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Experimental Investigation of GGBS based Geoploymer Concrete

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Abstract **-** *Ferro- geopolymer is Recent trending building material which replace cement for construction. Geopolymer mortar as a matrix and wire mesh as a reinforcement together called as ferro- geopolymer. Geopolymer is a by-product material such as Fly ash, Rice husk ash, GGBS, Blast furnace slag etc., which are rich in silicon and aluminum. Use of geopolymer mortar reduce the pollution due to release of CO2 into the air. Ferrocement is simply a cement mortar reinforced by a steel wire meshes of different shapes. Aim of this project is to Investigation of using geopolymer mortar in ferrocement by varying the combination, number and sizes of meshes. In this paper we are going to use geopolymer mortar, GGBS material is used with sodium silicate and sodium hydroxide. Ferrocement that means wire meshes such as Square woven, Square welded and Expanded metal mesh is used. The number of layers in each mesh was varied from single, double and triple layers. Mortar Mix of 1:3 have to take. Optimum molarity has to find out and then casting of cubes for 150mm *150 mm* 150 mm have to done, to check the desire w/c ration as well as molarity. Specimen have to cure for 28 days with ambient curing. Further casting of slab specimen of 1100mm * 400mm * 150mm have to cast with ferro geopolymer by varying the combination, number and sizes of meshes. Flexural behavior, acid attack, corrosion resistance test and long-term other test etc. preformation provision is done and effectiveness of the Square woven, Square welded and Expanded metal mesh were compared. Total nine rectangular slab have to cast with different meshes such as square woven, square welded and expanded metal mesh.*

Keywords: Ferro geopolymer, GGBS, molarity, Sodium hydroxide, sodium silicate, wire meshes

I. INTRODUCTION

The rate of production of carbon dioxide released to the atmosphere during the production of Portland cement and fly ash, a by-product from thermal power stations worldwide is increasing with the increasing demand on infrastructure development, and hence needs proper attention and action to minimize the impact on the sustainability of our living environment. De-carbonation of limestone in the kiln during manufacturing of cement is responsible for the liberation of one ton of carbon dioxide to the atmosphere for each ton of Portland cement, as can be seen from the following reaction equation :

$5CaCO_3 + 2SiO_2\ 3CaO.SiO_2 + 2\ CaO.SiO_2 + 5\ CO_2$ .The current contribution of green house gas emission from the Portland cement production is about 1.35 billion tons annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere[1]. Furthermore, Portland cement is also among the most energy-intensive construction materials, after aluminum and steel. Geopolymer concrete is a material that does not need the presence of Portland cement as a binder. Instead, the source of materials such as fly ash, that are rich in Silicon (Si) and Aluminium (Al), are activated by alkaline liquids to produce the binder. Hence, concrete with no cement. Geopolymer is produced without the presence of Portland cement as a binder; instead, the base material such as fly ash, that is rich in Silicon (Si) and Aluminium (Al), is activated by alkaline solution to produce the binder. The Geopolymer concrete possesses high strength, undergoes very little drying shrinkage and moderately low creep, and shows excellent resistance to sulphate attack[3][4][5].

Ferrocement is a material of construction having great variety, which possesses unique structural properties. It is a composite formed with closely wire mesh tightly wound round skeletal steel and filled with rich cement mortar. Welded mesh, mild steel angles or bars are used for forming skeleton, while chickenmesh, square mesh or expanded metal are used as mesh reinforcement. Mortar mix may be (1:1.5) to (1:4) by volume[2]. It combines the properties of thin sections and high strength of steel, mouldability of concrete, lightweight and eases of working of timber, high tensile strength capacity of prestressed concrete and crack control of fiber reinforced concrete. Ferrocement can replace all these materials. In addition it needs no formwork or shuttering for casting. Ferrocement has applications in all fields of civil construction, including water and soil retaining structures, building components, space structures of large size, bridges, domes, dams, boats, conduits, bunkers, silos, treatment plants for water and sewage and chimneys partially.

II. LITERATURE REVIEW

The experimental work was conducted by **Voraa and Dave (2013)**, casting 20 geopolymer concrete mixes to evaluate the effect of various parameters affecting its compressive strength in order to enhance its overall performance. Various parameters i.e. ratio of alkaline liquid to fly ash, concentration of sodium hydroxide, ratio of sodium silicate to sodium hydroxide, curing time, curing temperature, dosage of superplasticiser, rest period and additional water content in the mix have been investigated. The test results show that compressive strength increases with increase in the curing time, curing temperature, rest period, concentration of sodium hydroxide solution and decreases with increase in the ratio of water to geopolymer solids by mass 10 & admixture dosage respectively. The addition of naphthalene based superplasticiser improves the workability of fresh geopolymer concrete. It was further observed that the water content in the geopolymer concrete mix plays significant role in achieving the desired compressive strength. The effect of partial replacement and full replacement of cement by low calcium fly ash was studied by Patankar and Jamkar (2012) in two phases. It was found that the compressive strength decreases with increases in replacement of cement by fly ash. Up to 40% replacement of cement, initial strength is less but strength at 60 days of curing is more or less similar to that of conventional concrete at 28 days of curing. Beyond 40% replacement of cement, workability and strength has been reduced and setting time increased. Beyond 60% replacement of cement, increases the water 11 demand, difficulty in mixing, more time required for demoulding of cubes and rate of gain of strength is observed.

The mechanical properties of geopolymer concrete composite (GPCC) which contain fly ash, alkaline liquid and glass fiber are determined by **Satish Kumar et al (2012).** They found that the density of geopolymer concrete composite was found approximately equivalent to that of conventional concrete. In geopolymer concrete composite there is increase in compressive strength, flexural strength, and split tensile strength up to fiber percentage of 0.02% by volume of concrete with respect to geopolymer concrete.

The factors that influence the early age compressive strength of geopolymer concrete such as molarities of sodium hydroxide are presented by **Bhosale and Shinde (2012).** The mechanism of activation of fly ash with alkaline solution is also described. Alkaline activator was used as sodium hydroxide and sodium silicate solution. The comparison of ratio Na_2SiO_3 and NaOH at the values 0.39 and 2.5 were studied test were conducted to check mechanical properties of geopolymer concrete such as compressive strength, split tensile strength, flexural strength, rebound hammer test, acid resistant test for ambient temperature and oven dry temperature. From test result it was observed that compressive strength was more for oven dry temperature as compare to ambient temperature. Also it was observed that compressive strength increases as increase in molarities of sodium hydroxide.

The effect of water-to-geopolymer binder ratio on production of fly ash based geopolymer concrete was studied by **Patankar et al (2012).** In this study authors changes the quantity of water in mixture without disturbing the mix proportion and tested the mechanical properties of fresh concrete and hard concrete. It is observed that the flow of geopolymer concrete increases with increase in water-to-geopolymer binder ratio by maintaining other parameters constant. Means higher ratio gives segregated mixture while lower ratio gives viscous and dry mixture. Also it is observed that compressive strength of geopolymer concrete decreases as ratio of water-to-geopolymer binder increases. And it is reported that the suitable range of water-to-geopolymer binder ratio was in between 0.24 to 0.35.

By reducing the mean particle size of the fly ashes from 30 μm to below 10 μm, substantial improvement in the flow and strength properties of mortars and concrete are achieved by **Chaterjee (2010)** but the enhancement of properties corresponding to further reduction of fly ash particle size to even 3-5 μm is either incommensurate or inconsistent.

III OBJECTIVES OF INVESTIGATION

- To study the different mechanical properties of GGBS based geopolymer concrete.
- To study the effect of 12 molarity and 16 molarity NaOH solution on GGBS based geopolymer concrete.

IV. MATERIALS

1. Fly Ash: In the present experimental work, low calcium Class F (American Society for Testing and Materials 2001) dry fly ash obtained from the dirk India pvt.Ltd. was used as the base material. Fly ash (Pozzocrete 60) is a high efficiency class F pozzolanic material confirming to BS 3892 obtained by selection and processing of power station fly ashes resulting from the combustion of pulverized coal. Pozzocrete 60 is subjected to strict quality control. The general information of class F low calcium fly ash is shown in table 3.1. Also table 3.2 gives information about chemical composition of Pozzocrete 60 as obtained from Dirk India Pvt. Ltd.

2. Ground Granulated Blast Furnace Slag (GGBS): GGBS is a byproduct from manufacturing of iron and steel-making. Blast furnace slag is formed in the processes of iron manufacture from iron ore, combustion residue of coke, and fluxes such as limestone or serpentine and other materials. If the molten slag is rapidly chilled by immersion in water, a vitreous Ca–Al–Mg silicate fine grain glass is formed with a highly cementitious in nature. Due to presence of SiO2 and Al2O3 in GGBS it can be used in geopolymer as a base material. A typical chemical composition of GGBS is shown in Table. The GGBS was finely crushed in the laboratory for this study as the available GGBS was in larger size (around 20mm).

3. Water-to-Geopolymer binder ratio: The ratio of total water (i.e. water present in solution and extra water if required) to material involve in polymerization process (i.e. fly ash and sodium silicate and sodium hydroxide solutions) plays an important role in the activation process

4. Solution to fly ash ratio : As solution (i.e. sodium silicate + sodium hydroxide) to fly ash ratio increases, strength also increases. But the rate of gain of strength is not much significant beyond solution to fly ash ratio of 0.35. Similarly, the mix was more and more viscous with higher ratios and unit cost is also increases. So, in the present mix design method, solution-to-fly ash ratio was maintained at 0.35.

5. Preparation of Geopolymer Concrete Mixes: Preparation of geopolymer concrete is similar to that of cement concrete. Two types of coarse aggregates, sand and fly ash were mixed in dry state. Then add prepared mixture solution of sodium hydroxide and sodium silicate along with extra water based on water-to-geopolymer binder ratio and mix thoroughly for 3–4 min so as to give homogeneous mix. It was found that the fresh fly ash based geopolymer concrete was viscous, cohesive and dark in color. After making the homogeneous mix, workability of fresh geopolymer concrete was measured by flow table apparatus as per IS 5512-1983 and IS 1727-1967. Concrete cubes of side 150 mm are casted in three layers. Each layer is well compacted by tamping rod of diameter 16 mm. All cubes were placed on table vibrator and vibrated for 2 min for proper compaction of concrete. After compaction of concrete, the top surface was leveled by using trowel. After 24 h of casting, all cubes were demoulded and then placed in an oven for thermal curing (heating). To avoid the sudden variation in temperature, the concrete cubes were allowed to cool down up to room temperature in an oven. Three cubes were casted and tested for compressive strength for each curing period.

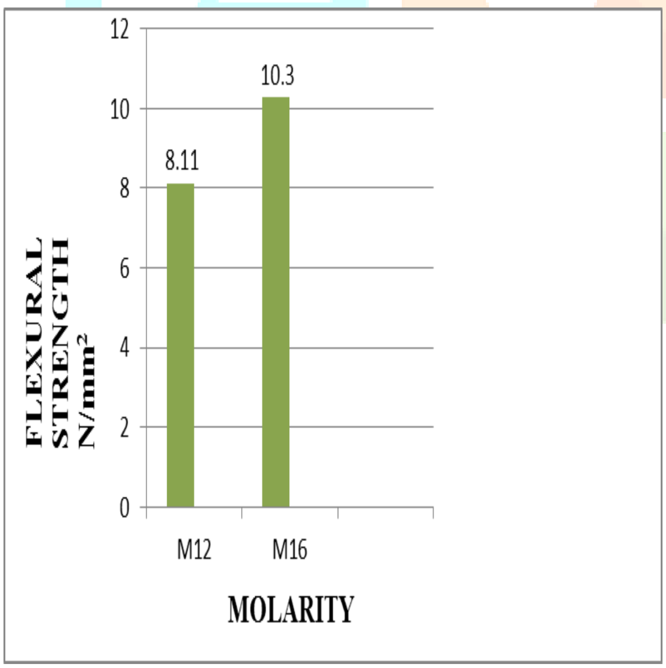
V Testing Program

Flexural strength : Beam section of size 100x100x500 mm were casted and cured for 28 days. All beams were tested under two-point loading in Universal Testing Machine. Each beam section was given 1-day rest period. After giving rest period these beams were cured at 45^{0}C temperature for 24 hours. Testing arrangement for beam sections are shown in figure . Beam sections were supported symmetrically over a span of 400mm in the machine. The load was increased until the specimen failed and the failure load was recorded. The results are shown in Table .Results show that maximum flexure strength is obtained for fly ash & GGBS combination 60-40 % for the trial no.6. The flexural strengths shall be obtained as described in IS 516 and IS 5816 respectively.

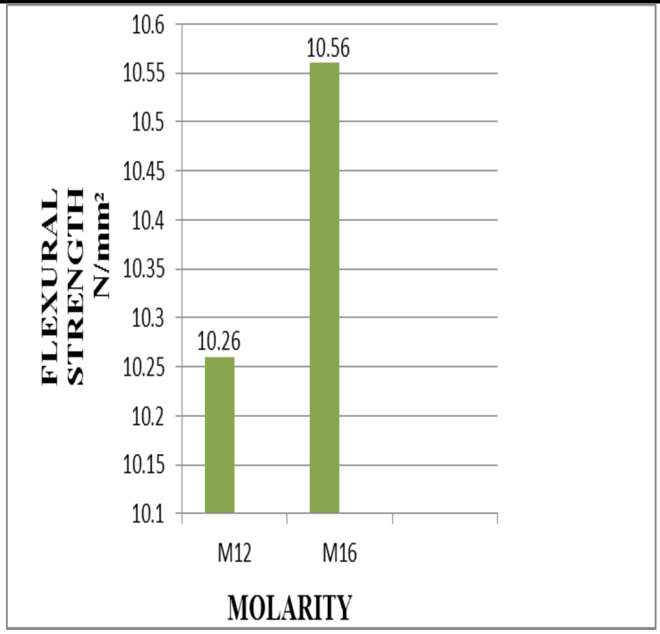
Fig. 1 - Flexural test on Specimens

Table : Flexure strength results for beams of GGBS based geopolymer concrete

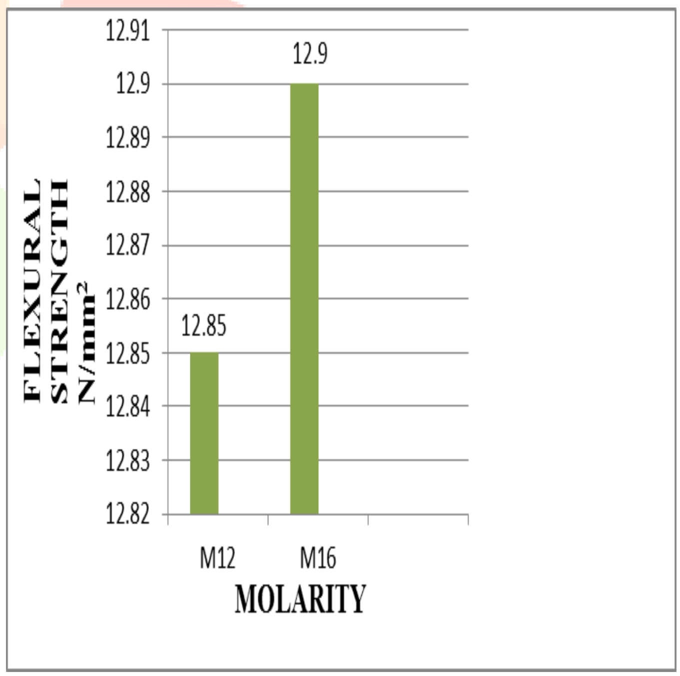
TRIAL	MOLARITY	FLY ASH	GGBS	FLEXURE STRENTGH AT 28 DAYS IN MPa
1	12M	100	0	8.11
2	16M	100	0	10.30
3	12M	80	20	10.26
4	16M	80	20	10.56
5	12M	60	40	12.85
6	16M	60	40	12.90
7	12M	50	50	12.38
8	16M	50	50	12.34



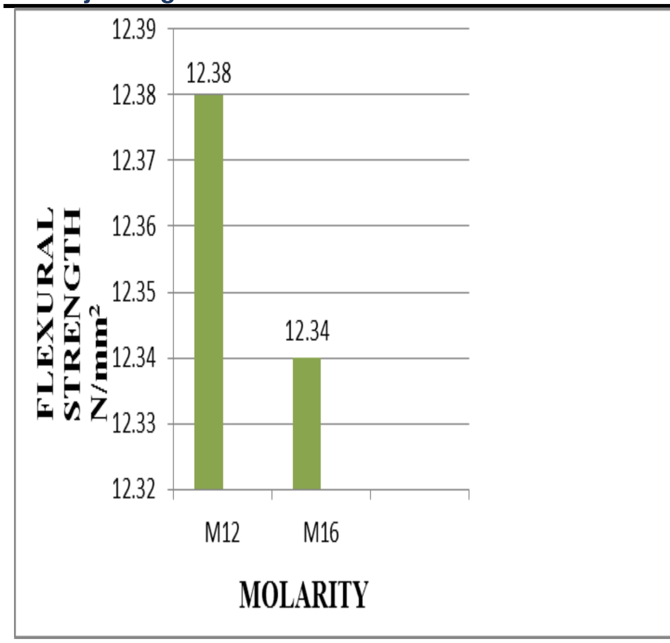
Graph : Effect of combination of fly ash and GGBS on geopolymer concrete for 12M and 16M for trial 1 and 2



Graph: Effect of combination of fly ash and GGBS on geopolymer concrete for 12M and 16M for trial 3 and 4.



Graph :Effect of combination of fly ash and GGBS on geopolymer concrete for 12M and 16M for trial 5 and 6.



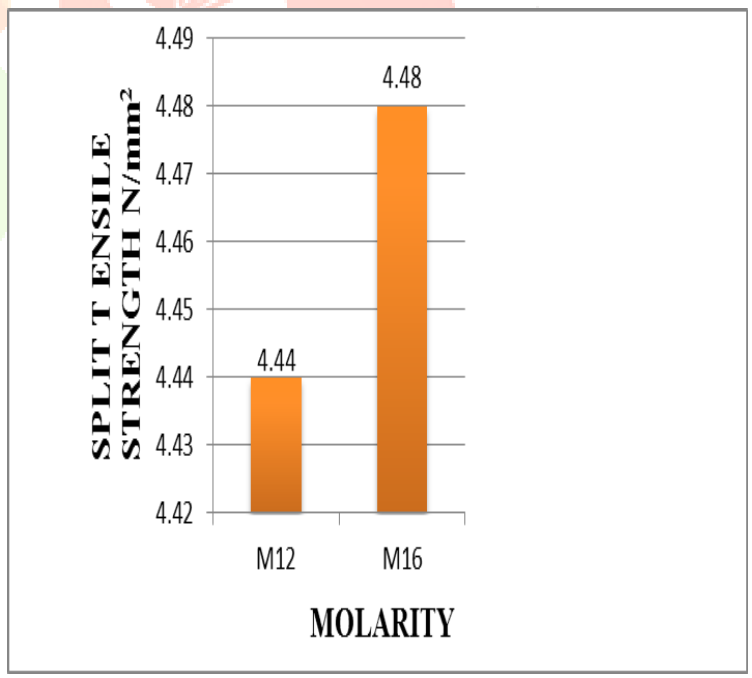
Graph : Effect of combination of fly ash and GGBS on geopolymer concrete for 12M and 16M for trial 7 and 8.

Split tensile test :The split tensile test is well known indirect test used to determine the tensile strength of concrete. Three cylindrical sections of diameter 150 mm and length 300 mm were casted and cured for 28 days. Each cylinder section was given 1-day rest period. After giving rest period these cylinders were cured at 60^0C temperature for 24 hours. Testing arrangement for cylinder sections are shown in Figure. The results are shown in Table. Results show that maximum split tensile strength is obtained for combination of fly ash and GGBS of 60-40% for the trial no.6. The load was applied at a uniform rate till the specimen failed by a fracture across vertical diameter. When the designer wishes to use an estimate of the tensile strength from the compressive strength as per the IS 456:2000 clause 6.2.2.

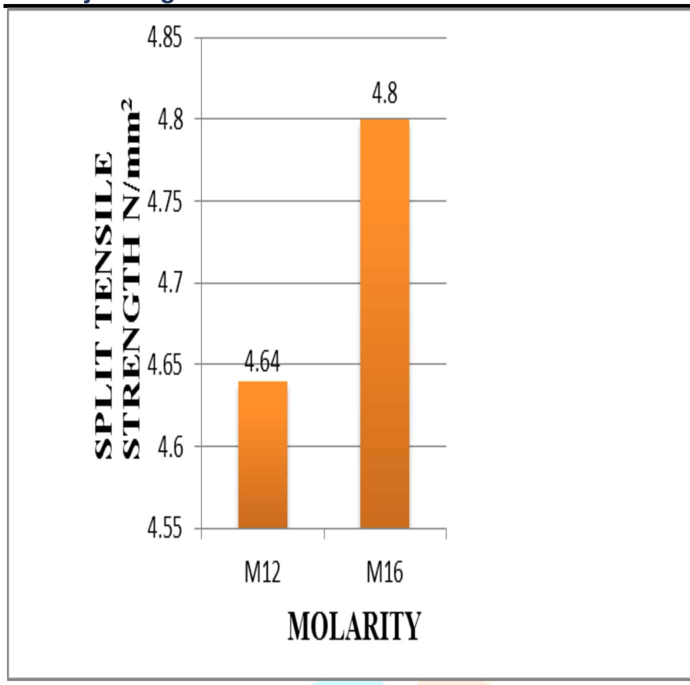
Figure No 2: Split tensile Test on Geopolymer Concrete

Table : split tensile strength results for cylinder of GGBS based geopolymer concrete.

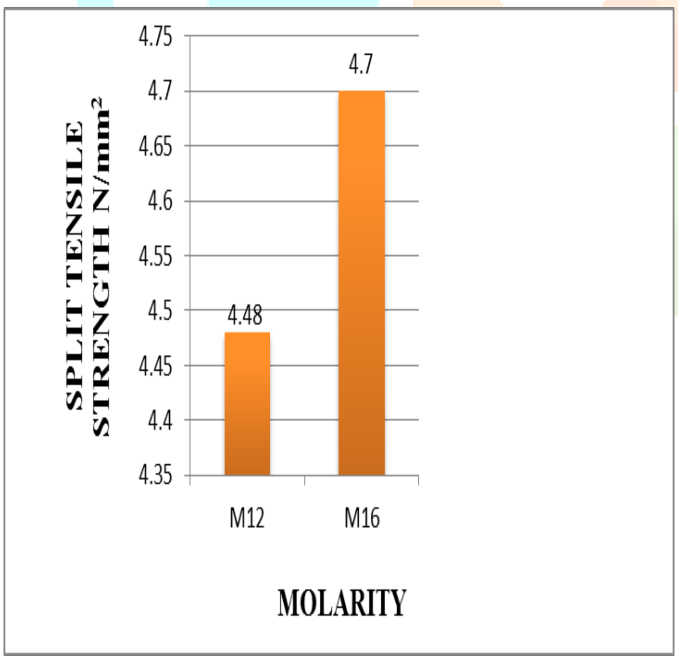
TRIAL	MOLARITY	FLY ASH	GGBS	SPLIT TENSILE STRENGTH AT 28 DAYS IN MPa
1	12M	100	0	8.11
2	16M	100	0	10.30
3	12M	80	20	10.26
4	16M	80	20	10.56
5	12M	60	40	12.85
6	16M	60	40	12.90
7	12M	50	50	12.38
8	16M	50	50	12.34



Graph: shows that effect of varying molarity of M12 and M16 to split tensile strength at 28 days on geopolymer concrete for trial 1 and 2



Graph:shows that effect of varying molarity of M12 and M16 to split tensile strength at 28 days on geopolymer concrete for trial 5 and 6.



Graph:shows that effect of varying molarity of M12 and M16 to split tensile strength at 28 days on geopolymer concrete for trial 7 and 8

VII. CONCLUSIONS

- As there is CaO content in GGBS based geopolymer concrete the curing temperature required for Fly ash based geopolymer concrete is 600C but it can be reduced by addition of GGBS to the fly ash based geopolymer concrete up to 450C.
- In case of fly ash based geopolymer concrete as there is no CaO content, curing of fly ash based geopolymer concrete takes place due to polymerization process but with the addition of GGBS to the fly ash based geopolymer concrete, the curing temperature due to combined effect of polymerization as well as heat of hydration due to presence of alkaline solution and CaO respectively.
- Maximum flexural strength achieved at 40% replacement of GGBS with fly ash is 65.73 % greater than that of convectional concrete at 28 Days.
- Maximum split tensile strength achieved at 40% replacement of GGBS with fly ash is 10.70 % greater than that of convectional concrete at 28 Days.

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