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A Study on the Mechanical Properties of Alkali Activated Concrete Using Various Types of Synthetic Zeolites

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Abstract*:* The world's most common man-made material is concrete. Portland cement is a key component of a typical concrete mix. However, about 5% of the world's carbon dioxide emissions are brought on by the manufacture of cement. Engineers and scientists need to invent and use a green building material to make the world more sustainable. Due to its corrosion resistance, geopolymer concrete is also significantly more durable than regular concrete. It is also significantly stronger than regular concrete. The development of green construction will be facilitated by the innovative sustainable building material known as geopolymer concrete. Alkali- activated materials also known as geopolymers, are made from a variety of materials (usually industrial byproducts) known as precursors. These are combined with an alkaline medium to create a cementitious material that can be used in place of Portland cement in the production of concrete. Mineral admixtures (such as fly ash and GGBS) are typically added in larger amounts in concrete to improve its workability, resistance to thermal cracking, alkali-aggregate expansion, and sulphate attack, and to allow for a reduction in cement content. In the current study, sodium hydroxide and sodium silicate were used as alkaline activators with a Molarity of 12M, and fly ash, GGBS, and types of synthetic zeolites as binder ingredients. 40% of GGBS is kept constant and fly ash is replaced with zeolite in various percentages. In this paper, zeolite is replaced with 5%, 7.5%, and 10% of fly ash to create geopolymer concretes. Zeolite powder obtained by the calcination process with the aid of sodium hydroxide and fly ash, industrial wastages. The performance of the created concrete is then evaluated using mechanical behavior on developed mix.

Key words: Alkali activator, fly ash, Ground granulated blast- furnace slag, synthetic zeolites, strength properties.

1.INTRODUCTION

The building industry must use new structural materials and technological breakthroughs in order to achieve sustainability. In the building sector, particularly developing countries concrete is that is utilized in large quantities. The second most essential substance on earth after water is concrete. In fact, experts and scientists' investigation to create and use a green building material. About 5% of the carbon dioxide emissions in the world are produced during the cement making process, which is a major threat for the environment. The high amount of energy also required for production of cement. Therefore, finding a new binder material is very important. The geopolymers depend on thermally activated materials like industrial byproducts and it provides a source of silicon and aluminium, these Si: Al is dissolved in an alkaline activating solution and subsequently polymerizes into molecular chains it become binder. [1]Professor B. Vijaya Rangan (2008), Curtin University, Australia, stated that, "the polymerization process involves a substantially fast chemical reaction under alkaline conditions on silicon- aluminium materials that results in a three-dimensional polymeric chain and ring structure" The getting of good strength in geopolymer concrete depends largely on the ratio of (Si: Al). In curing time temperature is very important, and it depending upon the materials type activating solution, heat often must be applied to facilitate polymerization, although some systems have been developed that are designed to be cured at room temperature. Synthetic zeolites mainly used in treatment of wastewater and making of good strength asphalt mixture, these zeolites also have good chemical properties equal to industrial by products. The preparation of zeolites is generally expensive and therefore, their use in environmental remediation is restricted duo to prohibitive costs. Cost limitations can be overcome by using low-cost materials for zeolite synthesis, such as fly ash, ground granulated blast furnace slag and metakaolin. Recently the classic alkaline hydrothermal synthesis has been improved by using more sophisticated treatments. Which include an alkaline fusion step followed by hydrothermal treatment, the application of microwave-assisted zeolite synthesis and a method for synthesizing zeolites under molten condition without any addition of water. [2]Palaniappan. A, S. Vasantha (2013) discussed the results of an experimental investigation and compare on the mechanicals properties of different binder compositions (17 to 20% replacement of cement by ground granulated blast furnace slag of geopolymer concrete. The test results show that GGBS concrete shown increase in compressive strength of 13.825 as compared with conventional concrete. 3Ganapati Naidu. P, A.S.S.N. Prasad (2008) reported in this paper that an attempt is made to study strength properties of geopolymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Higher concentrations of GGBS (slag) results in higher compressive strength of geopolymer concrete. 90% of compressive strength was achieved in 14 days. [4]Nakshatra B. Singh (2018) Presented on a geopolymer motor and concrete, the properties of geopolymer cement and concrete depends on various factors. It can be used as a fire resistance material in the construction industry. the high strength of geopolymer concrete is get at the temperature of 1000C after that it decrease and compare to OPC concrete the geopolymer concrete is give early strength, durable, economical and emits less carbon. [5]A. Hamadi and K. Nabih (2018) discussed the preparation of zeolites and experimental investigates the possibility of fly ash (FA) and modified oil shale ash (MOSA) are starting material for zeolite synthesis under identical experimental conditions, with the constant 5grm of fly ash adding in 4 different NaOH masses for getting of better zeolites that will help for treatment of wastewater and heavy metals removing. [6]Carlos Alberto Rios Reyes (2008) PhD thesis reported that the use of synthetic zeolite is to treatment of waste water and removing of heave metals in water. Experimental data suggest that the Fly ash could be converted into beneficial product, which can be used as ion exchangers in removing of heavy metals from wastewater. Therefore, it is necessary to develop further experiments under well-optimized conditions, to successfully prepare high crystallin zeolites. The alkaline fusion followed by hydrothermal reaction has the advantage of producing pure zeolite materials, in this paper they mentioned the preparation of zeolite, reaction between fly ash and NaOH also. [7]Dr. Hasan H. Joni and Humam H. Al-Araji (2018) concluded the experimental investigation synthetic zeolite is used for performance of asphalt mixture in terms of water sensitivity. 5% of synthetic zeolite is gives better strength compare to 7% of synthetic zeolite. Compressive strength for condition and unconditional samples increases with increase synthetic zeolite percentage up to 5%.

2.OBJECTIVE

The main objective of this study to investigate the potential use of synthetic zeolites (Fly ash based and Metakaolin based zeolites) which is prepared by using fusion method as a partial replacement of fly ash in geopolymer concrete. To study about GPC by varying the synthetic zeolites of Fly ash based and Metakaolin based zeolites with percentage of 5%, 7.5% and 10% for both.

Mechanical properties were investigated by the following tests.

1.compressive strength, 2. Split tensile strength, 3. Flexural strength.

3.EXPERIMENTAL STUDY

3.1. Materials

Fly ash is by-product of coal based thermal power plants. In this study class F fly ash is used which is obtained from the KPCL-Bellary thermal power station located in near Bellary, Karnataka and the specific gravity, specific surface area of fly ash is2.2, 360.78 m^2/kg. GGBS is a by-product of iron industry. When a blast furnace is operated at a temperature of around 1500^0 C and fed proportionate of lime, coke and iron ore, molten slag and molten iron are produced and the specific gravity, specific surface area of ground granulated blast-furnace slag is 2.9, 532 m^2/kg. Metakaolin is the highly reactive pozzolana, metakaolin is the anhydrous calcined form of the clay mineral kaolinite and the specific gravity, specific surface area of metakaolin is 2.42, 830 m^2/kg. The chemical properties of materials are shown in Table 1. Physical properties of coarse and fine aggregates are shown in Table 2.

Table 1. chemical properties of Fly ash, Ground granulated blast furnace slag and Metakaolin

Components	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	SiO_3
Fly ash	52	33.9	1.2	0.81	4.0	0.23
GGBS	28.2	9.73	52.96	0.978	2.9	1.85
Metakaolin	56.8	36.1	0.39	0.32	1.91	-

Table 2. Physical properties of fine and coarse aggregates

Characteristics	Fine aggregate	Coarse aggregate
Specific gravity	2.67	2.70
Bulk density	1668 Kg/m^3	1765 Kg/m^3
Fineness modulus	2.76	6.45
Water absorption	0.8%	1%
Grading zone	Zone II	20 mm

3.2. Synthetic zeolite preparation

In previous cases, synthetic zeolites are prepared by different methods and used for environmental purpose like water treatment, removing of large particles in water and used in synthesizing zeolites for agriculture, with a part in controlling release of fertilizers and as a soil amendment. In this project fusion method followed by direct activation method, and develop two types of synthetic zeolites with the ratio of 1:1 (fly ash and NaOH). firstly, 50% of NaOH and 50% of fly ash and second zeolite 50% of NaOH and 25% of fly ash, 25% of metakaolin with the help of fusion method to get synthetic zeolites. These synthetic zeolites are used in making of geopolymer concrete.

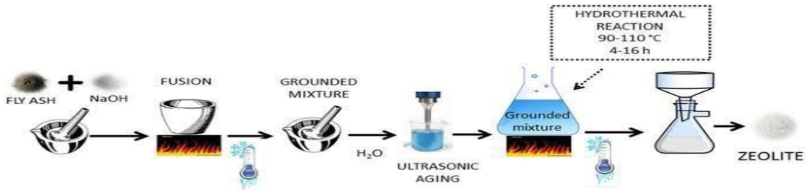


Figure 1. preparation of synthetic zeolite

Figure 2. Experimental procedure of synthetic zeolite

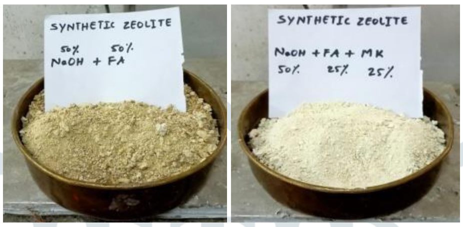


Figure 3. synthetic zeolites

3.3. Preparation of geopolymer concrete

The aggregate takes the largest volume in GPCs (roughly 75% – 80% by mass). The silicon and aluminum in the fly ash are activated by a combination of sodium hydroxide and sodium silicate. The thermodynamic properties of the studied fly ashes, i.e., enthalpy and entropy of reactions. Silica, aluminum oxide and titanium oxide consume hydroxides, whereas the earth alkalis (CaO, MgO), alkalis (Na_2O, K_2O), and iron oxide produce hydroxides. Fly ash contains a high percentage of amorphous alumina and silica that make it very suitable for making geopolymers. Fly ash – GGBS based geopolymer concrete with 60\:40 ratio with 12 molarity, SS/SH ratio is 1.5, AAS/ Binder ratio is 0.4 and 60:40 ratio of coarse and fine aggregates in the total mass of aggregates. Further mixes are prepared by replacing two types of synthetic zeolites with fly ash by different percentages i.e., 5, 7.5 and 10%. These specimens were cured for 28 days at ambient temperature. The mix proportions are shown in below Table 3.

Table 3. Mix proportion values

Ingredients	Density Kg/m^3
NaOH	80
Na_2SiO_3	120
Binder	500
Fine aggregates	328
Coarse aggregates	1360
SP	1%

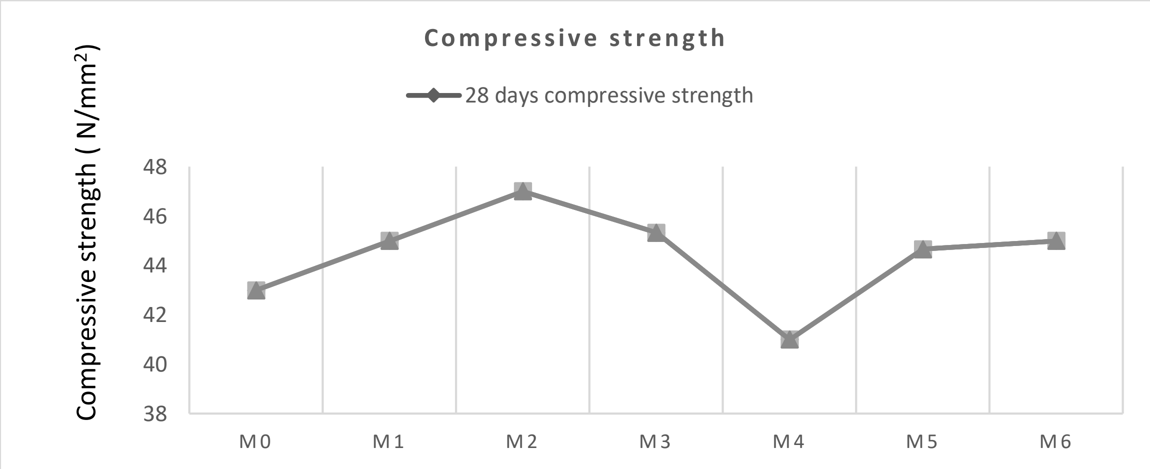
4.RESULTS and DISCUSSIONS

4.1. Compressive strength

The compressive strength of geopolymer concrete depends on various factors like fly ash, GGBS, molarity of alkaline liquid and type of aggregates. Based on the test results for different replacements of synthetic zeolite content under ambient curing of 28th days results. The maximum compressive strength was obtained for mix (M7.5%SZ(FA)) with 7.5% of synthetic zeolite replaced in fly ash. At 10 % of (M10%SZ(MK)) another Synthetic zeolite gives the maximum compressive strength.

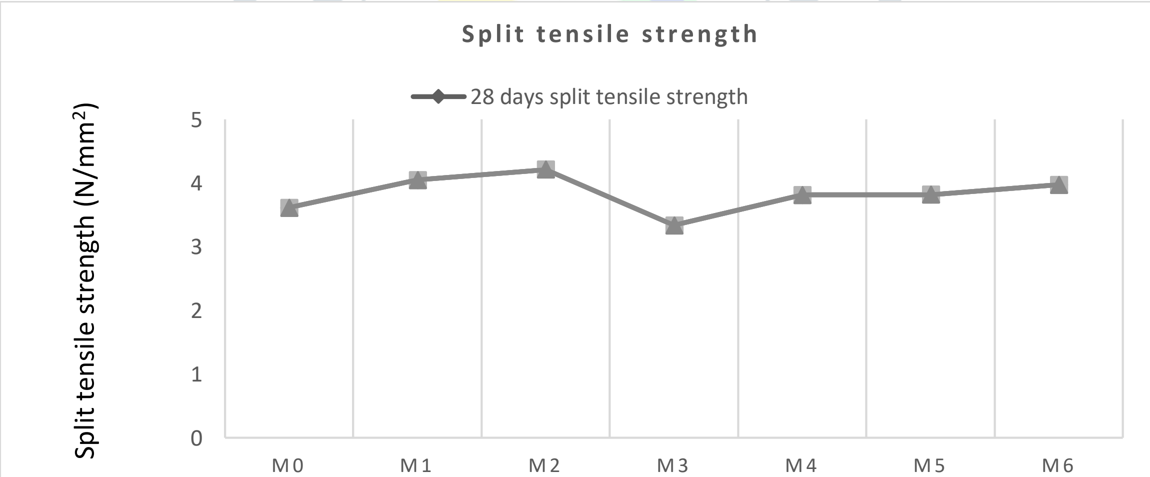
Table 4. Mechanical properties of Geopolymer concrete at 28 days

Mix Designation	28 days compressive strength	28 days split tensile strength	28 days flexural strength
M0% SZ	43	3.615	4.738
M5%SZ(FA)	45	4.05	5.005
M7.5%SZ(FA)	47	4.214	5.12
M10%SZ(FA)	45.33	3.34	4.875
M5%SZ(MK)	41	3.815	5.053
M7.5%SZ(MK)	44.66	3.82	5
M10%SZ(MK)	45	3.975	5.26



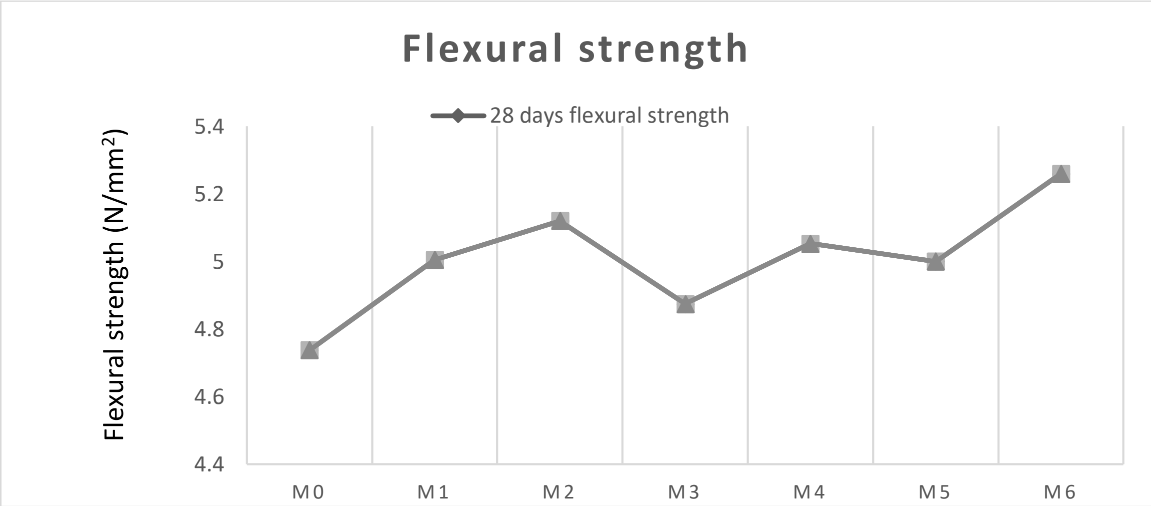
4.2. Split tensile strength

The variation of split tensile strength at the age of 28th days and the maximum strength was obtained for mix (M7.5%SZ(FA)) with 7.5% synthetic zeolite used. In second zeolite, the maximum split tensile strength obtained at (M10%SZ(MK)) the percentage of 10% synthetic zeolite.



4.3. Flexural strength

The results of flexural strength of concrete at the age of 28th days are presented in figure3. The maximum flexural strength was obtained for mix (M7.5%SZ(FA)) with 7.5% of synthetic zeolite. on the contrary, the strength decreases when the percentage of zeolite increased and in second zeolite using, the maximum strength (M10%SZ(MK)) obtained at 10% of synthetic zeolite.



5. Conclusion

1. The mechanical properties of GPC were found to be high strength at 7.5% replacement of Fly ash based synthetic zeolite and decreases thereafter.
2. The compressive, split tensile and flexural strength were 8.5%, 14.13% and 7.46% higher than the control mix respectively.
3. For the mix designated by M6(Z10%) the mechanical properties of increases by 5%, 9% respectively for compressive, split tensile and flexural strength.
4. Modification of concrete with synthetic zeolite additives improvise the durability of concrete that may be used in various structures.

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