

Ecofriendly Concrete by Partial Replacement of Cement by Zeolite

Anila Mary Jacob¹, Lakshmi G Das²

P.G. Student, Department of Civil Engineering, Indira Gandhi Institute of Engineering & Technology for Women
Nellikuzhy, Kothamangalam, Kerala, India¹

Associate Professor, Department of Computer Civil Engineering, Indira Gandhi Institute of Engineering & Technology
for Women Nellikuzhy, Kothamangalam, Kerala, India²

ABSTRACT: Global warming is the present serious issue and carbon dioxide is one of the harmful gas for this. Concrete is also emitting carbon dioxide so it's a responsibility of civil engineer to solve the problem. Zeolite is a material which absorb harmful gases such as carbon dioxide and doesn't emit it hence we are conducting an analysis of engineering properties of concrete containing natural zeolite as supplementary cementitious material in the Portland-cement based binder in an amount of 15%, 20%, 25% and 30% is presented. Along with the structural properties the carbon dioxide absorption ability is also evaluated. The studied parameters include basic physical characteristics, and mechanical properties.

KEYWORDS: CO₂, Zeolite, eco friendly concrete, absorption, slump.

I. INTRODUCTION

Production of cement is not only energy intensive but it presents also one of the important CO₂ emission sources in the world. Depending on the production technology, the CO₂ emission ranges from 0.73 to 0.99 t of CO₂ per 1 t of cement. More than one half of this amount is caused by calcinations, which is integral part of the cement production. Therefore there are a lot of attempts to use supplementary cementitious materials (SCMs) which can replace at least a part of cement in concrete by more environmental friendly materials.

The most common representatives of SCM are industrial by-products, such as fly ash, silica fume, or blast furnace slag. Zeolites, as probably the most often used natural SCM, belong to the volcanic pozzolans. By using zeolite may reduce the consumption of cement in concrete. It reduces of production of CO₂ while production of cement in industries. Natural zeolite as volcanic or volcano sediment material has a 3D frame structure and is classified as a hydrated aluminosilicate of alkali and alkaline earth cations. Crystals are characterized by a honeycomb like structure with extremely small pores and channels, varying in size from 3x10⁴. This project describes the feasibility of using the Zeolite in concrete production as partial replacement of cement which helps in generating an ecofriendly building material. This paper checks the optimum percentage of Zeolite that can be replaced with cement without any loss of strength and the absorbability of carbon dioxide. Experiments are carried out to obtain an inference.

Martin Keppert et al [1] found that 20% zeolite content in the blended binder is the most suitable option. Meysam Najimi et al. [2] Studies, the application of natural zeolite as a supplementary cementitious material. The incorporation of 15% natural zeolite was found as an appropriate option for improving strength and durability properties of concrete. Nai-Qian Feng et al.[3] says the effect of zeolite, including both an ion-exchange function and an adsorption function, that can be used in the manufacturing of new constructions products as well as building materials. These products have been successfully applied to overcome some construction difficulties in engineering practice. Fereshteh Alsadat Sabet

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

et al. [4] discusses the effect of natural zeolite, silica fume and fly ash on the properties of fresh and hardened concrete. Slump flow, super plasticizer demand, compressive strength, electrical resistivity, water absorption and chloride permeability was measured for all mixes. The test results indicate that incorporation of mineral admixtures generally improve mechanical and durability characteristics of the mixes. B.D. Ikotun et al. [5] presents an investigation into the effect of a modified zeolite additive (PWC) on strength and durability behaviour of concrete. The additive, a blend of selected alkaloids and zeolite, is commercially available and effectively used in soil stabilization for road construction. PWC was used in proportions of 0.6%, 0.8%, and 1.0% of the weight of cement. Concretes of 0.5 water / cementitious ratio were subjected to workability, split tensile strength, compressive strength, oxygen permeability, sorptivity, and porosity tests. Hydration behaviour of cementitious systems and the pozzolanic effect of PWC additive were studied using differential thermal analysis and thermo gravimetric analysis. Results show that PWC is effective in improving concrete strength when used at optimum proportions found to be between 0.6% and 1%.

The work in this paper is done by doing the experimental study. First of all materials required are collected and they are tested for the basic properties. In this work for the analysis of strength properties and carbondioxide absorbability concrete models including cubes beams and cylinders are made and checked for the fresh concrete tests and hardened concrete properties. Paper is organized as follows.

II. RELATED WORK

The present investigation focuses on assessment of the suitability of Zeolite as a cementitious material by conducting various analysis and hence to understand the influence of Zeolite on concrete properties (fresh state and hardened state). It was also proposed to determine the optimum level for replacement of Zeolite to attain maximum compressive strength. Materials used for the experiments and their tests are mentioned below. First of all studied the basic properties of materials and the experiment are carried out. These details are arranged in the following sections. These testes are carried out in the normal environmental conditions. The normal curing conditions are also provided for the concrete.

1. Cement

The binding materials used in concrete are Ordinary Portland cement. This cement is of 53 grades conforming to IS 456-2000 and is having desired properties. The properties of cement were determined by adopting standard procedure. The properties are given in the following table. The normal consistency, initial and final setting time, specific gravity and fineness are main basic properties which were determined

Table 1.: Properties of cement

Physical Property	Cement
Normal consistency	32 %
Initial setting time(min)	55
Final setting time(min)	340
Specific gravity	3.15
Fineness	8 %

2. Fine Aggregate

Fine aggregate used is M-sand. Laboratory test was conducted on fine aggregates to determine the different physical properties as per IS 2386 (part-3)-1963(Reaffirmed 2002). The test results are tabulated in table 2. The fineness is obtained using the sieve analysis and the result is such that the fine aggregate is confirming to IS 383 – 1970.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

Table 2. Properties of Fine aggregate.

Properties	Fine Aggregate
Specific Gravity	2.65
Fineness modulus	5.41
Water Absorption	1.8%

3 Coarse Aggregate

The coarse aggregate for the work is crushed stone. Angular shape aggregate of size is 20mm and below. The aggregate which passes through 75mm sieve and retain on 4.75mm are known as coarse aggregate. The grading of coarse aggregates should be as per specifications of IS 383-1970. The fineness is calculated from sieve analysis and the result is such that confirming to IS specifications.

Table 3. Properties of coarse aggregate

Properties	Coarse Aggregate
Specific Gravity	2.67
Sieve Analysis	As per IS code limit
Water Absorption	0.349

4. Water

The water should be fit for drinking. The water is used for mixing as well as for curing the samples. It should not have high concentrations of sodium and potassium and there is a danger of alkali-aggregate reaction. Natural waters that are slightly acidic are harmless, but water containing humic or other organic acids may adversely affect the hardening of concrete. Such water as well as highly alkaline water should be tested. Water satisfactory for mixing is also suitable for curing purposes. However, it is essential that curing water should be free from substances that attack hardened concrete like free CO₂ etc.

5. Zeolite

Zeolites are porous crystalline aluminosilicates. The zeolite framework consists of an assemblage of SiO₄ and AlO₄ tetrahedra, joined together in various regular arrangements through shared oxygen atoms to form an open crystal lattice containing pores of molecular dimensions into which molecules can penetrate. Like most silicates the zeolites are based on TO₄ tetrahedra, where T is an aluminum or silicon atom. The vast 3-dimensional networks are a result of all four corners for the tetrahedra being shared, producing low density micro porous materials. Zeolite structures can be thought to exist of finite or infinite (chains, layers etc.) component units.

Table 4: Properties of Zeolite

Physical Property	Zeolite
Normal consistency	38 %
Initial setting time(min)	55
Final setting time(min)	410
Specific gravity	2.98
Fineness	8 %

6. Concrete mixtures

The procedure for selection of suitable ingredients of concrete and determination of their relative amounts with the purpose of producing a concrete of the necessary strength, durability, and workability is termed as the concrete mix design. Mix ratio of 1: 1.5: 3 for water binder ratio of 0.5 was taken in the present investigation. Table 6.1 represents mix proportions of concrete for varying Zeolite replacements by weight of cement. The control concrete without Zeolite was also fabricated along with above mixes.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

Table 5: Mixture Proportioning

Sl.No	Mix	Water (L)	Cement (Kg)	Fa (Kg)	Ca (Kg)	Zeolite % (Kg)
1	M ₀	191.1	383	550	1279	0
2	M ₁	191.1	325.55	550	1279	15 % =57.45
3	M ₂	191.1	306.4	550	1279	20% =76.6
4	M ₃	191.1	287.25	550	1279	25% =95.75
5	M ₄	191.1	268.1	550	1279	30%=114.9

7. Testing of Specimens

Various experiments to find the fresh state and hardened properties of concrete at varying percentages of Zeolite were conducted in the present investigation. The Zeolite percentages correspond to 15%, 20%, 25% and 30% by weight of cement. The test on fresh concrete such as slump cone test and compaction factor tests were carried out and were obtained as per code specifications. The compressive strength was then found for 7 and 28 days on cubes of 150mm dimension. The Split Tensile Strength (STS) of concrete at 7 and 28 days was performed on cylindrical specimen of 150 mm diameter, 300 mm height. The Flexural Tensile Strength (FTS) was performed on beams of size 100×100×500mm after 7 days and 28 days curing. Three trials are conducted for each above mentioned tests. Along this the carbon dioxide test was also carried out. For this cubes were casted and placed at different sites and after 7 days ,28 days and 50 days the checking were done.

Experimental results

1. Fresh concrete properties

Workability of concrete assesses the behaviour of fresh concrete from mixing upto compaction. The terms mix-ability, 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 Table (6).

Table 6: Fresh concrete properties

Zeolite %	Compaction factor	Slump Value (mm)
0	.9	120
15	.885	114
20	.86	107
25	.83	101
30	.8	94

The results of slump test to assess the workability of fresh concrete indicates that the incorporation of natural zeolites in concrete tends to reduce the slump value of fresh concrete due to its cubical particle shape and rough surface. Hence the slump value gets decreases as the quantity of natural zeolite increases in the concrete mix.

2. Hard concrete properties

2.1 Compressive strength

The improvement of compressive strength from a period of 7 days to 28 days for mixes with varying percentages of Zeolite is presented in Fig.1. The compressive strength from control specimen and specimens with varying percentages of Zeolite is reported in Table 7. The table indicates that the 28 days strength increases from 20.53 MPa to 22.66 MPa with incorporation of 25% Zeolite. This enhancement of compressive strength of concrete with Zeolite implies that Zeolite can be added as supplementary cementitious material.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

Table.7 Compressive Strength

% of Zeolite	7 Days Strength (N/mm ²)	28 Days Strength (N/mm ²)
0	13.33	20.53
15	12.3	16.8
20	13.92	18.58
25	15.8	22.66
30	14.47	19.63

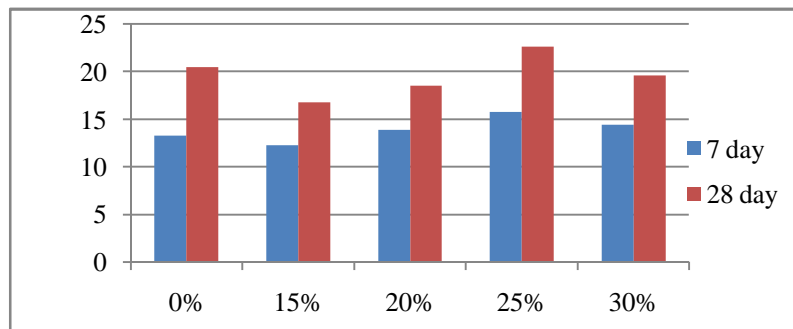


Fig: 1 graph for compressive strength of cube using zeolite

2.2 Split tensile strength

Fig. 2 shows the variation of split tensile strength with respect to the percentage of Zeolite for 7 days and 28 days. Table 8. Gives the values of split tensile strength of 7 days and 28 days for various % of Zeolite. It is seen that the split tensile strength of concrete is increasing from 3.57 MPa to 6 MPa as the percentage of Zeolite increases from zero to 25%. The ages shall be calculated from the time of the addition of water to the ingredients.

Table 8. Split tensile Strength

% Of Zeolite	7 Days Strength (N/mm ²)	28 Days Strength (N/mm ²)
0	2.45	3.57
15	2.38	2.78
20	3.22	5.23
25	3.36	6
30	2.66	5.73

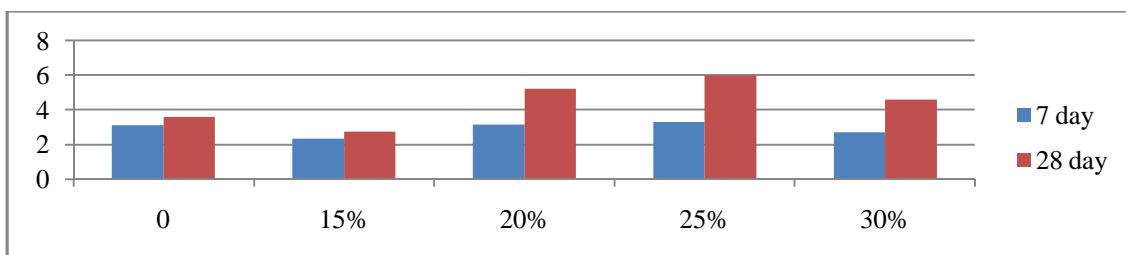


Fig: 2 graph for split tensile strength of concrete for various % of Zeolite

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

2.3. 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.

Table 5.5.1 Split Tensile Strength for M20 Grade Concrete

% OF ZEOLITE	7 DAYS STRENGTH (N/mm ²)	28 DAYS STRENGTH (N/mm ²)
0	4.83	9.3
15	5.33	9.16
20	6.33	10
25	9.16	10.5
30	6.5	9.2

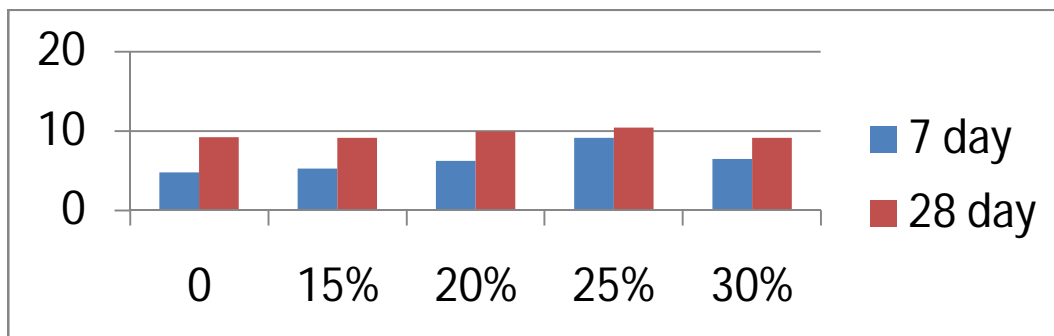


Fig: 3 graph for flexural strength of concrete for various % of Zeolite

2.4 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

Table 5.6: CO₂ absorbed value in mole

Percentage of zeolite	CO ₂ absorbed at 7 th day	CO ₂ absorbed at 28 th day	CO ₂ absorbed at 50 th day
15%	0.17 mole	0.45 mole	0.46 mole
20%	0.2 mole	0.42 mole	0.68 mole
25%	0.34 mole	0.613 mole	0.77 mole
30%	0.45 mole	0.79 mole	0.98 mole

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

Calculation:

Calculation of CO₂ absorbed by blocks = $\frac{\text{Final Weight} - \text{Initial weight}}{\text{Molecular weight of CO}_2}$

III. CONCLUSION

From the above studies the conclusions can be noted as below,

- The incorporation of natural zeolites in concrete tends to reduce the slump value of fresh concrete due to its cubical particle shape and rough surface.
- The zeolite made concrete is capable of absorbing CO₂ without any emission of it. The zeolite concrete block of size 15x15x15 cm has ability to absorb around 1 mole of CO₂ in 50 days. This property does not lose its strength and durability.
- The compressive strength, split tensile strength, flexural strength of concrete was found to be more at 25% of zeolite at the age of 28 days when compared with conventional concrete.

REFERENCES

- [1] Eva Vejmelkova, Dana Konřakova, Tereza Kulovana, Martin Keppert, Jaromir Z umar, Pavla Rovnanikova, Zbyne k Kerřner, Martin Sedlmajer, Robert C erny "Engineering properties of concrete containing natural zeolite as supplementary cementitious material: Strength, toughness, durability, and hygrothermal performance" *Cement & Concrete Composites* Vol. 55, (2015) pp 259–267M.
- [2] Meysam Najimi Meysam Najimi, Jafar Sobhani, Babak Ahmadi, Mohammad Shekarchi "An experimental study on durability properties of concrete containing zeolite as a highly reactive natural pozzolan" *Construction and Building Materials* Vol. 35, (2012) pp 1023–1033Marcelo Bertalmio, Luminita Vese, Guillermo Sapiro, Stanley Osher, "Simultaneous Structure and Texture Image Inpainting", *IEEE Transactions On Image Processing*, vol. 12, No. 8, 2003.
- [3] Nai-Qian Feng a, Gai-Fei Peng b, "Applications of natural zeolite to construction and building materials in China" *Construction and Building Materials* Vol. 19, (2005) pp 579–584 Eftyhios A. Pnevmatikakis, Petros Maragos "An Inpainting System For Automatic Image Structure-Texture Restoration With Text Removal", *IEEE trans.* 978-1-4244-1764, 2008
- [4] Fereshteh Alsadat Sabet, Nicolas Ali Libre, Mohammad Shekarchi "Mechanical and durability properties of self consolidating high performance concrete incorporating natural zeolite, silica fume and fly ash" *Construction and Building Materials* Vol. 44 (2013) pp 175–184
- [5] B.D. Ikotun, S. Ekolu "Strength and durability effect of modified zeolite additive on concrete properties" *Construction and Building Materials* Vol. 24, (2010) pp 749–757