Geopolymer Concrete by Using Flyash and GGBS as A Replacement of Cement with Addition of Nylon Crystals

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***Abstract*: Concrete Transportation is a major developing sector in India, and required for good quality of roads, railway and airways is high. Concrete has occupied an important place in construction industry in the past few decades and it is used widely in all types of constructions ranging from small buildings to large infrastructural dams or reservoirs. Cement is major ingredient of concrete. The cost of cement is increasing day by day due to its limited availability and large demand. At the same time the global warming is increasing day by day. Manufacturing of cement also releases carbon dioxide. In the present study an attempt been made on concrete and also an experimental investigation on the concrete using by replacing cement with FLYASH and GGBS to decrease the usage of cement as well as emission of concrete In the present study an attempt been made on geo polymer concrete and also an experimental investigation on the concrete using Nylon Crystal.**

Experimental studies were performed on plain geo polymer concrete and replacement of cement with Nylon crystal is done. In this study the concrete mix were prepared by using fly ash, sodium silicate, sodium hydroxide and Nylon crystal from 1% to soon by weight of fly ash were added partially to the mixes. A comparative analysis has been carried out for concrete to that of the Nylon crystal reinforced geo polymer concrete in relation to their compressive strength, split tension strength and flexural strength properties. The geo polymer concrete made with Nylon crystal performed well in terms of compressive strength, split tension strength and flexural strength showed higher performance at the age of 7, 28, 60 and 90 days than conventional concrete. And also two different types of acid attack is done to determine the Bond Strength and compressive strength both on conventional concrete and Nylon crystal reinforced geo polymer concrete.

***Index Terms*: Geo polymer, nylon crystals, Compressive strength, Flexural strength, Split Tensile strength, Acid Attack, alkaline**

I. INTRODUCTION

A. General

Development of a country depends on the connectivity of various places with adequate road network. Road constitute the important mode of communication in areas where railways have not developed much. The structure of a highway pavement consists of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements.

1. Types of pavements

The pavements can be classified based on the structural performance into two types.

Flexible Pavements

Rigid Pavements.

In Flexible pavements, wheel loads are transferred by grain-to-grain contact of the aggregate through the granular structure. The flexible pavement, having less flexural strength, acts like a flexible sheet (e.g. Bituminous Road). On the contrary, in Rigid Pavements, wheel loads are transferred to sub-grade soil by flexural strength of the pavement and the pavement acts like a rigid plate (e.g. Cement Concrete Roads).

a. Flexible pavements

Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure.

The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of these stress distribution characteristic, flexible pavements normally has many layers. Hence, the design of flexible pavement uses the concept of layered system. Based on this, flexible pavement may be constructed in a number of layers and the top layer has to be of best quality to sustain maximum compressive stress, in addition to wear and tear.

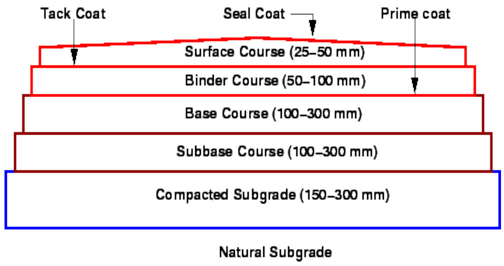


Figure 1.1: Typical Cross section of Flexible pavement

b. Rigid pavements

Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area below. Compared to flexible pavement, rigid pavements are placed either directly on the prepared sub-grade or on a single layer of granular or stabilized material. Since there is only one layer of material between the concrete and the sub-grade, this layer can be called as base or sub-base course.

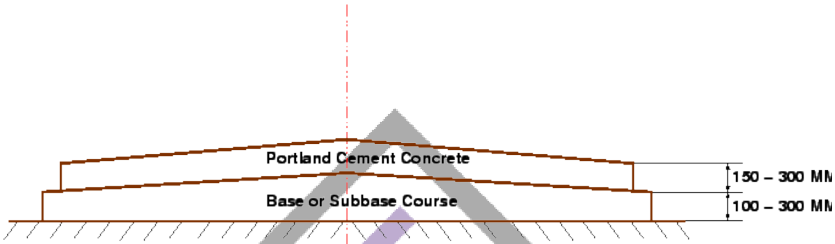


Figure 1.2: Typical Cross section of Rigid pavement

In rigid pavement, load is distributed by the slab action, and the pavement behaves like an elastic plate resting on a viscous medium. Rigid pavements are constructed by Portland cement concrete (PCC) and should be analyzed by plate theory instead of layer theory, assuming an elastic plate resting on viscous foundation.

2. Types of Rigid Pavements

- Rigid pavements can be classified into four types:
- Jointed plain concrete pavement (JPCP),
- Jointed reinforced concrete pavement (JRCP),
- Continuous reinforced concrete pavement (CRCP), and
- Pre-stressed concrete pavement (PCP).
- Failure criteria of rigid pavements

Traditionally fatigue cracking has been considered as the major or only criterion for rigid pavement design. The allowable number of load repetitions to cause fatigue cracking depends on the stress ratio between flexural tensile stress and concrete modulus of rupture. Of late, pumping is identified as an important failure criterion.

Hence it is required to relook at the methods of forecasting the traffic volume for the purpose of design. The pace of road construction in India was limited in the past but recently the two programmes have given a boost to road construction namely, National Highway Development Project's (NHDP's) Golden Quadrilateral, 5864 km (almost completed) and North South East West corridor (NSEW), 7300 km (completed 4863 km) and the Pradhan Mantri Grameen Sadak Yojana(PMGSY).

B. Cement

Cement, as a binding material, is a very important building material. Almost every construction work requires cement. Cements are materials that exhibit characteristic properties of setting and hardening when mixed to a paste with water. This makes them join rigid masses into coherent structures. It is powdery bonding material having adhesive and cohesive properties.

C. Composition of Cement

There are eight major ingredients of cement.

The general percentage of these ingredients in cement is given below:

Table 1.1: Percentages of components in Cement

Ingredient	Percentage in cement
Lime	60-65
Silica	17-25
Alumina	3-8
Magnesia	1-3
Iron oxide	0.5-6
Calcium Sulfate	0.1-0.5
Sulfur Trioxide	1-3
Alkaline	0-1

D. Geo polymer Concrete

Geo polymer was the name given by Daidovits in 1978 to materials which are characterized by chains or networks or inorganic molecules. It is an innovative and eco-friendly construction material and an alternative to Portland cement concrete. Generally Geo polymer cement concrete is made from utilization of waste materials such as fly ash and ground granulated blast furnace slag(GGBS).

Fly ash is the waste product generated from thermal power plant and ground granulate blast furnace slag is generated as waste material in steel plant. Use of geopolymer reduces the demand of Portland cement which is responsible for high CO2 emission.

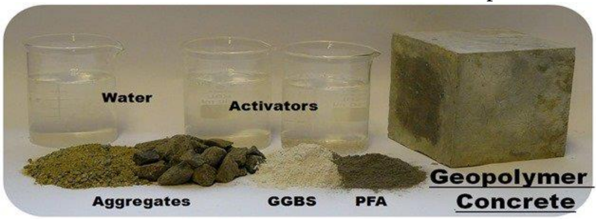


Figure 1.3 : Materials used in making Geo polymer Concrete

E. Need of Geo Polymer Concrete

In order to provide an Eco friendly environment there is a necessity to use a environmental friendly concrete, for this we have to replace the cement with some other binders which should not create any bad effect on environment. The usage of industrial by products as binders can reduce the problem. In this respect, the new technology geo-polymer concrete is a guarantee technique. In terms of reducing the global warming, the geo-polymer technology could reduce the CO2 emission to the atmosphere caused by cement and aggregates industries by about 80% (Davidovits, 1994c). The proper usage of industrial wastes can reduce the problem of disposing the waste products into the atmosphere.

F. Properties of Geo polymer Concrete

- It is non-toxic and bleed free.
- It Sets at room temperature.
- It is Higher resistant to heat and resist to all inorganic solvents.
- Higher compressive strength
- It is Light in weight.

The Compressive strength of Geo polymer concrete is very high compared to the Ordinary Portland Cement Concrete. Geo polymer Concrete also showed very high early strength. The compressive strength of Geo polymer Concrete is about 1.5 times more than the compressive strength of the Ordinary Portland Cement Concrete, for the same mix.

G. Objectives For The Study

The objectives of this research is to study the following long-term properties of fly ash-based Geo polymer concrete with the addition of nylon crystals

H. Scope Of The Project

The experimental work involved conduct of long-term tests on fly ash based geo polymer concrete. The tests currently available for cement concrete were used to test the GPC. In the experimental work, only one source of Fly Ash and GGBS was used along with Nylon Crystals. Analytical methods of Portland cement concrete were used to predict the test result

II. LITERATURE REVIEW

In this following Chapter there is a brief review of the terminology and chemistry of geo polymers, and as there is a wide range of research undergoing for the use of Geo-polymer Concrete. For our investigation, some important publications were reviewed to have a broad idea about Geo-polymer Concrete and they have been listed in the references at the end of the report.

DjwantoroHardjito, Steenie E Wallah, Dody M.J. Sumajouw, and B.V. Rangan (1992)2 gave a detailed description on the the effects of several factors on the properties of fly ash based Geo polymer concrete, primarily the compressive strength. The test variables included were the age of concrete, curing temperature, curing time, quantity geo-polymer of super-plasticizer, the rest period prior to curing, and the water content of the mix.

Van Jaarsveld et. al., (1997; 1999)3 identified the significant use of waste materials such as fly ash, GGBS, contaminated soil, mine tailings and building waste to toxic metals. Palomo et. al., (1999) reported the study of fly ash based geo polymer concrete.
Shuguang Hu, Hongxi Wang, GaozhanZhang ,Qingjun Ding(2007)4 made an attempt by preparing three repair materials by using cement-based, geo-polymeric, or geo-polymeric containing steel slag binders.
XiaoluGuo ,Huisheng Shi , Warren A. Dick(2009)5 in this the compressive strength and micro structural characteristics of a class C fly ash geo polymer (CFAG) were studied. They conclusion of this study was that a high compressive strength was obtained when the class C fly ash (CFA) was activated by the mixed alkali activator (sodium hydroxide and sodium silicate solution) with the optimum modulus viz., molar ratio of SiO2/Na2O of 1.5.
SmithSongpiriyakij,Teinsak Kubprasit,ChaiJaturapitakkul,PrinyaChindaprasirt (2010)6 they made an attempt by using Rice husk and bark ash as a source to partially replace fly ash in making a geo polymer. They concluded that the optimum SiO2/Al2O3 ratio to obtain the highest compressive strength was 15.9.
Aminul Islam Laskar and Rajan Bhattacharjee (2012)8 has made an attempt to study the variation of workability of fly ash based geo polymer concrete with the variation of lignin based plasticizer and poly-carboxylic ether based super plasticizer.
Ganapathi Naidu, A.S.S.N et al., (2012)9 had made an attempt in studying the strength properties of geo polymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Sodium silicate (103 kg/m3) and sodium hydroxide of 8 molarity

(41kg/m3) solutions were used as alkalis in all 5 different mixes. With maximum (28.57%) replacement of flyash with slag, achieved a maximum compressive strength of 57MPa for 28 days. The same mix is shown 43.56 MPa after exposure of 500°C for 2 hours.
In (2013)10 ,Jaarsveld et.al. reported that the particle size, calcium content, alkali metal content, amorphous content, and morphology and origin of the fly ash affected the strength properties of geo polymers. However, in order to obtain the optimal binding properties of the material, fly ash and GGBS as a source material should have calcium content and other characteristics such as unburned material lower than 5%, Fe2O3 content not higher than 10%, 40-50% of silica content, 80- 90% of particles with size lower than 45 µm and high content of vitreous bonding agents.
Prof. More Prathap Kishanrao (2013)11, There is an established fact that the green house gas emissions are reduced by 80% in Geo polymer concrete with respect to the conventional Portland cement manufacturing, as it does not involve carbonate burns etc. This study is continued to investigate the behaviour of such Geo polymer concrete under high temperatures ranging from 1000C to 5000C. Cubes of size 100mm x 100mm x 100 mm are tested for their residual compressive strengths after subjecting them to these high temperatures.

III. METHODOLOGY AND EXPERIMENTAL MATERIALS

A. Methodology
To investigate the strength behaviour of Geo polymer concrete which is made by replacement of cement with fly ash and ggbs and with the addition of nylon crystals . The results obtained by this mix are compared with the regular mix or conventional mix of M20 grade. The experimental programme consists of casting and testing of totally 40 cubes of size 150mm × 150mm × 150mm, . The specimens were tested after curing of 7,14, 28 and 90 days. The compressive test was conducted on the specimens

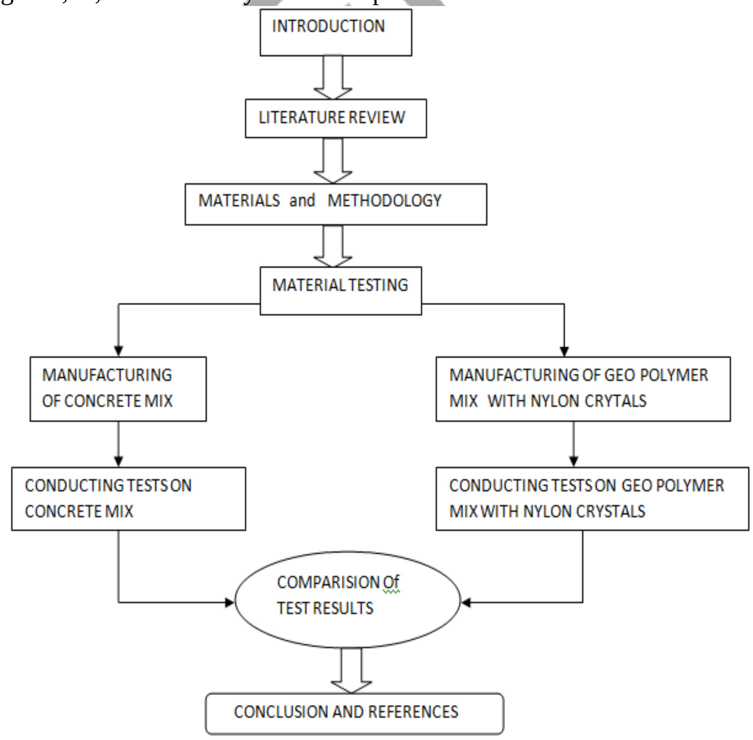


Figure 3.1: Methodology

B. Description of Materials

Raw materials required for the concrete use in the present work are:

- FLYASH
- GGBS
- CEMENT for manufacturing of M20 cement concrete
- FINE AGGREGATES
- COARSE AGGREGATES
- ALKALINE LIQUIDS
- SUPER PLASTISIZER
- WATER
- NYLON CRYSTALS

C. *Aggregates*:

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Aggregates occupy 70 to 80 percent of volume of concrete. Aggregates are obtained either naturally or artificially. Aggregates can be classified on the basis of size as fine aggregate and coarse aggregate.

3.3.1 FINE AGGREGATE (SAND):

The size of the fine aggregate is below 4.75mm.Fine aggregates can be natural or manufactured. The grade must be throughout the work. The moisture content or absorption characteristics must be closely monitored. The fine aggregate used is natural sand obtained from the river Godavari conforming to grading zone-II of table 3 of IS: 10262-2009.

The following tests have been conducted on fine aggregates.

1. Specific Gravity
2. Bulk density
3. Sieve analysis (fineness modulus)

Specific gravity: Specific Gravity is defined as the ratio of mass of material to the mass of the same volume of water at the stated temperature. The experiment was conducted as per IS: 2386-1963 and the values are tabulated in table 4.4.

Sieve analysis (fineness modulus): The process of dividing a sample of aggregates into fractions of same particle size is known as a sieve analysis and its purpose is to find fineness. The sieve analysis was carried out using locally available river sand and tabulated in table 3.2

Table 3.1 Sieve analysis of Fine aggregate

Sieve size	Weight retained in gms	Cumulative weight retained in gms	% 0f Cumulative weight retained in Gms	% 0f Cumulative weight passing in Gms
10	_	_	_	100
4.75	_	_	_	100
2.36	80	80	8	92.
1.18	113	188	18.8	81.2
0.6	178	366	36.6	63.4
0.3	470	836	83.6	16.4
0.15	164	1000	100	0
			247	

Fineness modulus = % of cumulative weight retained/100
= 247/100
= 2.47

D. Alkaline Liquid

The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution. The sodium silicate solution (Na_2O= 13.7%, SiO_2=29.4%, and water=55.9% by mass) was purchased in bulk. The sodium hydroxide (NaoH) in flakes or pellets from with 97%-98% purity was also purchased from a local supplier in bulk. The NaoH solids were dissolved in water to make the solution.

E. Super Plasticiser

In order to improve the workability of fresh concrete, high-range water-reducing naphthalene based super plasticizer was added to the mixture.

F. Water

This is the least expensive but most important ingredient of concrete. The quantity and quality of water is required to be looked in to very carefully. In practice very often great control on the properties of all other ingredients is exercised, but the control on the quality of the water is often neglected. Since quality of the water effects strength, it is necessary for us to go in to the purity and quality of water.

Table 3.2 Physical properties of water

S. No	Property	Value
1	PH	7.0
2	Taste	Agreeable
3	Appearance	Clear
4	Turbidity(NT units)	1.75

G. Nylon Crystals

Strength:- Good tenacity, strongest textile fiber, excellent abrasion resistance.
Elasticity: - Good elasticity, high elongation and excellent recovery.

Resilience: - Retains smooth appearance and wrinkles from daily activities.
Drapability:– Excellent draping qualities. Light weight sheer nylon has high draping quality:- Medium weight can drape very nicely.
Structure: – Normal cross section is circular.
Density: – 1.14 g/cc (light weight)
Effect of sunlight: - Fair resistance to sunlight

IV. MIX DESIGN AND EXPERIMENTAL SET UP

A. Mix Design

In the design of geo polymer concrete mix, total aggregates were (fine and coarse) taken as 78% of total concrete mix by mass. This value is almost equal to that used in OPC concrete .the percentage will be in the range of 75 to 80% of the entire concrete mix by mass. Fine aggregate was taken as 30% of the total aggregates taken. From the studied literature, it is observed that the average density of fly ash and GGBS based geo polymer concrete is similar to that of OPC concrete (2400 kg/m3). Considering the density of concrete, the combined mass of alkaline liquid and fly ash can be arrived. By assuming the ratios of alkaline liquid to fly ash as 0.4, mass of fly ash and mass of alkaline liquid was found out. To obtain mass of sodium hydroxide and sodium silicate solutions, the ratio between sodium silicate solutions to sodium hydroxide solution was fixed as 2.5. In the present studies, concentration of NaOH solution is taken as 8 M.

Let us Assume that normal-density aggregates in normal condition are to be used and all of us known that the unit-weight of concrete is 2400 kg/m3. I have Taken the mass of combination of coarse and fine aggregate as 77% of the mass of concrete,

i.e. 0.77x2400=1848 kg/m3. The combination of both aggregates may be selected to match the standard grading curves used in the design of Portland cement concrete mixtures. Let us take the coarse aggregates (70%) may combination of 776 kg/m3 (60%) of 20 mm aggregates, and 10 mm aggregates taken as 40% which will be equal to 517 kg/m3, and the other 30% was fine aggregate which is 554 kg/m3 to meet the requirements of standard grading curves. After finding and observing the water absorption values of coarse and fine aggregates, the values are a bit adjusted . the adjusted coarse and fine aggregates are 774 kg/m3 of 20 mm aggregates, 516 kg/m3 of 10 mm aggregates and 549 kg/m3 (30%) of fine aggregate. So now,

The mass of geo polymer binders (fly ash and GGBS) and the alkaline liquid
= 2400 – 1848 = 552 kg/m3.

Take the alkaline liquid-to-fly ash ratio by mass as 0.35 from the previous papers .so the mass of fly ash = 552/ (1+0.35) = 409 kg/m3

so the mass of alkaline liquid is = 552 – 409 = 143 kg/m3.

Considering the ratio of sodium silicate solution- and -sodium hydroxide solution by mass as 2.5;

The mass of sodium hydroxide solution = 144/ (1+2.5) = 41 kg/m3

The mass of sodium silicate solution =143 – 41=102 kg/m3.

After this nylon crystal is added according to weight of the GGBS starting from 1 percentage to 4 percentages. So the values of all the GPC with nylon crystals ingredients are calculated

The mix design considered is

Table 4.1 Mix Design

MATERIALS	WEIGHT(Kg/m^3)
20mm coarse aggregate	776
10mm coarse aggregate	517
Fine aggregate	554
Fly ash	102.2
GGBS	306.7
Sodium silicate	102
Sodium hydroxide	41
Super plasticizer	20
Nylon crystals	Starting from 1% of GGBS
Extra water	55

B. Preparation of Samples

The preparation of GPC was very similar to the convention concrete preparation. But first the sodium silicate and sodium hydroxide was mixed thourghly. In that mixture super plasticizer was mixed without developing any air bubbles. On the other hand the fly ash, GGBS, the coarse, fine aggregates and nylon crystals are mixed thourghly. Now the chemical liquid was added to the dry mixture. And this mixture was evenly mixed for 5-10 minutes. Before compacting the mixture is taken into mould and the slump cone is calculated.

C. Curing of GPC

Normally there were three types of curing are available for manufacture of GPC . they are HEAT, VAPOUR, or AMBENT curing. But as per the availability and local conditions I have used HEAT curing for the manufacturing of GPC.

In the heat curing the GPC was put into a woven and left it for 24 hours at a constant temp of 60 ° C

After 24 hours the specimen is taken out and the cube was carefully separated from mould. From now onwards until the day of testing it won't need any sort of curing.

EXPERIMENTAL TESTS

SLUMP CONE TEST:

This test is used extensively in site all over the world. The slump test does not measure the workability of concrete, but the test is very useful in detecting variations in the uniformity of a mix of given nominal proportions.

The slump test is done as prescribed by IS: 516.

The apparatus for conducting the slump test essential consists of a metallic mould in the form of a cone having the internal dimensions as under

Bottom diameter: 200 mm

Top diameter : 100 mm

The mould for slump is a frustum of a cone, 300 mm high. It is placed on a smooth surface with the smaller opening at the top, and filled with concrete in three layers. Each layer is tamped twenty five times with a standard 16 mm diameter steel rod, rounded at the end, and the top surface is stroked off by means of sawing and rolling motion of the tamping rod. The mould must be firmly fixed against its base during the entire operation; this is facilitated by handles or foot-rests brazed to the mould. Immediately after filling, the cone is slowly lifted vertically up, and the unsupported concrete will now slump – hence the name of the test. The difference in level between the height of the mould and that of highest point of subsided concrete is measured. This difference in height in mm is taken as slump of concrete.

COMPRESSIVE STRENGTH TEST:

Compression test was conducted on 150mm×150mm×150mm cubes. Concrete specimens were removed from curing tank and cleaned. In the testing machine, the cube is placed with the cast faces at right angles to that of compressive faces, then load is applied at a constant rate of 1.4 kg/cm2/minute up to failure and the ultimate load is noted. The load is increased until the specimen fails and the maximum load is recorded. The compression tests were carried out at 7,14, 28, days. For strength computation, the average load of three specimens is considered for each mix. The average of three specimens was reported as the cube compressive of strength.

Cube compressive strength = $\frac{\text{Load}}{\text{Area of cross section}}$

SPLIT TENSILE STRENGTH

The resistance of a material to a force tending to tear it apart, measured as the maximum tension the material can withstand without tearing. Tested by keeping the cylindrical specimen in the compressive testing machine and is continued until failure of the specimen occurs.

Splitting Tensile Strength shall be calculated by using the formula:

$$f_t = \frac{2P}{\pi DL}$$

P = maximum load in Newtons applied to the specimen,

L = length of the specimen in mm,

D = cross sectional dimension of the specimen in mm.

$$\frac{\text{Load}}{\text{Area of cross section}}$$

FLEXURAL STRENGTH

The flexural strength may be expressed as the modulus of rupture fb, which, if "a" equals the distance between the line of fracture and the nearer support, measured on the centre line of tensile side of the specimen, shall be calculated to the nearest 0.5kg/sq.cm as follows:

$$f_{bt} = \frac{Pl}{bd^2}$$

Where

b=measured width in cm of the specimen d=measured depth in cm of the specimen.

l= length in cm of the span in which the specimen was supported

p=maximum load in kg applied to the specimen.

V. RESULTS AND DISCUSSIONS

In this following chapter we are going to discuss about the experimental results of Geo polymer concrete and the conventional concrete specimens. We are going to compare the test results of both GPC and CC. Here we conducted compressive strength, split tensile, flexural strength, water absorption and acid resistance tests to both the GPC and CC and compared all those test results.

A. Compressive Strength Test

The compressive strength of CC and GPC was calculated for 7days, 14 days and 28 days. After the Heat curing the GPC specimen were tested at 7, 14,28 days with 3 cubes each for the better and accurate result and the average was taken as the compressive strength at that specific time period. As usually the water cured CC also tested in the same period with three specimens each for accuracy

For 7 days of curing (N/mm2)

specimen	Sample 1	Sample 2	Sample 3	Average
CC	18	18.6	18.3	18.3
GPC + 1%NC	23.09	23	23.60	23.23
GPC + 2%NC	24.40	24.06	24.23	24.23
GPC + 3%NC	25.40	25.60	25.40	25.45
GPC + 4%NC	24.50	24.05	24.20	24.25

Table 5.1: Compressive Strength for 7 days of curing (N/mm2)

For 14 days of curing(N/mm2)

specimen	Sample 1	Sample 2	Sample 3	Average
CC	19.29	20	19	19.43
GPC + 1%NC	27	27.40	27.02	27.14
GPC + 2%NC	28.50	28.04	28.20	28.24
GPC + 3%NC	28.90	28.18	28.60	28.56
GPC + 4%NC	28.50	28.40	28.46	28.45

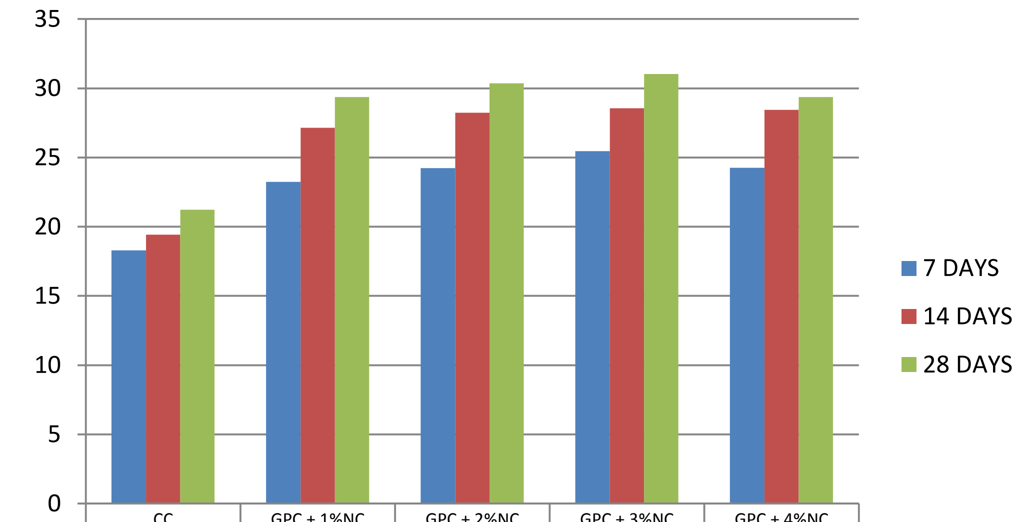
Table 5.2: Compressive Strength for 14 days of curing (N/mm2)

For 28 days of curing(N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	21.20	21.16	21.30	21.23
GPC + 1%NC	29.50	29.56	29.02	29.36
GPC + 2%NC	30.08	30.60	30.40	30.36
GPC + 3%NC	31.90	31.10	31.06	31.02
GPC + 4%NC	29	29.50	29.58	29.36

Table 5.3: Compressive Strength for 28 days of curing (N/mm2)

Compressive Strength of Nylon Crystal in Cube Specimens



	CC	GPC + 1%NC	GPC + 2%NC	GPC + 3%NC	GPC + 4%NC
7 DAYS	18.3	23.23	24.23	25.45	24.25
14 DAYS	19.43	27.14	28.24	28.56	28.45
28 DAYS	21.23	29.36	30.36	31.02	29.36

Figure 5.1: Compressive Strength for (7,14,28 days of curing (N/mm2))

B. Split Tensile Test

The tensile strength of CC and GPC was calculated for 7days, 14 days and 28 days. After the Heat curing the GPC specimen were tested at 7, 14,28 days with 3 cubes each for the better and accurate result and the average was taken as the split tensile strength at that specific time period. As usually the water cured CC also tested in the same period with three specimens each for accuracy.

A table containing the test values was prepared for comparison of both types of concrete

For 7 days of curing (N/mm2)

specimen	Sample 1	Sample 2	Sample 3	Average
CC	2.30	2.27	2.00	2.19
GPC + 1%NC	2.44	2.50	2.50	2.48
GPC + 2%NC	2.60	2.78	3.00	2.76
GPC + 3%NC	3.1	3.3	3.0	3.2
GPC + 4%NC	3.1	2.9	2.9	2.9

Table 5.4: Split Tensile Strength test for 7 days of curing (N/mm2)

For 14 days of curing(N/mm2)

specimen	Sample 1	Sample 2	Sample 3	Average
CC	3.00	3.06	3.03	3.03
GPC + 1%NC	3.36	3.30	3.35	3.34
GPC + 2%NC	3.34	3.50	3.60	3.48
GPC + 3%NC	4.00	4.02	3.92	3.98
GPC + 4%NC	3.90	3.90	3.78	3.86

Table 5.5: Split Tensile Strength test for 14 days of curing (N/mm2)

For 28 days of curing(N/mm2)

specimen	Sample 1	Sample 2	Sample 3	Average
CC	3.10	3.20	3.15	3.15
GPC + 1%NC	3.50	3.60	3.64	3.58
GPC + 2%NC	3.90	3.80	3.88	3.86
GPC + 3%NC	4.10	4.30	4.44	4.28
GPC + 4%NC	4.24	4.14	4.16	4.18

Table 5.6: Split Tensile Strength test for 28 days of curing (N/mm2)

Split Tensile Strength of Nylon Crystal in Cylinder Specimens

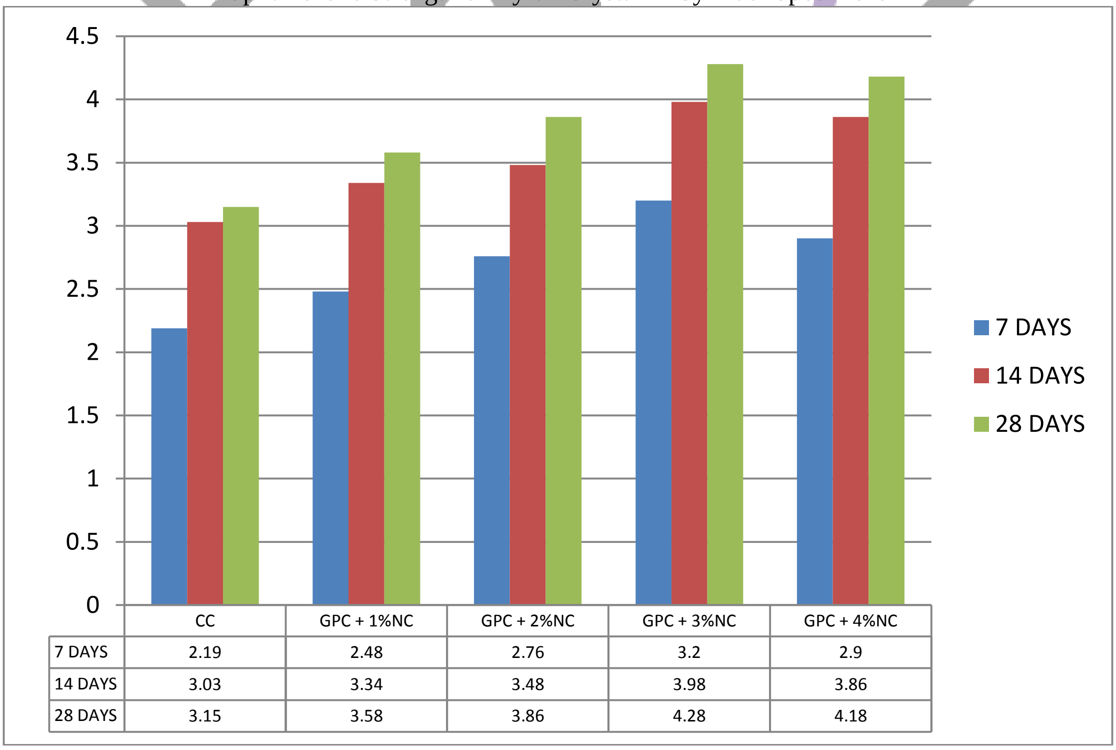


Figure 5.2: Split Tensile Strength Test for (7,14,28 days of curing (N/mm2))

5.3 FLEXURAL STRENGTH

The flexural strength of CC and GPC was calculated for 7days, 14 days and 28 days. After the Heat curing the GPC specimen were tested at 7, 14,28 days with 3 cubes each for the better and accurate result and the average was taken as the flexural strength at that specific time period. As usually the water cured CC also tested in the same period with three specimens each for accuracy

14 days of curing (N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	2.4	2.2	2.3	2.3
GPC + 1%NC	2.40	2.60	2.56	2.52
GPC + 2%NC	2.80	2.70	2.74	2.75
GPC + 3%NC	3.01	2.90	2.98	2.93
GPC + 4%NC	2.80	2.83	2.78	2.81

Table 5.7: Flexural strength test for 14 days of curing (N/mm2)

For 28 days of curing(N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	4.00	4.15	4.15	4.1
GPC + 1%NC	4.35	4.40	4.30	4.35
GPC + 2%NC	4.60	4.50	4.46	4.52
GPC + 3%NC	4.84	4.74	4.96	4.78
GPC + 4%NC	4.62	4.56	4.44	4.54

Table 5.8: Flexural strength test for 28 days of curing (N/mm2)

For 60 days of curing(N/mm2)

specimen	Sample 1	Sample 2	Sample 3	Average
CC	5.3	5.2	5.1	5.2
GPC + 1%NC	5.36	5.30	5.42	5.36
GPC + 2%NC	5.44	5.40	5.48	5.44
GPC + 3%NC	5.61	5.58	5.50	5.573
GPC + 4%NC	5.1	5.4	5.39	5.3

Table 5.9: Flexural strength test for 60 days of curing (N/mm2)

The flexural strength of CC and GPC

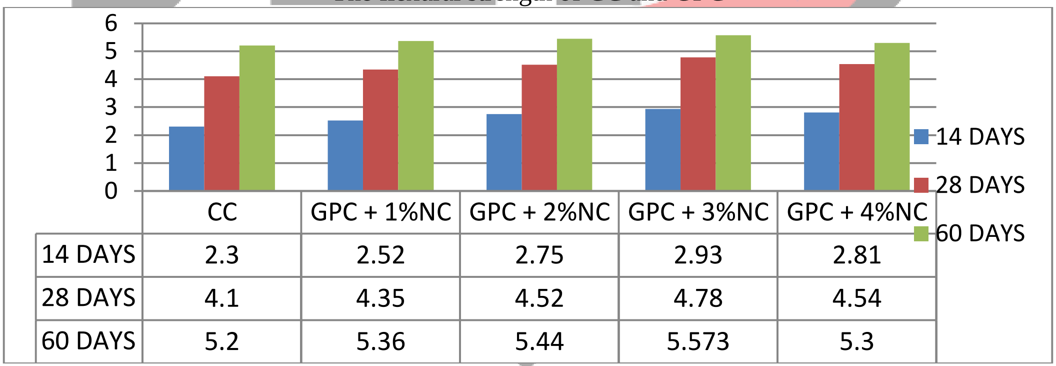


Figure 5.3: Flexural Strength Test for (14, 28, 60 days of curing (N/mm2))

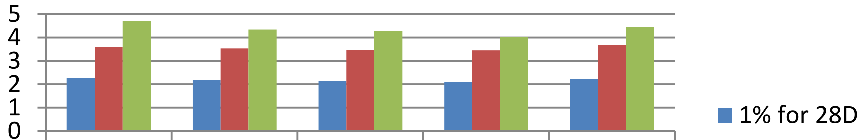
C. *Acid Resistance Tests*

The acid resistance tests were conducted on GPC and CC with HCL as well as with H2SO4. The tests were conducted with a specific time period of 28 days. But the percentage of acid in water was changed from 1% to 3%. simply the test was conducted by increasing acid percentage.

For HCL, three specimens of each type of concrete was exposed and the loss in weight was calculated

The average loss was considered and compared

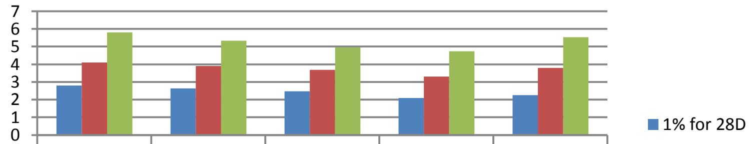
1. Effect of Acid on Geo Polymer Concrete with Nylon Crystal Cube with HCL



	CC	1%NC	2%NC	GPC + 3%NC	GPC + 4%NC
1% for 28D	2.27	2.2	2.14	2.1	2.23
2% for 28D	3.6	3.54	3.47	3.45	3.67
3% for 28D	4.7	4.34	4.29	4.02	4.45

Figure 5.4: Weight loss percentage of G.P.C with Nylon Crystal cube with HCL

2. Effect of Acid on Geo Polymer Concrete with Nylon Crystal Cube with H2SO4



	CC	GPC + 1%NC	GPC + 2%NC	GPC + 3%NC	GPC + 4%NC
1% for 28D	2.8	2.64	2.48	2.1	2.25
2% for 28D	4.1	3.9	3.69	3.3	3.8
3% for 28D	5.8	5.34	4.95	4.73	5.54

Figure 5.5: Weight loss percentage of G.P.C with Nylon Crystal cube with H2SO4

VI. CONCLUSIONS

1. It is observed that the concrete slump values are decreasing with the increasing Nylon Crystal percentage. The reduction in slump with the increase in the Crystal will be attributed to presence of Crystal which causes obstruction to the free flow of concrete.
2. It is observed that the optimum dosage of Nylon Crystal is 4%.
3. It is observed that the compressive strength of the GPC is high as the values are 21.23, 29.36, 30.36, 31.02 when % of Nylon crystal increases from 1%,2%,3%,4% for GPC when it is compared with conventional concrete at 28 days.
4. It is observed that split tensile strength of the GPC is high as the values are 3.58, 3.86, 4.28, 4.18 when % of Nylon crystal increases from 1%, 2%, 3%, 4% for GPC when it is compared with conventional concrete at 28 days.
5. It is observed that flexural strength of the GPC is high as the values are 5.36, 5.44, 5.573,5.3 when % of Nylon crystal increases from 1%, 2%, 3%, 4% for GPC when it is compared with conventional concrete at 28days.
6. It is observed that in the acid resistance tests of the GPC is losing less weight when % of Nylon crystal increases from 1%, 2%, 3%, 4% for GPC when it is compared with conventional concrete at 28days

Scope for Future Development

As we already discussed so far, the lime should be fully exhausted within a span of 50 years. And the emission of carbon dioxide and other harmful gases are increasing so the Geo polymer concrete which should be useful in many ways and a perfect experiment for further development options by using different materials and minerals

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