A Study on Partial Replacement of Cement by Zeolite and Silica Fume in Concrete

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***Abstract*:- Releasing of greenhouse gas results in global warming. In which cement production plants are also blamable for some quantity of carbon dioxide emission. Hence it is necessary to minimize the amount of carbon dioxide emission from cement production plants. So zeolite 4a powder and silica fume substituting for cement, investigation is carried out. Zeolite has the property of absorbing carbon dioxide up to certain percentage and silica fume used to keep the strength of the concrete. In this study grade of concrete used is M30 and cement is substituted by 5%, 15%, 25% of zeolite and silica fume combination. Concrete is checked for its carbon dioxide absorbing capacity, workability parameters and strength parameters**.

1. INTRODUCTION

Cement is producing by heating clay, limestone, silica, at high temperatures at (around 1500℃) of which limestone is the cause for CO_2 emission, resulting from decomposition of calcium carbonate. More than 50% carbon dioxide emissions in construction sector come from cement production only. Depending on the technique nearly 0.73 to 0.99 tons of CO_2 is released per 1 ton of cement. The manufacture of Portland cement was patented nearly for about 200 years ago, since then it hasn't seen much difference in the process which makes it a challenge in climate change action. In this study grade of concrete used is M30 and cement is substituted by 5%, 15%, 25%, of zeolite, silica fume combination. Concrete is checked for its strength parameters and carbon dioxide absorbing capacity as well as its workability.

2. LITERATURE REVIEW

Akshatha K. B. (2018), Studied about Concrete using Silica Fume and concluded that compressive strength of concrete gets enhanced with the use of silica fume and the split tensile strength and flexural strength is also found with similar variation when silica fume was used. There is no particular trend of variation in modulus of elasticity of normal and silica fume concrete.

Mr. Mengal G A et al. (2018), Studied on carbon dioxide absorbing concrete roads and stated that the zeolite made concrete is capable of absorbing CO2 without any emission of it. General concrete evolves huge amount of CO2 into the atmosphere. The zeolite of bottle of size 10 cm diameter and 12 cm height has ability to absorb around 1 to 14 moles of CO2 in 5 days.

P. Ramu et al. (2017), Study on Replacement of Fine Aggregate and Cement by Zeolite Sand & Zeolite Powder by 30% & 10% and concluded that at 28 days the compressive strength is found to be 6% more and the split tensile strength is 10% more than conventional concrete.

Syed Eashan Adil et al. (2017), study on carbon dioxide absorbing concrete blocks and observed that zeolite powder-based concretes have achieved a high strength for replacement of zeolite powder for 28 days when compared to conventional concrete and there is no effect on strength of block prepared by zeolite sand and powder as a substitute. The zeolite block can be used in the road pavements, Chimney of factory as well as at the faces of building.

S. Subash et al. (2016), Replacement of cement by 10% & 30% of zeolite for the absorption of carbon dioxide by M30 concrete and found the similar compressive strength.

Balraj More et al. (2014), Even a block of size of 10x10x10 cm made of zeolite mix, has the ability to absorb 1 mole of carbon dioxide in 50 days. And the property of zeolite doesn't lose the durability and strength.

T. Subramani et al. (2016) have studied about partial replacement of cement by 25% of zeolite for the absorption of carbon dioxide by M30 concrete. He stated that addition of zeolite up to 25% improves the strength properties of concrete.

Balraj More et al. (2014) have studied about carbon di oxide absorbing concrete blocks and observed there is a reduction in pollution. In this experiment they have used a block of size 10x10x10 cm, which has the ability to absorb 1 mole of carbon di oxide in 50 days. And the property of zeolite doesn't lose the strength and durability and This type of blocks is affordable and hence can be used general purpose and it will be eco-friendly.

3. OBJECTIVES

The main objective of this project is to know the behaviors of concrete with partial replacement of cement from silica fume and zeolite at different proportions of replacement in M30 grade concrete and to study the effect of different replacement levels of silica fume and zeolite on the strength development of masonry mortar, concrete and to obtain the optimum replacement level of silica fume and zeolite based on strength requirements. The objectives of study include,

- To determine the engineering properties of Zeolite.
- To study the behaviors of conventional concrete.
- To study the mechanical properties of modified concrete with Zeolite by 5%,15% & 25%.
- To study the mechanical properties of Silica Fume.
- To compare the strength properties of conventional concrete with modified concrete.

4. MATERIAL USED

Cement: ordinary Portland Cement.

Fine Aggregate: River sand passing through 4.75mm IS Sieve. Coarse Aggregate: Local quarry aggregates of 20mm down size and 12.5 mm down size.

Zeolite: Zeolite is a rock composed of micro porous alumina silicates, and oxygen. It occurs naturally in several regions of the world where volcanic activity has occurred near water. Since they are unreactive and based on naturally occurring minerals, they are not believed to have any harmful environmental impacts. Zeolites having high degree of hydration and it has ability to absorb harmful gases.

For example, the removal of water, carbon dioxide, and sulfur dioxide from certain natural gas streams can be accomplished with the help of zeolites.

Characteristics of zeolite

- High degree of hydration
- Low density and large voids volume when hydrated
- Stability of the crystal structure when hydrated
- Cation exchange properties
- Uniform molecular-sized channel in dehydrated crystal
- Ability to absorb gases and vapour's.
- Catalytic properties.

Properties of Zeolites

- Absorption
- Ion exchange
- Catalytic activity

Silica fume: Silica fume is a byproduct of silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete work, because of its chemical and physical properties. Concrete containing silica fume can have very high strength and has good workability, bond Strength and can be very durable. Silica fume is available from suppliers of concrete admixtures. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor.

Properties of silica fume

- Silica fume enhances the properties of fresh and hardened concrete.
- Silica fume reduces segregation and bleeding
- Low slump value
- High durability
- High compressive strength
- Suitable for mass concreting since it prevents thermally induced cracking

5. MATERIAL PROPERTIES

A. Test on cement

The following tests have been conducted on cement used

1. Specific gravity
2. Normal consistency
3. Initial and final setting time
4. Fineness test

1. Specific gravity of cement

Specific gravity normally defined as the ratio of the mass of given volume of the materials and mass of equal volume of water.

2. Normal Consistency of cement

This test was conducted according to Indian Standard method using vicat's apparatus, the object of conducting this test is to find out the amount of water to be added to get a paste of normal consistency that the paste of certain standard solidity.

3. Initial and Final Setting Time of Cement

This test was conducted according to Indian standard method using vicat's apparatus, initial setting time is regarded as the time elapsed between the moment water is added to the cement to the time that the paste starts losing its plasticity.

4. Fineness test (Sieve method) method

The Fineness test of cement is done by sieving cement sample through standard IS sieve. Table 1 shows basic properties of cement.

Table 1 Basic properties of cement

TEST	RESULT	AS PER IS CODE
Specific Gravity	3.15	3.1-3.16 for OPC as per IS 4031(part 4)-1998
Normal consistency	28%	22-30% as per IS:4031(part 4)-1998
Initial setting time	33min	Should not be less than 30 min as per IS 4031(part 4)-1998
Final setting time	10 hrs.	Should not be more than 10 hrs. (600 min)
Fineness test by sieve analysis	6.14%	IS code for finance test of cement is IS: 4031 (Part 1) – 1996.

B. TEST ON FINE AGGREGATE

1. Specific gravity of fine aggregate

Specific gravity normally defined as the ratio of the mass of given volume of materials and mass of equal volume of material and mass of an equal volume of water.

2. Sieve analysis of fine aggregate

The fineness modulus is an index number which is roughly proportional to the average size of the particles in an aggregate sample. Table 2 shows the Properties of fine aggregate. Fig 2 shows the graph showing the results of sieve analysis of fine aggregate.

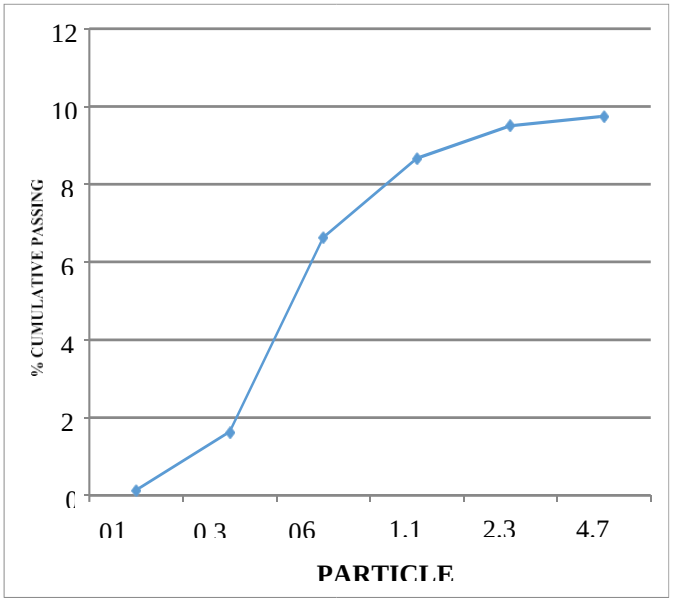

Fig 2 Graph showing the results of sieve analysis of fine aggregate

Table 2: Properties of fine aggregate

Test	Result	As per IS code
Specific Gravity of fine aggregate	2.74	As per IS:2386(part I)-1963
Sieve analysis test	2.39	2.0-4.0 as per IS:2386(part I)-1963

C. Tests on coarse aggregates

1. Specific Gravity Test

It is done to determine the density of aggregate.

2. Impact test on aggregate

It is the **ability of aggregates** that resist sudden **impact or shock load on it.** Also, it can be defined as the **resistance of aggregate** to failure by **impact load** is known as the **impact value of aggregate.**

3. Crushing Value Test of Aggregate

Aggregate Crushing value is a relative resistance of aggregates to crushing under gradually applied compressive load. Aggregate

4. Abrasion Test of Aggregate

Abrasion Test is the measure of aggregate toughness and abrasion resistance such as crushing, degradation and disintegration.

5. Shape Test on Aggregates (Elongation & Flakiness Index)

This test is done to determine the shape of aggregate dimension.

6. Water Absorption

Water absorption of aggregates is the % of water absorbed by an air-dried aggregate when immersed in water at 27°C for a period of 24 hours. Table 3 shows the properties of Coarse aggregate

Table 3: Properties of Coarse aggregate

Test	Result	As per IS code
Specific gravity test	2.74	2.5-3.0 as per IS:2386(part I)-1963
Water absorption test	0.5%	0.1-2% as per IS:2386(part I)-1963
Impact value test	26.86%	20-30% as per IS: 9377:1979
Abrasion value test	12.55%	As per IS 2386(part IV)-1963
Crushing strength test	10.77%	As per IS: 9377:1979
Flakiness test	11.54%	As per IS:2386(part I)-1963
Elongation test	28.9%	As per IS:2386(part I)-1963

6. DESIGN MIX RATIO

This is obtained from design mix calculation using IS 10262:2009 & IS 456:2000.

Table 4: Quantity of material

S NO.	MATERIALS	QUANTITY
1	Cement	426 kg/m^3
2	Fine Aggregate	660 kg/ m^3
3	Coarse Aggregate (20mm)	1153 kg/ m^3
4	WATER	192 L
5	Silica admixture (1.1% of cement)	4.686 kg/ m^3
6	Zeolite admixture (1.1% of cement)	4.686 kg/ m^3

To find the design mix ratio, divide the calculated value of all materials by the weight of the cement. Therefore, Mix Ratio of M30 Grade concrete by weight is

Cement: F.A: C.A: Water = 1 :1.54: 2.7: 0.45

8.Result and discussion

A. WORKABILITY TEST RESULT

It is the most common method for measuring the workability of freshly mixed concrete. It can be performed both in lab and at site. Uniformity of the concrete regarding workability and quality aspects can be assessed from batch to batch by observing the nature in which the concrete slumps. Fig 2 shows the graph for workability test result. And fig 5 shows the slump Cone test.

Table 5: Workability test result

Zeolite (%)	Silica fume (%)	Height of mould H1(mm)	Height of subsided concrete H2(mm)	Slump=H1-H2 (mm)
0%	0%	300	224	76
5%	0%	300	225	75
0%	5%	300	229	71
5%	5%	300	227	73
15%	0%	300	225	68
0%	15%	300	237	63
15%	15%	300	238	62
25%	0%	300	232	68

Fig 2: Slump Cone test

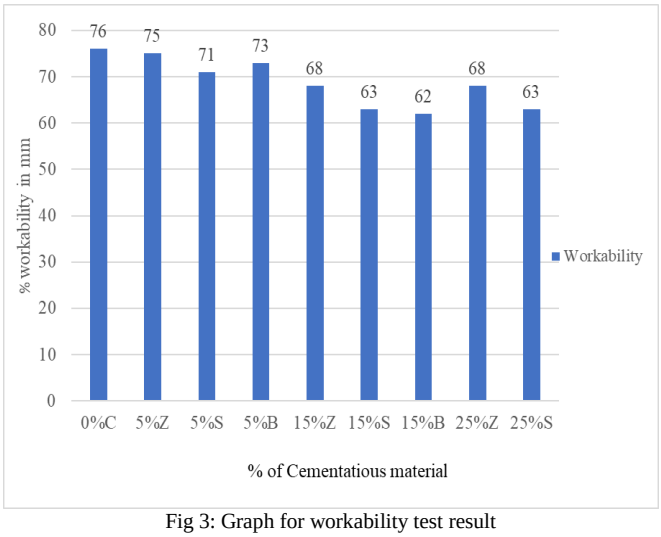

Fig 3: Graph for workability test result

Hence, it is found that if we are increasing the percentage of Zeolite and silica fume in fresh concrete it is found to be decrease in workability.

B. **COMPRESSIVE STRENGTH**

The tests were conducted on cubic samples. The size of the cube is 150 x 150 x 150 mm, if the total nominal size does not exceed 20 mm. Table 6 shows the compressive strength test result. Fig 4 shows the casting of modified and conventional concrete, Fig 5 shows the curing of modified and conventional concrete & Fig 6 shows the compressive strength test

Fig 4: Casting of modified and conventional concrete

Fig 5: Curing of modified and conventional concrete

Fig 6: Compressive strength test

Table 6: - Compressive strength test result

Zeolite (%)	Silica fume (%)	Compressive Strength for 7 days N/mm^2	Compressive Strength for 14 days N/mm^2	Compressive Strength for 28 days N/mm^2
0%	0%	23.14	29.20	33.81
5%	0%	23.24	29.51	33.97
0%	5%	23.63	29.87	34.75
5%	5%	24.57	30.69	35.49
15%	0%	23.68	29.66	33.63
0%	**15%**	**26.08**	**33.08**	**37.84**
15%	**15%**	**26.84**	**32.39**	**36.95**
25%	0%	21.57	27.44	31.61
0%	25%	25.96	30.84	35.86

Hence, at 15% addition of Zeolite and silica fume in fresh concrete is found to be best increment in strength comparison with conventional concrete and also found to be decreasing if we go above 15%.

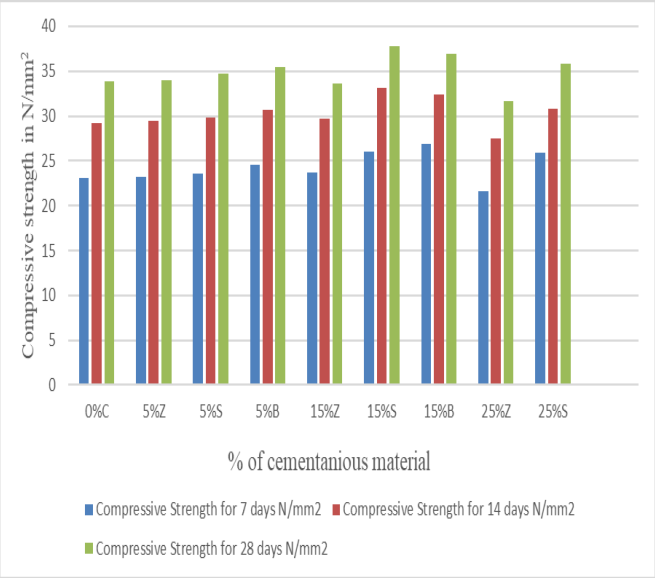

Fig 7: Graph for compressive strength test result.

B. SPLIT TENSILE TEST

Tensile strength is one of the main and significant properties of concrete. Concrete in general should not withstand direct pressure because of its low tensile strength and fragile nature. (a) direct (b) indirect. Figure 5.4 Shows the arrangement for Tensile test and Table 5.3 shows the Split tensile test result.

Figure 8: Arrangement for Tensile test

Hence, at 15% addition of Zeolite and silica fume in fresh concrete is found to be best increment in split tensile strength comparison with conventional concrete and also found to be decreasing if we go above 15%.

Table 5.3: Split tensile test result

Zeolite (%)	Silica fume (%)	Split tensile Strength for 7 days N/mm²	Split tensile Strength for 14 days N/mm²	Split tensile Strength for 28 days N/mm²
0%	0%	2.32	2.92	3.34
5%	0%	235	2.95	3.38
0%	5%	2.36	2.98	3.47
5%	5%	2.45	3.06	3.54
15%	0%	2.36	2.96	3.36
0%	**15%**	**2.51**	**3.10**	**3.58**
15%	**15%**	**2.68**	**3.23**	**3.59**
25%	0%	2.15	2.74	3.16
0%	25%	2.59	3.08	3.58

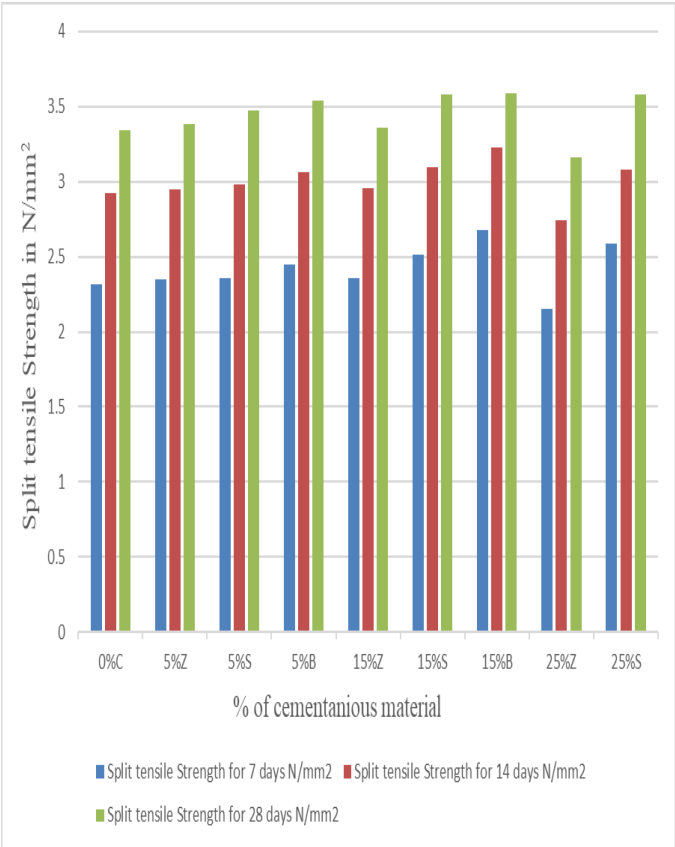

Fig 9: Graph for Split tensile test result

D. CARBON DIOXIDE ABSORPTION TEST RESULT

Calculation of CO2 absorbed by blocks

= Final Weight – Initial weight/Molecular weight of CO2.

Table 5.4 Shows carbon dioxide test result. fig 5.9 Shows the Specimen for Carbon dioxide test

Table 5.4: Carbon dioxide test result

Zeolite (%)	Silica fume (%)	Weight of block (W1)	Weight of block after 14 days (W2)	Amount of CO_2 absorbed= W2-W1/44 (mole)
0%	0%	860	860	0
5%	0%	860	868	0.18
0%	5%	910	910.5	0.01
5%	5%	855	862	0.15
15%	0%	920	933	0.29
0%	15%	835	836	0.02
15%	**15%**	**875**	**887**	**0.27**
25%	**0%**	**900**	**915**	**0.34**
0%	25%	890	891	0.04

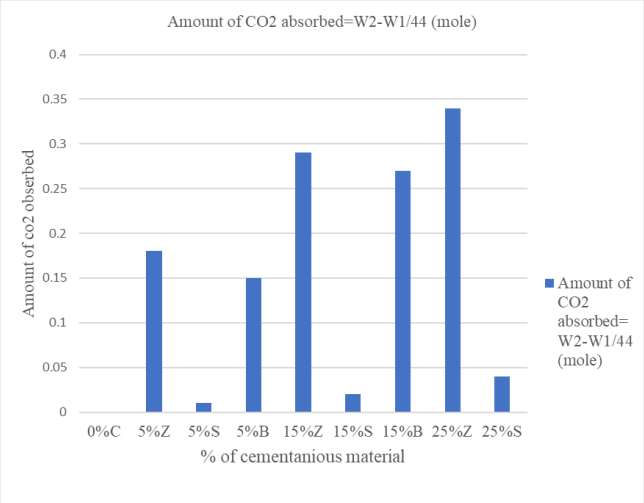

Fig 10: Graph for Carbon dioxide test result

CONCLUSION

It is estimated that there will be increase in the cement consumption by 23% in coming 30 years. 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.

- For 28 days the Compressive strength is found to be increased by 3.19%.ie: -from 33.81 MPa to 36.95 Mpa by using 15% Silica fume and zeolite in comparison with convectional concrete.
- Tensile strength also increased from 3.34 Mpa to 3.59 MPa (for 15% Silica fume and zeolite) and it also decreases if more than 15% of Silica fume and zeolite are added.
- Silica fume and Zeolite is found to be little bit costlier than cement but even though it is costlier but have more importance in places like Delhi, Jaunpur, Rajasthan, etc.
- Carbon Dioxide absorbed by convectional concrete is found to be 0 mole of CO2 and for 25% of zeolite it is found to absorb 0.34 mole of CO2.

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[3] Balraj More, Pradeep Jadhav, Vicky Jadhav, Giridhar Narule, Shahid Mulani “Carbon dioxide Absorbing Concrete Block”.

[4] Is code book IS 456-2000 for plain and reinforced concrete and IS 2386 for method of test for aggregate for concrete and IS 10262-2019 for mix design has also been used.