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Experimental Study on Partial Replacement of Cement in Geopolymer Concrete

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Abstract: In today's construction scenario, concrete is one of the most frequently used Building material. Concrete's world wide usage has led the researchers to improvise its Properties, which required large quantities of Portland Cement. Ordinary Portland Cement Production is the second only to the automobile as the major generator of carbon dioxide, which pollute the atmosphere. Hence, it is inevitable to find an alternative material to the Existing most expensive, most resource consuming Portland Cement. Geopolymer Concrete is an innovative construction material which shall be produced by the chemical Action of inorganic molecules. Fly Ash, a by- product of coal obtained from the thermal Power plant is plenty available worldwide, rich in silica and alumina reacted with alkaline Solution produced aluminosilicate gel that acted as the binding material for the concrete. It is an excellent alternative construction material to the existing plain cement concrete. Geoploymer concrete require oven drying curing which is not possible at site. Therefore, in our project we are adding some amount of cement to avail water curing suitable for site Utilization, for M25 grade of concrete up to 10%,20%&30% replacement of cement.

I. INTRODUCTION

Cement manufacture causes environmental impacts at all stages of the process. These include emissions of airborne pollution in the form of dust, gases, noise and vibration when operating machinery and during blasting in quarries, and damage to countryside from quarrying. Equipment to reduce dust emissions during quarrying and manufacture of cement is widely used, and equipment to trap and separate exhaust gases are coming into increased use. Environmental protection also includes the re-integration of quarries into the countryside after they have been closed down by returning them to nature or re-cultivating them. Carbon concentration in cement spans from ≈5% in cement structures to ≈8% in the case of roads in cement. Cement manufacturing releases CO2 in the atmosphere both directly when calcium carbonate is heated, producing lime and carbon dioxide, and also indirectly through the use of energy if its production involves the emission of CO2. The cement industry produces about 10% of global human-made CO2 emissions, of which60% is from the chemical process, and 40% from burning fuel. A study from 2018estimates that the 4 billion tonnes of cement produced annually account for 8% of worldwide CO2 emissions.

Geopolymer Concrete has become a perfect alternative to the world's sustainable construction industry because the concrete demand is the second largest in the world after water. The expansion of infrastructure accelerates the development of the country and society. So, concrete production will increase exponentially in the future with development. A comparable amount of carbon is emitted into the environment during the production of OPC cement. In the GPC, industrial solid waste, fly ash, and slag are used. GPC shows better physical, chemical, and mechanical properties compared to OPCcement concrete. Durability properties of the GPC are also higher than those of OPC concrete is more sulphate-resistant than OPC concrete. The Geopolymerisation reaction plays a vital role in developing the strength of the GPC, and some factors affect the geopolymerisation process, like curing conditions, alkaline solution content, and binding material content in the design mix.

II. LITERATUREREVIEW:

By M. I. Abdul Aleem, P. D. Arumairaj (2012):
The materials used in this journal are fly ash, Sodium Hydroxide, Sodium Silicate for binder. They observed that higher concentration of sodium hydroxide (molar) resulted higher compressive strength and higher the ratio of sodium silicate-to-sodium hydroxide liquid ratioby mass, showed higher compressive strength of Geopolymer concrete. They also found that the increased in curing temperature in the range of 30 to 90 °C increased the compressive strength of Geopolymer concrete and longer curing time also increased the compressive strength. They handled the Geopolymer concrete up to120 minutes without any sign of settingand without any degradation in the compressive strength, resulted very little drying shrinkageand low creep.
By Ayesha Siddiqua, Ailar Hajimohammadi, Md. Abdullah Al Mamun, Rayed alyyousuf and Wahid Ferdous(2021):
In this journal, the authors has replaced coarse aggregates with waste glass for 15%, 30%, 45%, 60%, gave better results of compressive strength compared to OPC. They followed steam curing method for curing of hardened concrete. The drying shrinkage of WGconcrete is lower than that of plain concrete (PC). they have analyzed Microstructure of WGConcrete, Durability of Concrete with WG, Electrical Resistivity and Environmental Benefit of WG Concrete.

By Jhutan Chandra Kuri, Anwar Hosan, Faiz Uddin Ahmed Shaikh andWahidul K. Biswas:
This study investigated the characteristics of ordinary Portland cement (OPC) and Geopolymer concretes containing different proportions of recycled glass as a partial replacement of natural coarse aggregate. It was found that the 28-day compressive and tensile strengths of OPC concrete decreased up to 21%, and 7% and of Geopolymer concrete decreased by 11–26% and 11–29% with the increase in the recycled glass coarse.The mechanical and durability properties of the OPC and Geopolymer concretes containing a 10 to 20% glass coarse aggregate are comparable to the corresponding properties of the control sample (using a natural coarse aggregate). Furthermore, for the same glass Coarse aggregate, the heat-cured Geopolymer concrete provided better mechanical and Durability-related properties compared to the OPC and ambient-cured Geopolymer concretes. Therefore, a glass coarse aggregate could be a feasible alternative to a natural coarse Aggregate for up to a 20% replacement of a natural coarse aggregate.

III.MATERIALS

Materials used are
1. Cement
2. Fly ash
3. Ground granulated blast furnace slag
4. Fine aggregates
5. Course aggregates

A.CEMENT:
A cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and aggregate together. Cement starts to set when mixed withWater, which causes a series of hydration chemical reactions. The constituents slowly Hydrate and the mineral hydrates solidify and harden. The interlocking of the hydrates Gives cement its strength.

B.FLYASH:
Fly ash is finely divided residue resulting from the combustion of powdered coal And transported by the flue gases and collected by electrostatic precipitator. In U.K. it is Referred as pulverized fuel ash (PFA). Fly ash is the most widely used pozzolanic material All over the world. ASTM broadly classify fly ash into two classes.

Class F: Fly ash normally produced by burning anthracite or bituminous coal, usually has Less than 5% CaO. Class F fly ash has pozzolanic properties only.

GROUND GRANULATED BLAST FURNANCE SLAG:
Ground granulated blast-furnace slag (GGBS or GGBFS) is obtained by Quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace In water or steam, to produce a glassy, granular product that is then dried and ground intoA fine powder. Ground granulated blast furnace slag is a latent hydraulic binder formingCalcium silicate hydrates (C-S-H) after contact with water.

Typical physical properties
Colour: off-white
Specific gravity: 2.9
Bulk density: 1000 – 1100 kg/m3 (loose)
1200 – 1300kg/m3 (vibrated)
Fineness: >350m2/kg

FINE AGGREGATE

Fine aggregates comprise regular sand or any squashed stone Particles that are less than 4.75mm IS sieve. Fine aggregates are the structural filler that Occupies most of the volume of the concrete mix formulas. It provides resistance against Shrinking and cracking.

- Mix Design

In our experimental work, we used concrete of grade M25 with a mix ratio of 1:1:2 and a water-cement ratio of 0.45. The proportioning of the concrete mix is done in accordance with IS 10262 (2009): Guidelines for Concrete Mix Design.

IV. METHODOLOGY

- The primary goal of the current experiment is to investigate the consequences of using fly ash, a mineral byproduct, GGBS an iron by-product in replacement of cement.
- Mix design is obtained from IS 10262:2009
- Mixing of the concrete is done mechanically.
- There are a total of 12 cylinders, 12 cubes, and 12 beams or prisms that are casted. The specimens undergo 7, 14, and 28 days of curing. The specimens are tested when they have finished curing.
- Cubes, beams , andcylinders,respectively,weresubjectedtocompression,flexure,andsplit-tensiletesting.

V. TESTSONFRESHCONCRETE

Fresh concrete's ability to fully compress without bleeding or segregation in the final product is measured by the quantity of practical internal work required. One of the physical characteristics of concrete that influences strength and durability as well as labour costs and final product appearance is workability. When concrete is simply poured and compacted uniformly, that is, without bleeding or segregation, it is considered to be workable. Unworkable concrete requires more work or effort to compact in place, and completed concrete may also have visible honeycombs.

The workability of concrete can be evaluated using one of the three methods below, depending on the water cement ratio in the mix.

1. Slump cone test
2. Compaction factor
3. Vee - bee test

VI. TESTS ON HARDENED CONCRETE

As the name suggests, hardened concrete has acquired its shape and has served the intended purpose for the designated amount of time; it is no longer plastic. It won't be feasible, meaning that it won't be possible to modify the structure's shape. It is essentially at the "plasticity" stage, where its fluidity has completely disappeared. With time, hardened concrete becomes stronger, thus it's critical to assess the durability and quality of the material. The following tests are conducted on hardened concrete:

[1] Compressive strength test
[2] Split-tensile test
[3] Flexural test

Figure1:CompressiveStrengthTest

Figure2:Split-TensileStrengthTest

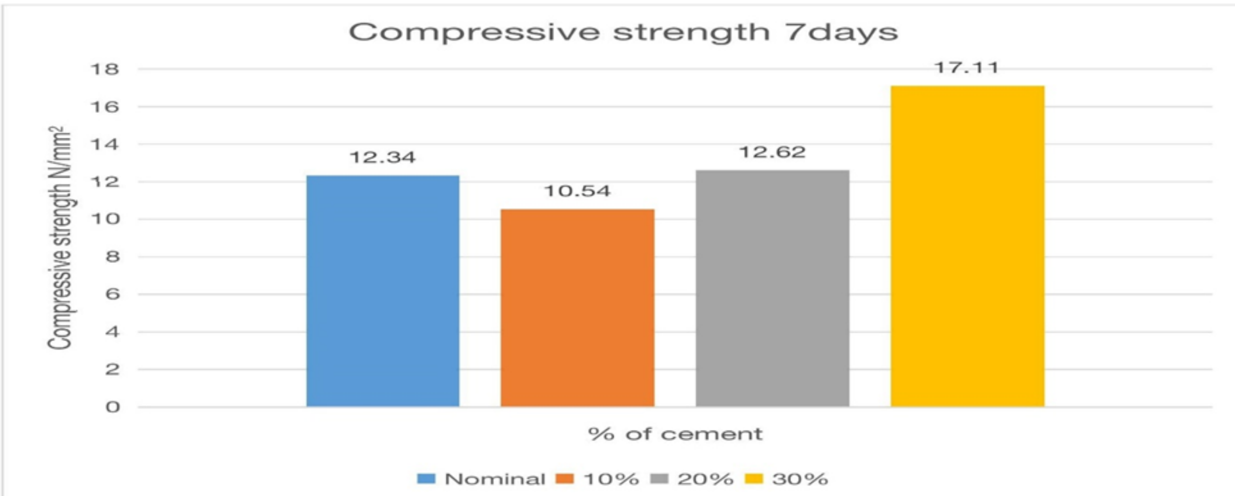
Figure 3: Flexural StrengthTest

VII. RESULTS AND DISCUSSION

A. Compressive Strength Test:

Table.1: Compressive strength at 7 days

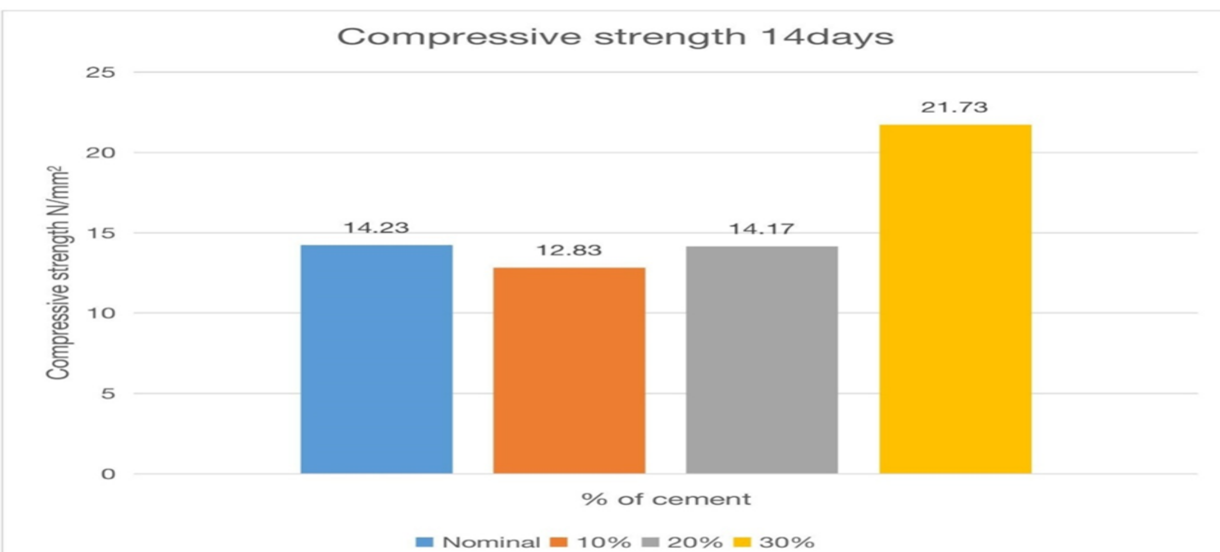
Grade of concrete	% of cement added	Load in KN	Area in mm2	Compressive strength in MPa
M 25	0	282	22500	12
	10	254	22500	10.54
	20	284	22500	12.62
	30	385	22500	17.11



Graph.1-Compressive Strength At 7 Days

Table.2: Compressive strength at14days

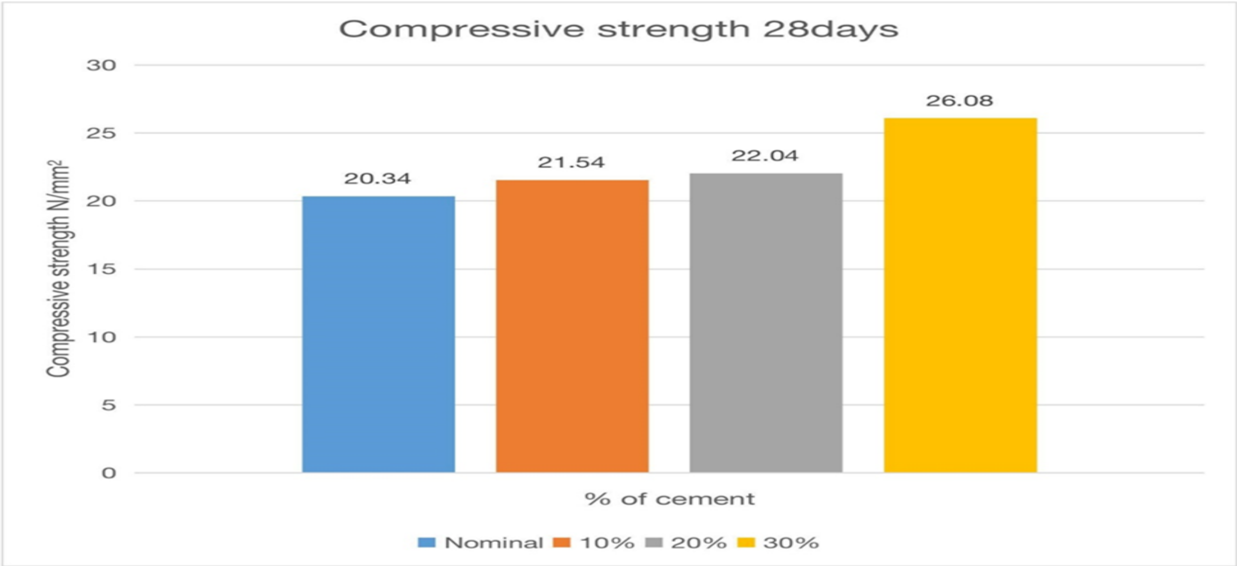
Grade of concrete	% of cement added	Load in kN	Area in mm^2	Compressive strength in MPa
M 25	0	315	22500	14.23
	10	281	22500	12.83
	20	319	22500	14.71
	30	489	22500	21.73



Graph.2-Compressive Strength At 14 Days

Table.3 compressive strength at 28 days

Grade of concrete	% of cement added	Load in KN	Area in mm^2	Compressive strength in MPa
M 25	0	456	22500	20.34
	10	478	22500	21.54
	20	496	22500	22.04
	30	587	22500	26.08

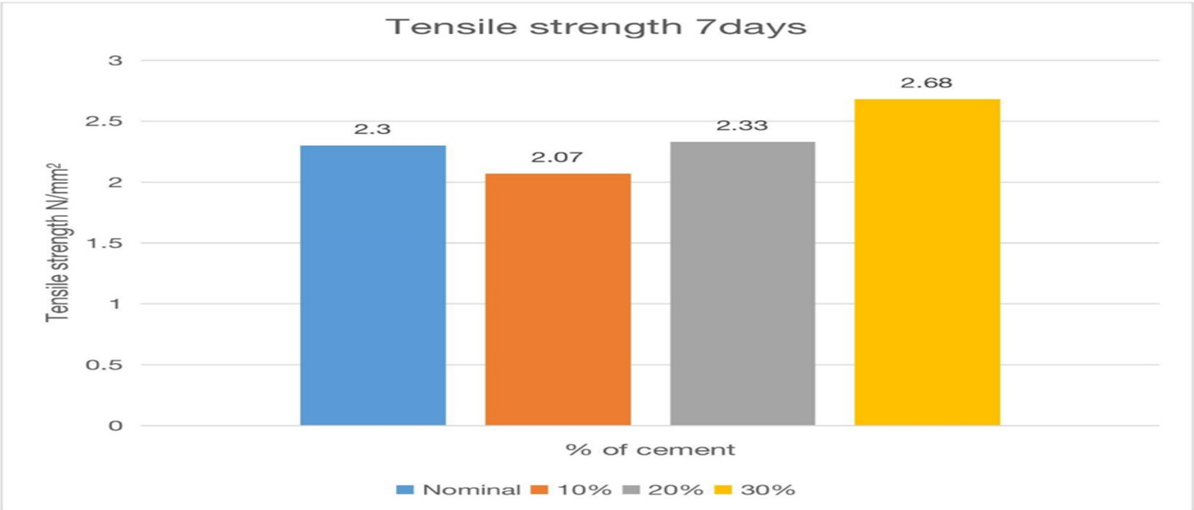


Graph.3-Compressive Strength At 28 Days

B. Split-tensile test:

Table4: Tensile strength at 7 days

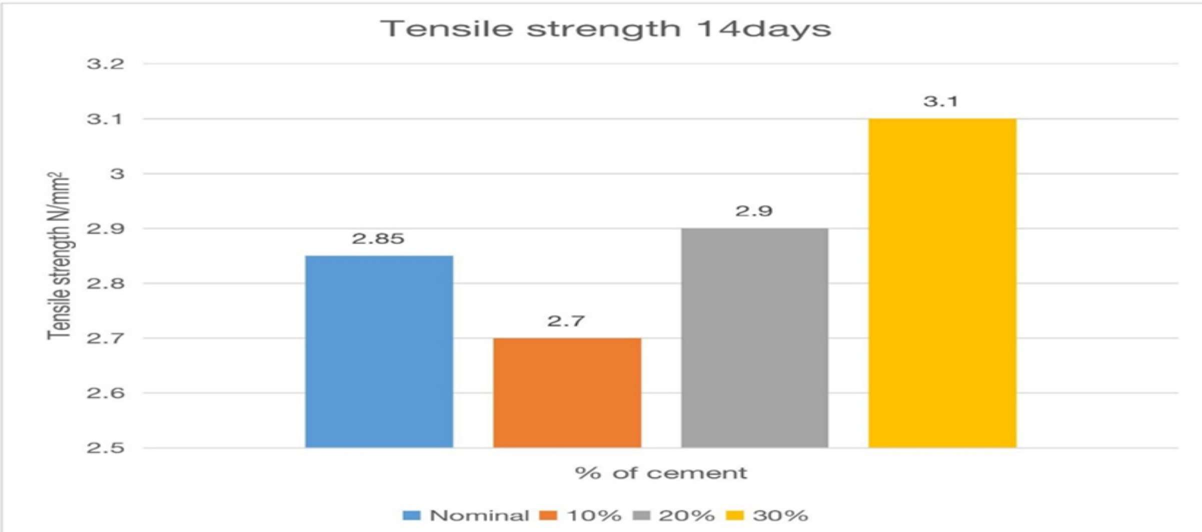
Grade of concrete	% of cement added	Load in kN	dimension	Flexural strength inMPa
M 25	0	21	L=500 mm B=100mm D=100mm	2.80
	10	21.75		2.5
	20	22		2.88
	30	25		2.91



Graph 4: tensile Strength At 7 Days

Table5: Tensile strength at 14 days

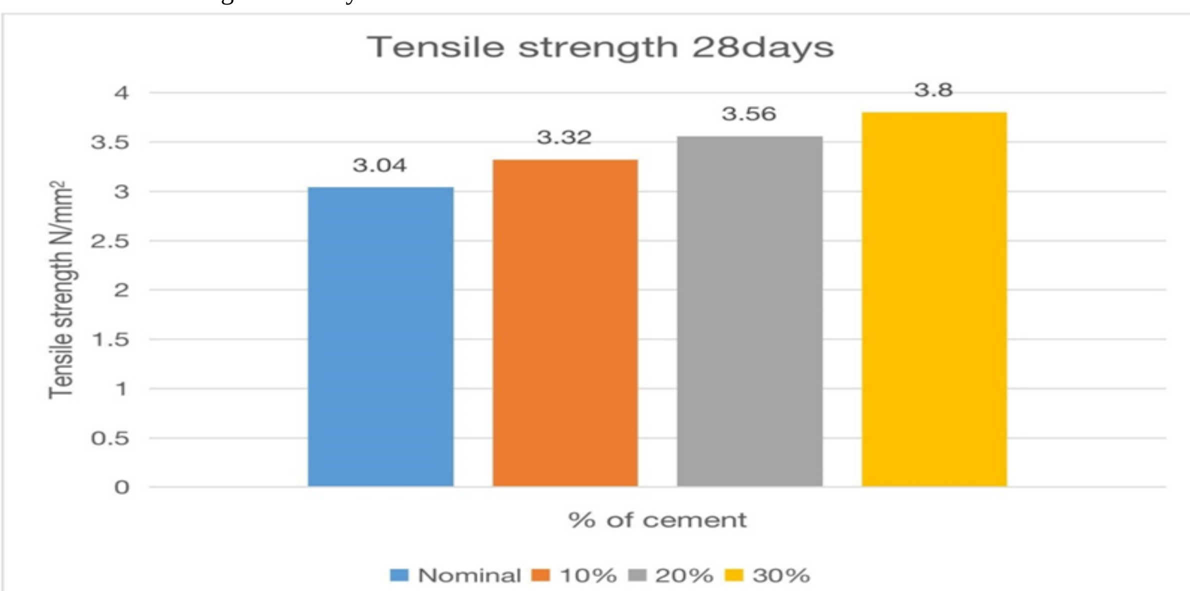
Grade of concrete	% of cement added	Load in KN	dimension	Tensile strength in MPa
M 25	0	202	L=300 mm B=150mm	2.85
	10	190		2.7
	20	215		2.9
	30	230		3.1



Graph 5: tensile Strength At 14 Days

Grade of concret e	% of cement added	Load in kN	dimension	Tensile strength in MPa
M 25	0	219	L=300 mm B=150mm	3.04
	10	235		3.32
	20	250		3.56
	30	275		3.8

Table6: Tensile strength at 28 days

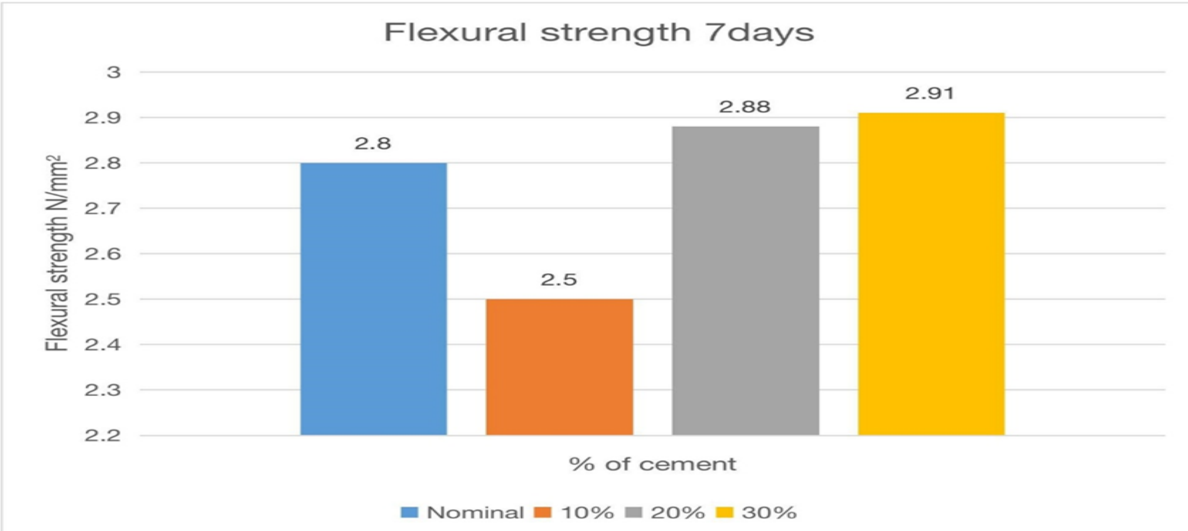


Graph 6 : tensile Strength At 28 Days

B. Flexure Strength Test

Table 7 :flexural strength at 7 days

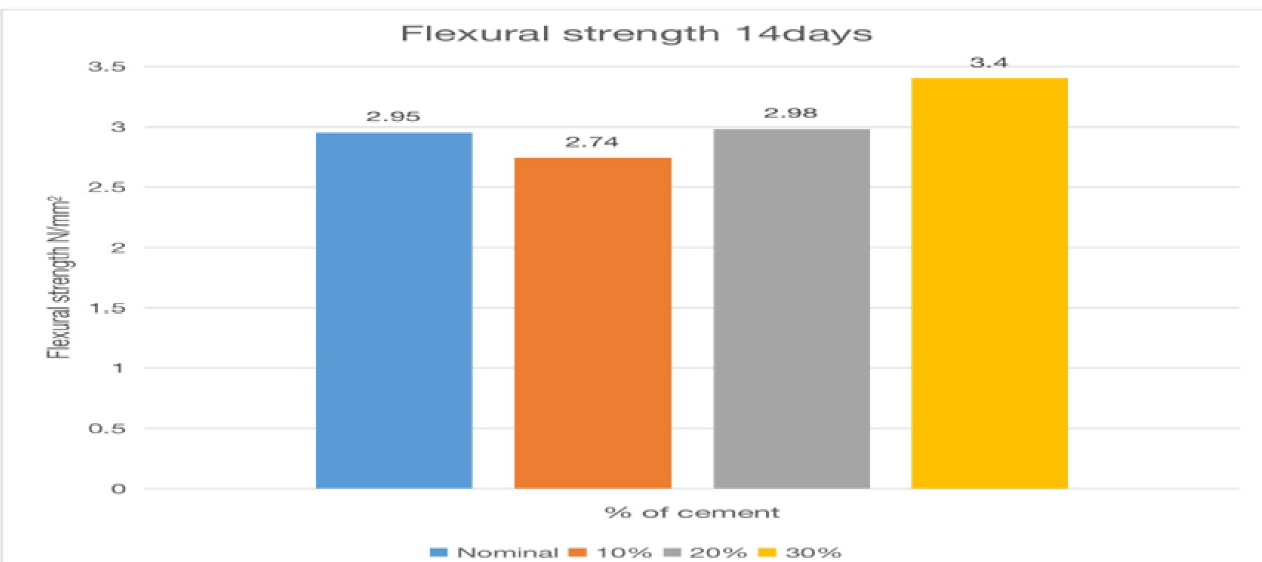
Grade of concrete	% of cement added	Load in KN	dimension	Flexural strength in MPa
M 25	0	21	L=500 mm B=100mm D=100mm	2.80
	10	21.75		2.5
	20	22		2.88
	30	25		2.91



Graph7 :flexural Strength At 7 Days

Table 8 :flexural strength at 14 days

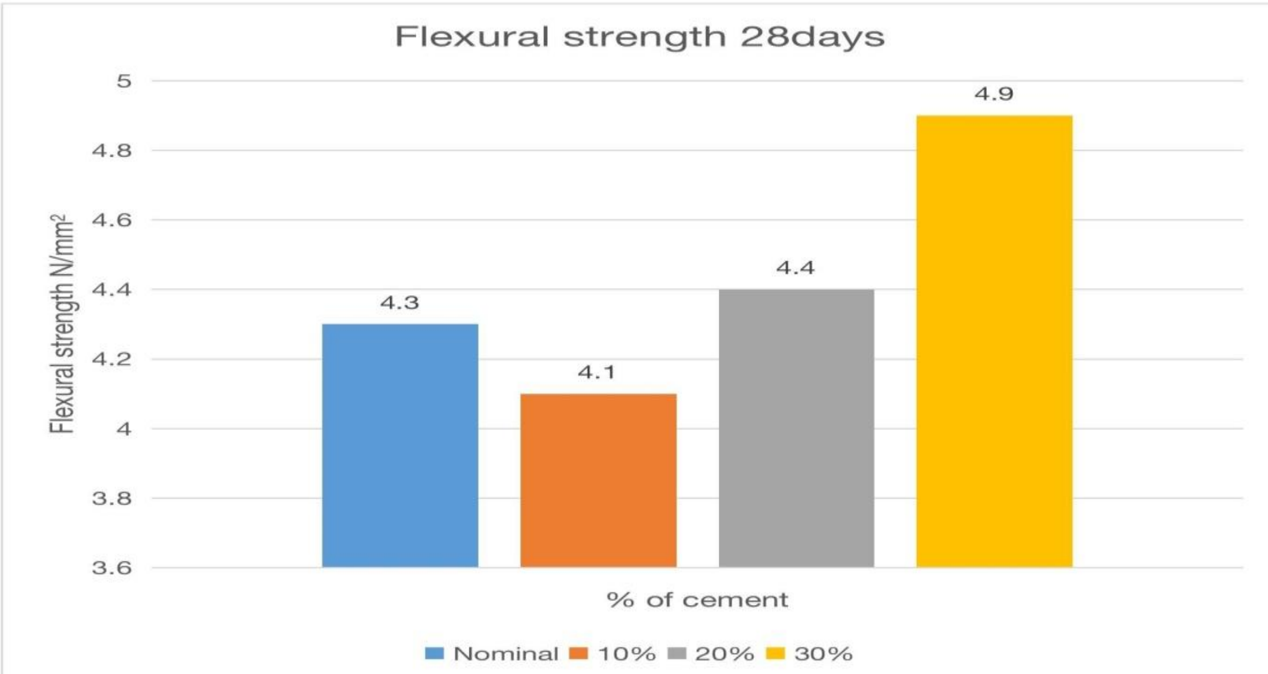
Grade of concrete	% of cement added	Load in kN	dimension	Flexural strength inMPa
M 25	0	25	L=500 mm B=100mm D=100mm	2.95
	10	28.5		2.74
	20	31		2.98
	30	33		3.4



Graph 8 :flexural Strength At 14 Days

Table 9 :Flexural strength at 28 days

Grade of concrete	% of cement added	Load in kN	dimension	Flexural strength in MPa
M 25	0	43	L=500 mm B=100mm D=100mm	4.3
	10	42		4.1
	20	43.5		4.4
	30	45		4.9



Graph 9 :flexural Strength At 28 Days

VIII. CONCLUSION

- Geopolymer concrete offers environmental protection by means of fly ash and blast furnace slag, waste/by-products from the industries, into a high value construction material needed for infrastructure developments.
- There is a better improvement in the compressive strength after addition of the cement to the concrete. The maximum compressive strength was achieved at 28 days for 30% cement with an increase of 22% strength as compared to control mix.
- 30% cement gives good tensile strength than other mixes and control mix or control concrete at 28 days with an increase of 20%.
- There is no strength development for 10% and 20% of cement in flexure. But at 30% it gave better results. The maximum flexural strength was achieved at 30% cement steel with an increase of 12.24%.
- As the increase in percentage of cement in geopolymer concrete it gave better results.

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