available as powder as well as sand. This zeolite powder or sand is used to replace cement or coarse aggregates. The concentrations of zeolite powder or zeolite sand used can be varied according to the requirements of final concrete properties. Some of the properties of concrete which are changed when mixed with concrete are as follows:

3.1 Compressive strength

Various experiments and researches conducted have shown that the compressive strength of concrete increases with increase in zeolite concentration. Syed Eashan Adil et al. conducted experiment where maximum compressive strength was found for 20% of zeolite [9]. Similarly, research conducted by Jegan Mohan et al. showed that compressive strength increased by increasing zeolite concentration from 10% to 30% and was maximum for 30% concentration of zeolite [2]. In most research works, initial compressive strength of concrete with zeolite was almost comparable or similar with that of concrete with ordinary Portland cement, but increased by significant values at 28th day. However, Sammy Y.N Chan showed that increasing zeolite concentration to above 40% resulted in decrease in compressive strength. So we need to understand that there is optimal concentration of zeolite that can be added which has to be determined [4]. In most of experimental works, the optimum amount of zeolite that can be used was found to be in the range of 10-20%.

3.2 Carbon dioxide absorption

The main advantage of using zeolite in concrete is it absorbs carbon dioxide from atmosphere and reducing the overall carbon dioxide emissions in the manufacturing process of concrete. Concrete generally has ability to absorb carbon dioxide, but this phenomenon takes place very slowly. The carbon dioxide absorption capacity of concrete is increased by approximately 30% when mixed with zeolite. The amount of carbon dioxide that can be absorbed

by concrete is directly related to the amount of zeolite added to it. The amount of carbon dioxide absorbed also depends on the environmental conditions in which concrete is kept. In an experiment, Concrete with zeolite of bottle size of 10cm diameter and 12 cm height was found to absorb 1gm-14gm of carbon dioxide in 5 days[3].

3.3 Sulphate Resistance

Sulphate resistance is one of important factors to be considered while choosing the type of concrete. Because of the small pore size and high cation exchanging capability adding zeolite leads to change in pore design of the concrete, thereby decreasing permeability of concrete. This makes it difficult for the sulphate ions from to enter the pores and react with concrete. Sulphates react with the calcium hydroxides and aluminosilicates present in matrix of the concrete [4]. These reactions are expansive, leading to cracking of the concrete. These cracks ultimately result in decrease in adhesive strength of cement. It is found that replacing cement by 15% of zeolite produced the sulphate resistance as that of Portland cement made specially for protection against sulphates [4].

3.4 Chloride permeability

Chloride permeability has proven to be dangerous for concrete which degrades the quality of concrete. When concrete is exposed to environment containing chloride ions, diffusion of chlorine takes place due to difference in concentration in two ways. Some of the ions diffuse and bond to the pores and some of them diffuse as free atoms and reach the reinforced steel in case of reinforced concrete. When the concentration of chloride ions is high enough in the reinforced concrete corrosion of steel takes place [6]. This leads to degradation of concrete. Zeolites decrease the permeability by changing the pore structure of the concrete and hence improves the resistance of concrete to chloride ions[4].

3.5 Expansion Resistance

In many western countries temperatures drop to minus centigrades. In such situations expansion resistance of concrete plays a vital role. When concrete is subjected to temperatures below 0°C, there is a possibility for water in pores to freeze, increasing in volume and causing cracks in the interior of concrete. These cracks decrease the adhesion capacity of the cement paste. But when zeolites are added, zeolites in concrete create aerated pores which increase the freeze thaw resistance [4]. Thereby providing some extra space for water to expand, zeolites increase expansion resistance if concrete.

3.6 Setting time

Setting time is the time in which concrete hardens completely. Concrete with different mixture concentrations have different specified setting times which determine the hardness and mechanical strength of the concrete. Zeolites increase the setting time of concrete. At higher temperatures gypsum loses water molecules but zeolites retain water below 90°C, regulating the reaction between aluminosilicates and calcium hydroxides [4].

3.7 Fineness

Fineness is the extent to which the cement is finely divided. The fineness of cement has an major impact on the rate of hydration. It also determines the rate of gain of strength and the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence faster development of strength[10]

3.8 Flexular strength

Flexular strength is the maximum bending a material can withstand without braking. In experiment conducted by Pouria Mohsen Zadeh et al. showed that flexular strength is increased by 17.85% by replacing 10% cement with zeolite. In the study of properties of concrete conducted with varying the concentrations of zeolite from 10%, 20%, 30% , Lakshmi G Das et al noticed a increase in flexular strength of the concrete of maximum 25%, Zeolite enhances the flexular strength of the concrete. It also increases its durability and lifetime.

IV. RESULTS AND DISCUSSION:

4.1. Fresh concrete properties

Workability of concrete assesses the behavior of fresh concrete from mixing up to compaction. The terms mixability, transportability, mouldability and compactability collectively represent workability. Various tests were performed to measure workability of concrete and the effects of Zeolite on workability properties of concrete were studied. The workability values in terms of Slump (mm) and compaction factor for varying Zeolite percentage of concrete mix are given in Fig.2

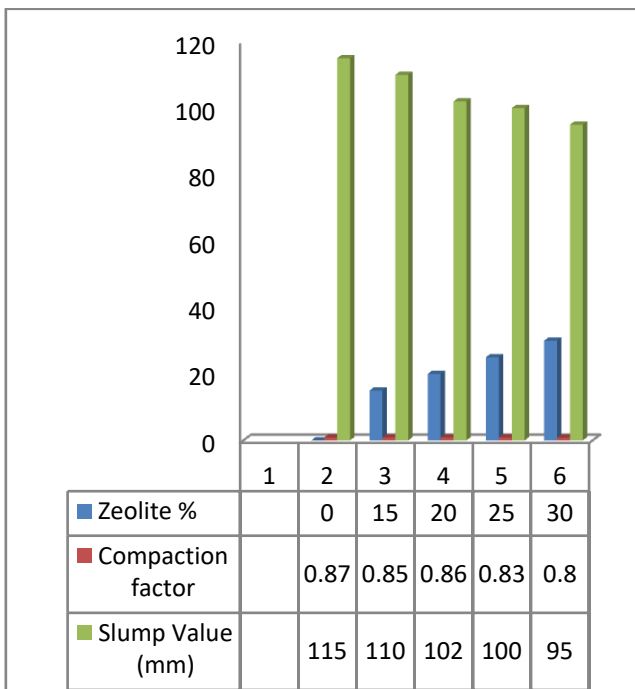


Fig: 2 Fresh Concrete Properties

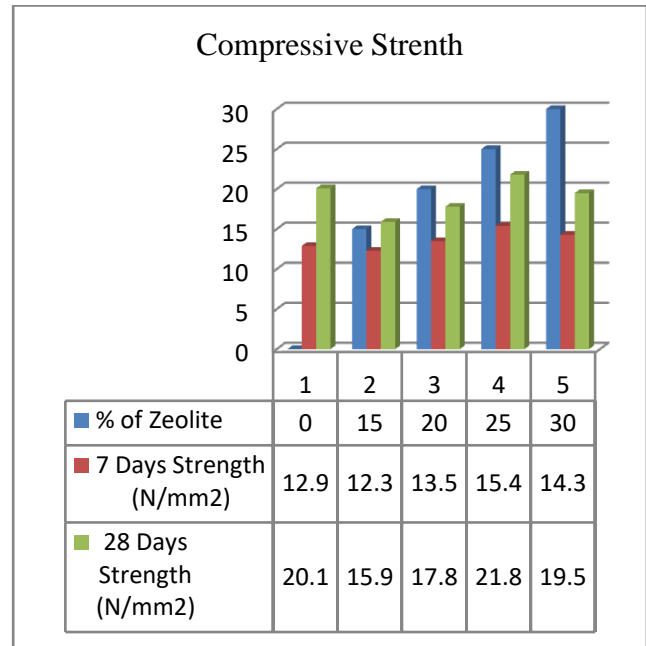


Fig: 3 Compressive strength using Zeolite

4.2. Flexural strength

The change in flexural strength with respect to different percentages of Zeolite is represented in Fig. 3, which shows that maximum Flexural Tensile Strength (FTS) was reached corresponding to 10% addition of Zeolite. The improvement of FTS due to 10% addition of Zeolite was because of the increase in strength of concrete with the addition of Zeolite. The value of flexural strength is shown in table 9 for different % of Zeolite in 7 days and 28 days.

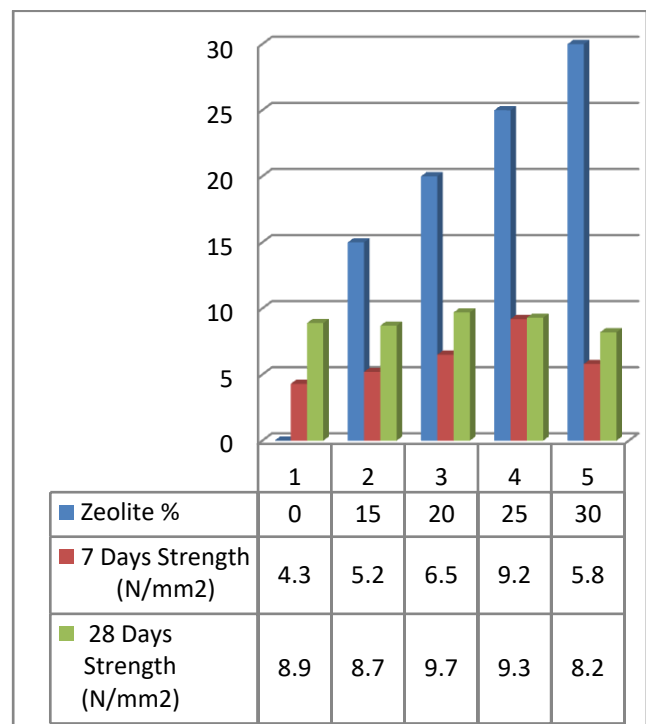


Fig:4 Flexural strength of concrete for various % of Zeolite

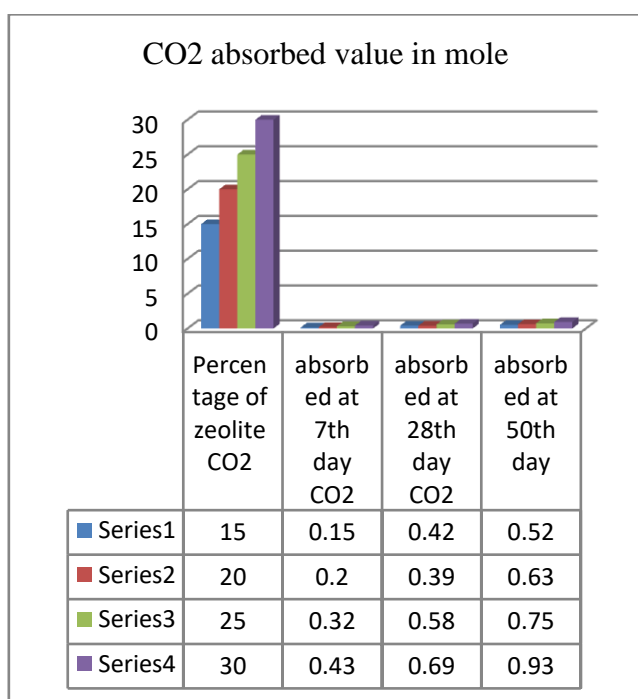
4.3 CO₂ Absorption Test

In this study another test was conducted to determine the amount of CO₂ absorbed by the concrete block using Zeolite. Test on zeolite block (CO₂ absorption test)

Aim- Test of CO₂ Absorption by Zeolite concrete block
Apparatus- Weighing Balance, Moulds of Size 15x15x15 cm.

Procedure:-

1. Take Water, Cement, M sand, zeolite and aggregate in the required proportion.
2. Prepare blocks of dimension 15x15x15 cm for testing of CO₂ absorption.
3. By mixing suitable quantities of materials the concrete blocks are casted.
4. These blocks are then kept in water for curing.
5. Weight of the blocks are taken on pre-planned days up to 50th day
6. Following observations are obtained.



V. ADVANTAGES AND LIMITATIONS

5.1 Advantages

- Eco friendly
- Concrete with zeolite can used as the carbon dioxide sink
- Enhances mechanical strength, surface hardness

5.2 Limitations

- Increase in zeolite concentration results in decrease of slump value due to the cubical and rough shape. Workability of concrete is measured by conducting slump cone test. As zeolite concentration is increased slump value is decreased decreasing the workability of concrete [5].
- Is expensive

VI. CONCLUSION

It is estimated that there will be increase in the cement consumption by 23% in coming 30 years[8]. Hence, it is required to look for ways to decrease carbon emissions from

cement. In this regard, replacement of cement and its coarse aggregates in concrete by natural zeolites is one of the effective ways which is proven. Zeolites increase strength, mechanical properties of concrete and therefore can be used in construction, in laying roads etc. Although they are abundant in nature, Zeolites are expensive, which limits the amount of zeolite that can be used to make it commercially available for everyone. They improve surface hardness, flexural strength, resistance to sulphates and chlorides. Concrete incorporated with zeolite has the capability to absorb carbon dioxide from atmosphere making it eco-friendly.

FUTURE SCOPE

Pouria Moshen Zadeh et al. studied the properties and durability, mechanical strength of concrete with zeolite mixed with meta-kaolin found that best outcomes were achieved with a combination of 10% zeolite, and 10% meta-kaolin mixed with 100% micro-nano bubbles of water, which increased compressive strength, tensile strength and flexural strength. Further research in properties of concrete which provide us more information and behavior of concrete when zeolite is used along with other admixtures and additives gives us more options to replace cement in concrete to decrease overall carbon dioxide emission.

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