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Effect of Natural Zeolite on Properties of Binary Blended High Strength Cement Concrete

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ABSTRACT: In the present-day construction practice, the application of high-strength concrete has emerged as a viable material to conventional concrete in high-rise structures, bridges, offshore structures, and dams. The use of high-strength concrete permits efficient structural designs that allows longer span members and smaller sections. The use of ternary cements benefits long-term properties, reduction of the heat of hydration, and excellent durability properties of high-strength concrete. The advantages of ternary cements by incorporating more than one Supplementary Cementitious Material (SCM) possess the potential synergistic effects, allowing for a higher level of Portland cement replacement in concrete. In this present experimental investigation, natural zeolite and fly ash are utilised in high-strength concrete. The present experimental study of mechanical and durability properties of concrete for different percentages of natural zeolite and fly ash as a replacement to cement. The main influence of the addition of natural zeolite as SCM has a noticeable reduction in workability, especially for the concrete mix exceeding 10% of natural zeolite content. Higher replacement of natural zeolite yields better resistance to bleeding and segregation of concrete. The use of natural zeolite yields a cost-effective solution to high-strength concrete.

KEYWORDS: Natural Zeolite, Fly Ash, High Strength Concrete, Supplementary Cementitious Materials.

I. INTRODUCTION

High strength Concrete is defined based on compressive strength at a given age. In the late 1970s, before the advent of superplasticisers, concrete with compressive strength of 40 MPa or more at 28 days was called high strength concrete (P. Kumar Mehta and Monteiro Paulo J M, 2014). Later, it was modified as 60 to 120 MPa; in 2002 ACI committee on high strength concrete (ACI 363R) revised the definition to cover mixtures with a specified design strength of 55MPa or more.

Thirty years ago, tall buildings were almost all steel frames. Today, perhaps one-third of tall buildings are concrete. Also, the Commercial availability of high-strength concrete provided an economical alternative to bulky columns of conventional concrete for the lower stories of high-rise buildings.

The use of aggregate and pozzolans with fine grain size is required to produce high-strength concrete (Richard and Cheyrezy, 1995). Various types of fine size powders have been used as pozzolan and filler in concrete mixtures to achieve high mechanical and durability properties due to superior properties such as high pozzolanic activity, enhancement of rheological characteristics and filling, (Yazıcı, Halit& Yardımcı, 2009). Silica fumes are the principal constituent of the high-strength concrete mixture. The silica fume content of high-strength concrete mixtures is generally 5%-15% of cementitious material.

Besides numerous advantages, Silica fume has some disadvantages, such as a relatively high cost of production and the specific surface area of its particles, which leads to increased water and superplasticiser demand. Fly Ash, Rice husk ash, pulverised granulated blast furnace slag, Natural Zeolite, limestone powder, and metakaolin can also be considered a substitute for silica fume in high-strength concrete.

According to research (Maage 1986, 1987), ternary blend concrete reduces permeability and ionic diffusivity in the system. Indeed, the ternary cement system showed dramatically increased resistance to chloride ion penetration and sulphate attack compared with either a binary cement system or a system with only Portland cement.

In the present research work, natural zeolite, a supplementary cementitious material (SCM) used as an alternative to silica fume, is an economical solution that can also improve the mechanical strength properties of high-strength concrete. They consist of an open three-dimensional network of silicon-oxygen and aluminium oxygen tetrahedral. Natural Zeolite crystals have a honeycomb-like structure with small channels & pores, which leads to a



large surface area. Natural zeolite can also absorb and lose water up to 30% of its dry weight & exchange extra framework cations without any crystal structure change. In most cases, natural zeolite shows a better pozzolanic reaction and appropriately affects concrete mechanical and durability characteristics. Natural Zeolite can also be used as an internal curing agent and reduces the autogenous shrinkage of concrete.

II. MATERIALS

The following materials were used in the experimental investigation:

- i) Ordinary Portland Cement (OPC) confirming to IS 269 (2015).
- ii) Supplementary Cementitious Materials (SCMs) (or) Mineral Admixtures
 - a) Natural Zeolite conforming to ASTM C618
 - b) Class F Fly Ash confirming to IS 3812 Part 1 2013,

The properties of natural zeolite, Class F fly ash, and silica fumes are indicated in Table 1.

iii) Coarse Aggregate: Single Sized 12.5 mm and 20 mm crushed angular aggregate conforming to IS 383:2016.

iv) Fine Aggregate: Zone I river sand confirming to IS 383:2016.

v) Super Plasticizer: Polycarboxylate ether (PCE) based superplasticiser confirming IS 9103-1999(2007) with a specific gravity of 1.09.

Table 1 Properties of Natural Zeolite, Fly Ash, and Silica Fumes

Properties	Natural Zeolite	Fly Ash	Silica fumes
Oxide composition % by mass			
SiO ₂ + Fe ₂ O ₃ + Al ₂ O ₃	88.72	89.94	99.963
MgO	0.63	1.22	-
Na ₂ O	-	-	0.004
Chloride Content	-	0.025	-
Loss on Ignition	2.97	-	0.001
Ph	4.2	-	6.91
Specific gravity	2.2	2.2	2.64

III. HIGH STRENGTH CONCRETE MIX PROPORTIONS

Initially, the controlled high-strength concrete was prepared using Cement, Fly Ash, and Silica fume. Then Cement, Fly ash, and natural zeolite are utilised to prepare high-strength concrete test specimens. The cement content is replaced by natural zeolite in various percentages of 5%, 7.5%, 10%, 12.5%, and 15% in addition to the replacement of cement by fly ash 15%, 12.5%, 10%, 7.5%, and 5% by the weight of the cement, such that the total replacement of cement by fly ash and natural zeolite is constant i.e., 20%. As fly ash content is decreased, the content of natural zeolite is increased. The water to binder ratio w/b is 0.3. The quantities of materials required for different concrete mix is mentioned in Table 2. The chloride and sulphate attack tests were also performed.

Table 2 Ingredients of Concrete per cum of Concrete

Mix Proportion	Control Concrete Mix - CFS	Type of Concrete Test Mix				
		CFNZ1	CFNZ2	CFNZ3	CFNZ4	CFNZ5
Cement (kg/m ³)	395 (80%)	395 (80%)	395 (80%)	395 (80%)	395 (80%)	395 (80%)
Fly Ash(kg/m ³)	74.1 (15%)	74.1 (15%)	61.7 (12.5%)	49.4 (10%)	37.0 (7.5%)	24.7 (5%)
Silica Fume(kg/m ³)	24.7 (5%)	-	-	-	-	-
Natural Zeolite (kg/m ³)	-	24.7 (5%)	37.0 (7.5%)	49.4 (10%)	61.73 (12.5%)	74.07 (15%)

Fine Aggregate (kg/m ³)		600	600	600	600	600	600
Coarse Aggregate(kg/m ³)	a) 12 mm	477	477	477	477	477	477
	b) 20 mm	715.8	715.8	715.8	715.8	715.8	715.8
Chemical Admixture(kg/m ³)		4.9 (1%)	4.9 (1%)	6.2 (1.25%)	7.4 (1.5%)	8.6 (1.75%)	8.6 (1.75%)
Water (kg/m ³)		146.2	146.2	146.2	146.2	146.2	146.2
w/b ratio		0.3	0.3	0.3	0.3	0.3	0.3

IV. PREPARATION OF TEST SPECIMEN

Twenty-four Cubes, six Cylinders, and three prism samples with dimensions as mentioned in table 3 were cast according to IS 10086:1982(2006) for each type of concrete mix. The dimensions of the specimens are listed in Table.3. The specimens were tested to obtain the compressive strength of concrete at 3days, 7 days, 28 days, and 56 days, split tensile strength, flexural strength, and modulus of elasticity.

Table 3 Tests Conducted and Dimensions of Concrete Specimens

Type of Specimen	Size	Test(s) Conducted
Cube	150mm×150mm×150mm	Compressive Strength, Chloride Attack, and Sulphate Attack
Cylinder	150mm Diameter and 300 mm Height	Young's Modulus and Split Tensile Strength
Prism	500mm×100mm×100 mm	Flexure Strength

V. EXPERIMENTAL INVESTIGATION

a) Compressive Strength

The variations of cube compressive strength of high-strength ternary blend concrete at 3 days, 7 days, 28 days, and 56 days for different mixes, with different quantities of fly ash and Natural Zeolite, are shown in Fig.1. It can be observed that the mix with 80% OPC, 10% Fly Ash and 10% Natural Zeolite results in the maximum value of 28 days and 56 days cube compressive strength. The increase in the compressive strength can be attributed to the availability of additional CHS gel in natural zeolite and fly ash.

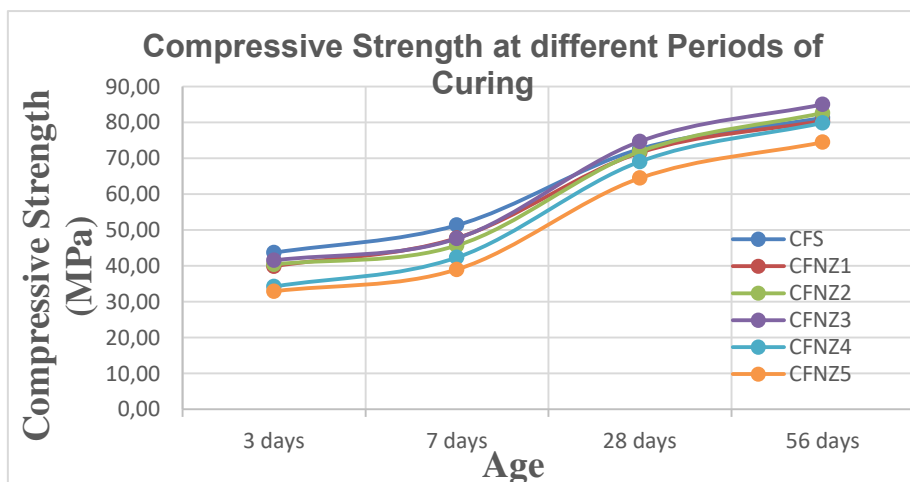


Figure 1 Compressive Strength at different periods of Curing

b) Split Tensile Strength

The variations of split tensile strength of concrete with different types of mixes are shown in Figure 2. Similar to the cube compressive strength, it can also be observed that the concrete mix with 80% OPC, 10% Fly Ash and 10% Natural Zeolite results in the maximum value of Split Tensile Strength.

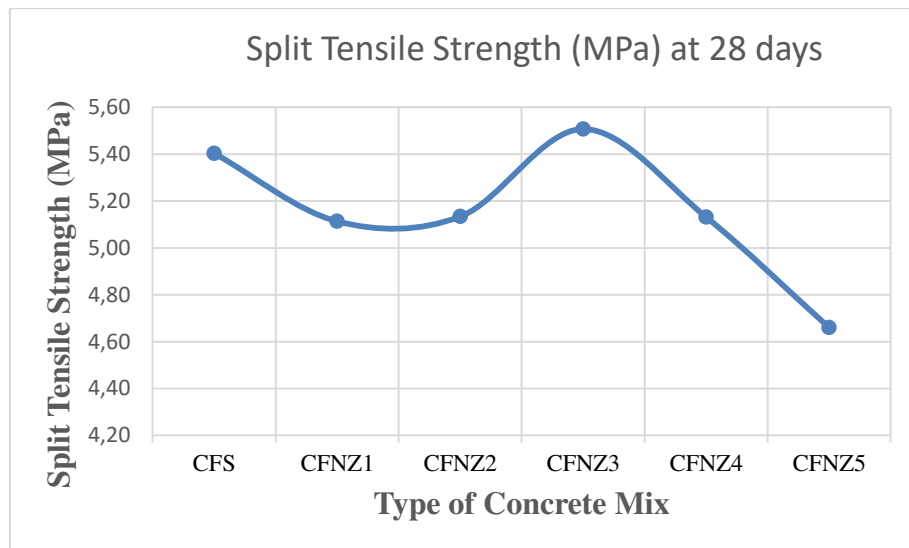


Figure 2 Split Tensile Strength

c) Modulus of Elasticity

The variations in modulus of elasticity of concrete with different test mixes were plotted in Figure 3. It can be observed that the mix with 80% OPC, 10% Fly Ash and 10% Natural Zeolite results in the maximum value of Modulus of Elasticity.

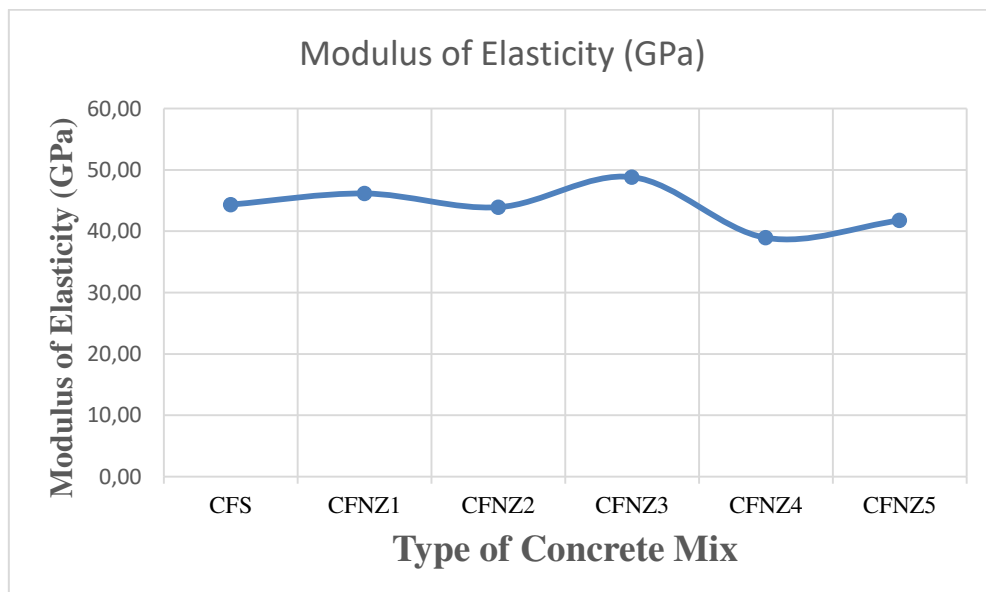


Figure 3 Modulus of elasticity of concrete

d) Flexural Strength

The variations in flexural strength of concrete with different types of test mixes were plotted in Figure 4. It can be observed that the mix with 80% OPC, 10% Fly Ash and 10% Natural Zeolite results in the maximum value of flexural strength.

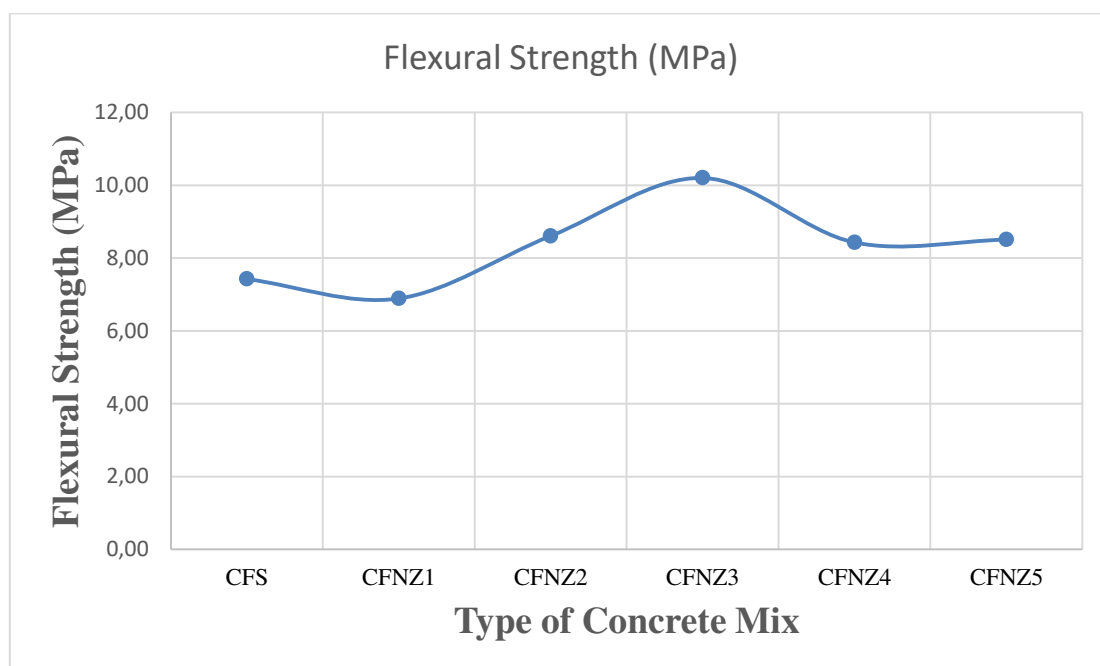


Figure 4 Flexural Strength of Concrete at 28 days

e) Chloride Attack and Sulphate attack

The environment for chloride and sulphate attack on high strength ternary blend concrete is created in a laboratory by immersion of 28 days normal cured concrete specimens in 5% Sodium Chloride (NaCl) for chloride attack and 5% Sodium Sulphate (Na_2SO_4) solution for sulphate attack of concrete. The mass of concrete cubes before immersion and after removal from respective solutions must be noted. In addition, the chloride and sulphate attack test the compressive strength of concrete after 28 days and 56 days of immersion in the 5% Sodium chloride and 5% Sodium Sulphate solution, which indicates the negligible reduction in weight loss of concrete.

The test results presented in figure 5 show that the effect of chloride and sulphate attacks ternary blend concrete with 10% natural zeolite and 10% fly ash is negligible. So, from the test results, it can be concluded that the high strength concrete containing fly ash and natural zeolite can perform better resistance to chloride attack and sulphate attacks.,

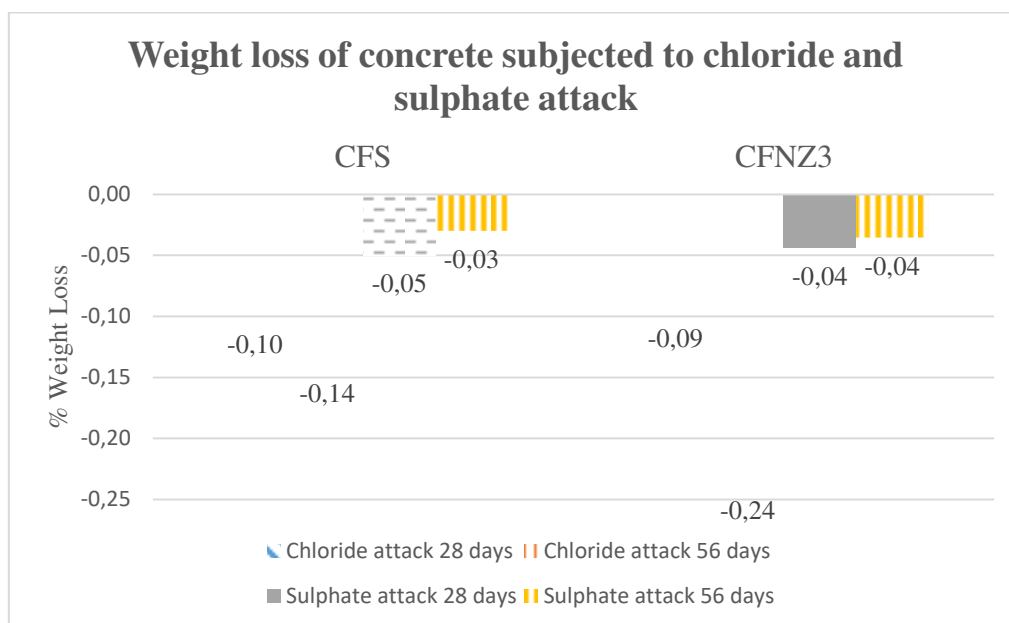


Figure 5 Weight loss of concrete subjected to chloride and sulphate attack.

VI. CONCLUSIONS

Based on the test results, the following conclusions can be made

- Water demand increases as the percentage of natural zeolite increases.
- Dosage of Superplasticiser increases with an increase in the quantity of natural zeolite.
- The workability of concrete decreases with an increase in the quantity of natural zeolite.
- The concrete mix with cement replaced by 10% natural zeolite and 10% fly ash is observed to possess improved properties of high-strength concrete.
- The chloride and sulphate resistance of high-strength concrete increases as the quantity of natural zeolite increases.
- Out of the different types of test mixes, the concrete mix with 10% natural zeolite and 10% fly ash showed improved mechanical and durability properties.
- Natural Zeolite is an SCM considered as an economical alternative to silica fumes in high-strength concrete based on its mechanical properties and resistance to chloride and sulphate attack of concrete.

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