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Experimental analysis on strength and durability of concrete with partial replacement of Natural Zeolite and Manufactured Sand

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ABSTRACT

An experimental investigation was carried out to evaluate the influence of Natural Zeolite and Manufacture sand on Physical and mechanical properties of concrete, containing natural zeolite and Manufacture sand in binary blended system up to varying 5%, 10%, 15% and 20% of zeolite and 20%,40%,60%,80% and 100% of manufacture sand replacements. Concrete is evaluated for compressive strength, split tensile strength and flexural strength at different ages 7 days, 28 days and 90 days and Durability study is conducted by treating specimens for 28 days with 5% concentrated Hydro Chloric Acid and the concrete mix with 10% of Natural zeolite and 60% of manufactured sand replacement has given good durable properties The results showed that despite the observed increase of compressive strength, split tensile strength and flexural strength of proposed composites, natural zeolite concrete and manufactured sand gained enough strength even at the later ages similar to that of normal concrete. Moreover, the results confirmed the beneficial effects of zeolite and Manufacture sand concrete which lead a green and environment friendly concrete.

Keywords— *Natural Zeolite, M-sand*

1. INTRODUCTION

Concrete is the most versatile construction material being used in the construction of structures, like, buildings and bridges. Concrete is fairly strong in compression week in tension. Concrete is made up of inert filler a chemically active binder. The binder adheres all ingredients together to forms a synthetic conglomerate. Aggregates are the solid particles that are bound together by the cement paste to create concrete. Aggregates are the fundamental components of Concrete. The coarse aggregates, being the principle control material for maximum strength, and fills most of voids, providing lateral restrain (inter particular locking) to the coarse particles. Aggregates occupy around 40 to 30% of the volume of concrete. Generally, aggregates are given less importance by assuming them to be only as economic interring fillers, but they influence the strength, dimensional stability, wear-resistance and durability of concrete.

2. OBJECTIVES

Therefore, in this investigation, it is attempted to conduct a study on mechanical property of Natural zeolite and manufactured sand concrete. In this research, M20 grade concrete mix is designed and used in costing specimens (cubes, cylinders, and beams). The details are given the test matrix as mentioned in Table 1. Also, compressive strength, split tensile strength, and flexural strength tests are conducted. The test results are detailed and reported in chapter 5. The primary objectives of the primary research work are:

- To study the influence of Natural zeolite and manufactured sand on compressive strengths of M20 concrete mix proportion by replacing of cement 5%, 10%, 15% and 20% by weight and by replacing of fine aggregate by manufacture sand by 20%,40%,60%,80% and 100% by weight.
- To study the influence of Natural zeolite on split tensile strengths of M20 concrete mix proportions by replacing of cement 5%, 10%, 15% and 20% by weight.
- To study the influence of Natural zeolite on split tensile strengths of M20 concrete mix proportions by replacing of cement 5%, 10%, 15% and 20% by weight and by replacing of fine aggregate by manufacture sand by 20%,40%,60%,80% and 100% by weight
- To study the influence of Natural zeolite on flexural strengths of M20 concrete mix proportion by replacing of cement 5%, 10%, 15% and 20% by weight.

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- To study the influence of Natural zeolite on the workability of M20 concrete mix proportions by replacing of cement 5%, 10%, 15% and 20% by weight
- To study the influence of Natural zeolite on the workability of M20 concrete mix proportions by replacing of cement 5%, 10%, 15% and 20% by weight and by replacing of fine aggregate by manufacture sand by 20 %, 40 %, 60%, 80% and 100% by weight.

3. SCOPE FOR FURTHER RESEARCH

The present research has been conducted under available conditions and certain limitations. Hence there is a large scope for further research on influence of natural zeolite and manufactured sand on performance of concrete, both short term and long term effects. The enlisted list helps to identify direction on which further study be continued. The durability of construction material properties is also very important parameters such as

(a) Rapid chloride permeability
(b) Drying shrinkage
(c) Alkali-aggregate reaction
(d) Sulphate resistance
(e) X-ray diffraction test and SEM

Hence further study can be conducted on the enlisted parameter due to the influence of natural zeolite and manufactured sand to concrete.

Table 1: Test Matrix of test specimen used in this experimental investigation

Concrete mix designation	Cubes			Cylinders			Beams		
	7 days	28 days	90 days	7 days	28 days	90 days	7 days	28 days	90 days
0%NZ	3	6	3	3	3	3	3	3	3
5%NZ	3	6	3	3	3	3	3	3	3
10%NZ	3	6	3	3	3	3	3	3	3
15%NZ	3	6	3	3	3	3	3	3	3
20%NZ	3	6	3	3	3	3	3	3	3
10%NZ+20%M	3	6	3	3	3	3	3	3	3
10%NZ+40%M	3	6	3	3	3	3	3	3	3
10%NZ+60%M	3	6	3	3	3	3	3	3	3
10%NZ+80%M	3	6	3	3	3	3	3	3	3
10%NZ+100%M	3	6	3	3	3	3	3	3	3

4. LITERATURE ON NATURAL ZEOLITE CONCRETE

S.Yasmine (2018): In conventional concrete, we want to gain more strength with the optimum materials. That's why here we are using zeolite in concrete for the replacement of cement which might absorb CO2. Due to rapid change in metrology, deep minimizing emission will be required in coming decades. Global warming is controlled by the process of reducing greenhouse gases like CO2, HFC, and Sulphur-di-oxide in atmosphere. Zeolite powder is good agent to absorb harmful gases. Natural zeolites form where volcanic rocks and ash layers react with alkaline groundwater. Zeolites also crystallize in post-depositional environments over periods ranging from thousands to millions of years in shallow marine basins. Concrete with zeolite as partial replacement material with mean ratio it absorbs harmful gases and gives high compressive strength, hence it is eco-friendly.

D. Georgie et. al (2017): The synthesis of zeolite with valuable properties is a serious task, requiring numerous laboratory studies. Zeolite Nax (also called zeolite X, Nax, Linde X, and molecular sieve 13X) is an analog of the natural zeolite faujasite. The aim of the present paper is to investigate the most important stage of synthetic zeolite production - the process of its granulation. The granulation is obtained on the basis of three mechanisms involving different types of granulators or installations. The subject matter of the work is zeolite granulate of type Zeolite Nax with or without a binding substance. For this purpose, a laboratory installation of fluidized bed "was designed and manufactured. The method of fluidized bed "is a very effective method by which the synthesis takes place in the micro- volumes of the material. The granules obtained have an average particle size within the range of about 1 to 4 mm and also good mechanical strength. They find out the possibility to prepare synthetic zeolite Nax from Bulgarian kaolin as the basic raw material was studied. The synthesis of zeolite Nax involves preliminary formation of granules by the method of "fluidized bed", followed by crystallization (zeolitization). Thus, the following experimental results were obtained: spectroscopy. The synthetic product Zeolite Z3 (obtained by the method of preliminary formation of granules in a fluidized bed, followed by zeolitization with a suitable reactive solution from the initial material kaolin of Bulgarian origin) was proved to have the same structure as Zeolite Nax.

Nalleni Sreeharsha (2016): Zeolite is a popular type of natural pozzolanic material that has been widely utilized in constructions since ancient times and zeolite is the largest group of silicate minerals. The present study is, carried out in two phases in first phase mix of M35 grade concrete with partial replacement of cement by 0%, 10%, 15%, 20%, and 25% zeolite is carried out to determine the optimum percentage of replacement at which maximum compressive strength, tensile strength, flexural strength is achieved. It is observed that when cement is partially replaced with 15% of zeolite concrete maximum strength is achieved. In phase two mix of M35 grade concrete combination of zeolite and metakaolin is partially replaced with cement. The composition

15% of zeolite constant + 5%, 10%, 15%, 20% of metakaolin is carried out to determine the maximum strength. It is observed that when cement is partially replaced with 15 % of zeolite + 10 % of metakaolin concrete maximum strength is achieved. Test results indicate that use of combination of zeolite and metakaolin in partial replacement of cement in the concrete has improved the mechanical properties.

B.uzal, L.Turanlı, et. al (2015): In this study, properties and hydration characteristics, as well as paste microstructure of blended cements containing 55% by weight zeolitic tuff composed mainly of clinoptilolite mineral, were investigated. Free Ca (OH)2 content, crystalline hydration products and decomposition of zeolite crystal structure, pore size distribution and microstructural architecture of hydrated cement pastes were examined. Superplasticizer requirement and compressive strength development of blended cement mortars were also determined. The blended cement containing high volume of natural zeolites were characterized with the following properties; no free Ca(OH)2 in hardened pastes at the end of 28 days of hydration, less proportion of the pores larger than 50 nm when compared to Portland cement paste, complete decomposition of crystal structure of zeolite at the end of 28 days of hydration, presence of tetra calcium aluminates hydrate as a crystalline product of Pozzolanic reaction, more compatibility with the melamine-based superplasticizer when compared to the naphthalene based product, and similar 28 days compressive strength of mortars to that of reference Portland cement.

He reported cement containing large amount of clinoptilolite tuff demonstrated faster initial and final setting time than the ordinary Portland cement. This fact may be related to consistency loss resulted from high water absorption of zeolite particles indicated by high water demand of blended cement for normal consistency, rather than setting off the blended system. In blended cement pastes, Ca (OH) 2 formed from hydration of PC phase was almost completely consumed at the end of 28 days of hydration. Accordingly, blended cement containing large amounts of clinoptilolite tuff were found to be more reactive in terms of pozzolanic when compared to similar blended systems with non-zeolitic natural pozzolans studied by the authors previously. The type of major cation was found to be one of the probables governing the Pozzolanic activity of clinoptilolite zeolites by affecting their degree of solubility in alkaline conditions. It was experimentally demonstrated that pastes of blended cement containing large amount of clinoptilolite tuff contain less amount of pores >50 nm when compared to Portland cement paste, which is beneficial in terms of mechanical strength and impermeability of the pastes. The dissolution of clinoptilolite phase in blended cement pastes was demonstrated by reduced intensity and sharpness of X-ray diffraction peaks corresponding to clinoptilolite crystals between 7 days and 28 days of hydration. Tetra calcium aluminates hydrate (4CaO.Al2O3.13 H2O) was detected as a crystalline product of Pozzolanic reaction in blended cement pastes. BS-SEM observations on hardened pastes of blended cement containing 55% natural zeolite indicated that some part of zeolitic tuff particles, especially relatively coarse grains, remains unreacted at 28 days of age. EDX analyses of outer rim of unreacted zeolite particles indicated a possible decomposition and Pozzolanic reaction of clinoptilolite on the surface with more calcium and less silicon content when compared to the inner parts. It can be concluded that the natural zeolite of Bigadic source seems to be more viable for use in production of blended cement containing high volume of natural pozzolans since water or superplasticizer requirement of blended systems with Bigadic zeolite is lower than that of Gourd's zeolite. Blended cement consisting of 55% zeolitic tuff (BZ) and 45% Portland cement exhibited an extraordinary strength performance because it showed similar 28-day compressive strength to that of 100% Portland cement. Therefore, it can be concluded that the use of zeolitic tuffs in high-volume natural pozzolans systems could eliminate the disadvantage of the lower 28-day strength of this kind of blended systems when compared to ordinary Portland cement.

5. MATERIAL USED

The different materials used in this work are:

- Cement 53 grades (Ultratech cement).
- Fine aggregate
- Coarse aggregate
- Natural zeolite
- Manufactured sand (M-sand) Yashas Enterprises, Hyderabad.
- Coloplast sp 430(G)
- Water

5.1 Mix proportion

Table 2: Mix Proportion Zeolite concrete (1:2.2:4:0.5)

MIX NO	REPACEMENT DETAILS	ZEOLITE Kg/m^3	CEMENT Kg/m^3	CA Kg/m^3	FA Kg/m^3	WATER Kg/m^3	SUPER PLASTICIZER lt/m^3
M0	0%Natural zeolite	0	315	1271.14	715	157.6	0
M1	5% natural zeolite	15.75	299.25	1271.14	715	157.6	1.575
M2	10% natural zeolite	31.5	283.5	1271.14	715	157.6	1.575
M3	15% natural zeolite	47.25	267.5	1271.14	715	157.6	1.575
M4	20% natural zeolite	63	252	1271.14	715	157.6	1.575

Table 3: Mix Proportion of Zeolite + M-sand concrete (1:2.2:4:0.5)

MIX NO	REPACEMENT DETAILS	ZEOLITE Kg/m^3	M-SAND Kg/m^3	CEMENT Kg/m^3	CA Kg/m^3	FA Kg/m^3	FA Kg/m3	SUPER PLASTICIZER lt/m^3
M0	0%NZ+0%M	0	0	315	1271.14	715	157.6	0
M5	10%NZ+20%M	31.5	143	299.25	1271.14	572	157.6	1.575
M6	10%NZ+40%M	31.5	286	283.5	1271.14	429	157.6	1.575
M7	10%NZ+60%M	31.5	429	267.5	1271.14	286	157.6	1.575
M8	10%NZ+100%M	31.5	715	252	1271.14	0	157.6	1.575

6. TEST RESULTS

Various tests are conducted on hardened concrete the results are depicted below

6.1 Compressive Strength Results

Table 4: Compressive Strength Test of Natural zeolite

CONCRETE MIX DESIGNATION	0%NZ	5%NZ	10%NZ	15%NZ	20%NZ
7 days	21	21.44	22	19.3	18
28 days	30	31.96	33.3	31.2	29
90 days	31	35.5	38	34	32

Table 5: Compressive Strength Test of Natural Zeolite and manufactured sand

CONCRETE MIX DESIGNATION	10%NZ + 0%M	10%NZ + 20%M	10%NZ + 40%M	10%NZ + 60%M	10%NZ + 80%M	10%NZ + 100%M
7 days	20	21	22.87	23.44	23.22	22.83
28 days	32.3	34.65	35.58	38.75	36.15	35.68
90 days	38	41.42	42.66	43.51	42.7	39.64

Table 6: Split Tensile Strength Test of natural zeolite

CONCRETE MIX DESIGNATION	0%NZ	5%NZ	10%NZ	15%NZ	20%NZ
7 days	1.717	1.614	1.68	1.433	1.28
28 days	2.235	2.425	2.62	2.39	2.328
90 days	2.201	2.52	2.7	2.42	2.4

Table 7: Split Tensile Strength Test of natural zeolite and manufactured sand

CONCRETE MIX DESIGNATION	10%NZ + 0%M	10%NZ + 20%M	10%NZ + 40%M	10%NZ + 60%M	10%NZ + 80%M	10%NZ + 100%M
7 days	1.68	1.8	1.92	2.17	2.09	2.03
28 days	2.62	2.72	2.87	3.03	3.01	2.9
90 days	2.7	3.1	3.12	3.22	3.1	3.08

6.2 Flexural Strength

Table 8: Flexural strength

CONCRETE MIX DESIGNATION	0%NZ	5%NZ	10%NZ	15%NZ	20%NZ
7 days	4.23	4.03	3.72	3.34	3.17
28 days	5.7	6	6.66	5.33	4.8
90 days	5.8	6.4	6.9	6.1	5.83

Table 9: Flexural Strength Test of Zeolite and Manufactured sand

CONCRETE MIX DESIGNATION	10%NZ + 0%M	10%NZ + 20%M	10%NZ + 40%M	10%NZ + 60%M	10%NZ + 80%M	10%NZ + 100%M
7 days	3.72	3.82	3.85	4.33	4.16	3.95
28 days	6.66	6.85	7.05	7.85	7.6	7.32
90 days	6.9	7.1	7.6	8.17	8	7.73

6.3 Durability Test

Table 10: Compressive strength of Natural zeolite before and after acid treatment

CONCRETE MIX DESIGNATION	0%NZ		5%NZ		10%NZ		15%NZ		20%NZ	
	Before	After	Before	After	Before	After	Before	After	Before	After
28 days	30	25.35	31.96	28.44	33.3	30.53	31.2	28.48	29	26.4

Table 11: Compressive strength of Natural zeolite and manufactured sand before and after acid treatment

CONCRETE MIX DESIGNATION	10%NZ + 20%M		10%NZ + 40%M		10%NZ + 60%M		10%NZ + 80%M		10%NZ + 100%M	
	before	After	Before	After	Before	After	Before	After	Before	After
28 days	34.65	29.8	35.58	31.90	38.75	35.18	36.15	32.35	35.68	31.75

7. CONCLUSIONS

Based on the present experimental study, the following conclusions are drawn.

- The addition of natural Zeolite to concrete mix results in reduction in workability. The reduction in workability increases with increase of natural zeolite quantity and manufactured sand.
- Addition of natural Zeolite and manufactured sand to concrete mix results in an increase in strength of the concrete. Concrete strength improvement is observed to be optimum at 10% zeolite and 60% Manufactured sand.
- The slump values of 5%NZ, 10%NZ, 15%NZ, 20% NZ, 10%NZ+20%M, 10%NZ+40%M, 10%NZ+60%M, 10%NZ+80%M, 10%NZ+100%M decreased 11.11%, 16.66%, 33.33%,44.4%,47.8%,66.7%, 80%, 88.7%, and 92.2% respectively when compared to NCC.
- It was observed that the compressive strength (at 7days) of 5% NZ, 10 %NZ, 15%NZ and 20%NZ increased by 2.1%, 4.75%, 8.1%, and 14.3 %respectively when compared with 0%NZ.
- It was observed that the compressive strength (at 28 days) of 5% NZ, 10%NZ, 15%NZ, 20%NZ increased by 6.5%,11.1%,4%,3.5% respectively when compared with 0%NZ.
- It was observed that the compressive strength (at 90 days) of 5% NZ, 10%NZ,15%NZ,20%NZ increased by 14.5%,22.5%,9.6%,3.22% respectively when compared with 0%NZ.
- It was observed that the compressive strength (at 7days) of 10%NZ+20%M , 10%NZ+40%M,10%NZ+60%M,10%NZ+80%M,10%NZ+100%M increased by 5%, 14.35%, 17.21% ,16.11, 14.15 %respectively when compared with 10%NZ+0%M.
- It was observed that the compressive strength (at 28days) of 10%NZ+20%M , 10%NZ+40%M,10%NZ+60%M,10%NZ+80%M,10%NZ+100%M increased by 8.2%, 10.15%, 20% ,12%, 10.5% respectively when compared with 10%NZ+0%M.
- It was observed that the compressive strength (at 90days) of 10%NZ+20%M , 10%NZ+40%M,10%NZ+60%M,10%NZ+80%M,10%NZ+100%M increased by 9.1%, 12.26%, 14.51% ,16.11%, 4.3% respectively when compared with 10%NZ+0%M.
- It was observed that the split tensile strength (at 7days) of 5%NZ, 10%NZ, 15%NZ and 20%NZ increased by 5.86%, 2.15%, 16.5%, and 25.45 %respectively when compared with 0%NZ
- It was observed that the split tensile strength (at 28days) of 5%NZ, 10%NZ, 15%NZ and 20%NZ increased by 8.5%, 17.22%, 6.9%, and 4.16 %respectively when compared with 0%NZ.
- It was observed that the split tensile strength (at 90days) of 5%NZ, 10%NZ, 15%NZ and 20%NZ increased by 14.5%, 22.6%, 10%, and 0.43 %respectively when compared with 0%NZ.
- It was observed that the split tensile strength (at 7days) of 10%NZ+20%M, 10%NZ+40%M,10%NZ+60%M,10%NZ+80%M,10%NZ+100%M increased by 14.1%, 29% ,24.5%, 21% respectively when compared with 10%NZ+0%M.
- It was observed that the split tensile strength (at 28days) of 10%NZ+20%M, 10%NZ+40%M,10%NZ+60%M,10%NZ+80%M,10%NZ+100%M increased by 14.5%, 9.4%, 15.8% ,15%, 14%respectively when compared with 10%NZ+0%M.
- It was observed that the split tensile strength (at 90days) of 10%NZ+20%M, 10%NZ+40%M,10%NZ+60%M,10%NZ+80%M,10%NZ+100%M increased by 14.4%, 9.4%, 15.7% ,15%, 14 %respectively when compared with 10%NZ+0%M.
- It was observed that the flexural strength (at 7days) of 5%NZ, 10%NZ, increased by 4.5%, and 12%, and15% NZ, 20% NZ decreased by 21%, and 25%, respectively when compared with 0%NZ.
- It was observed that the flexural strength (at 28days) of 5%NZ, 10%NZ, 15%NZ increased by 6.8%, 11%, and6.4%. 20% NZ decreased by 15.6% respectively when compared with 0%NZ.
- It was observed that the flexural strength (at 90days) of 5%NZ, 10%NZ, 15%NZ increased by 10%, 17%, and5%. 20% NZ decreased by 10.5% respectively when compared with 0%NZ
- It was observed that the flexural strength (at 7days) of 10%NZ+20%M, 10%NZ+40%M,10%NZ+60%M,10%NZ+80%M,10%NZ+100%M increased by 2.7%, 3.5%, 16.4% ,12%, 6.3 % respectively when compared with 10%NZ+0%M.
- It was observed that the flexural strength (at 28days) of 10%NZ+20%M, 10%NZ+40%M,10%NZ+60%M,10%NZ+80%M,10%NZ+100%M increased by 3%, 6%, 18% ,14%, 6.3 % respectively when compared with 10%NZ+0%M.

- It was observed that the flexural strength (at 90days) of 10%NZ+20%M , 10%NZ+40%M,10%NZ+60%M,10%NZ+80%M,10%NZ+100%M increased by 14.4%, 10%, 18.5% ,16%, 12% respectively when compared with 10%NZ+0%M.
- It was observed that the compressed strength of concrete for 5%NZ, 10%NZ, 15%NZ and 20%NZ after acid curing has decreased by 15.5%, 11%, 8.33%, 8.7%, and 9% of compressive strength before acid curing with HCL after 28 days.
- 23 It was observed that the compressed strength of concrete for 5%NZ, 10%NZ, 15%NZ and 20%NZ after acid curing has decreased by 14%, 10.33%, 9.2%, 10.5%, and 11% of compressive strength before acid curing with HCL after 28 days.

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