FATIGUE BEHAVIOUR OF LOW CONCENTRATION ALKALINE SOLUTION, CLASS-F FLYASH BASED GEOPOLYMER CONCRETE

Ram Charan L V[1], Sai Mithil Krishna Kumar[1], Tejesh Kumar B[1], Varshith Gowda[1] ,Sreenivasa Murthy A[2]

[1] *Student, Department of civil engineering, BMS College of Engineering , Karnataka, India*
[2] *Assistant Professor, Department of civil engineering, BMS College of Engineering , Karnataka, India*

ABSTRACT

This Project work is an integral attempt to find the ever increasing emphasis on energy conservation and environmental protection that has led to the investigation of alternatives to customary building materials. This research report presents the study on the development of strength for M40 grade of geopolymer concrete at ambient curing. Trial mix was chosen for low calcium fly ash and slag based geopolymer concrete using mix design reported in the research report. The concentration of the sodium hydroxide solution used was as low as a molarity of 5 Molar, the alkaline solution used in the study is a combination of sodium silicate and sodium hydroxide solution with the ratio of 1:2. An experimental study was conducted to assess the fracture properties of fibre reinforced geopolymer concrete beams. Crimped steel fibres with an aspect ratio of 65 were also added in percentages of 0.5 % and 1.0 % to enhance tensile, shear and ductile behaviour of the members.

From the experimental investigation conducted in this research programme and based on the overall performance of the new concrete mixture, it is concluded that various characteristics of GPC posses a high potential to be an alternative structural material because they are not only environmental friendly but also possess adequate mechanical and durability properties.

Keywords – *Geopolymer concrete, Low concentration, Fly Ash, Steel fibres.*

1. INTRODUCTION

Concrete is the most predominantly used construction material in the world. The basic ingredient of concrete is Ordinary Portland Cement, which is a major contributor of global warming. The yearly global cement production of 1.6 billion tons is responsible for about 7% of the total CO2 emission into the atmosphere. To produce environmental friendly concrete, the cement must be replaced with alternate binders which minimise any significant ill-effects on the environment. The use of industrial by-products as binders could aid in solving the problem. With regards to this, the new technology geo-polymer concrete is a promising technique. In terms of reducing global warming, the geo-polymer technology could reduce the CO2 emission to the atmosphere caused by the cement and aggregates industries by about 80% (Davidovits, 1994c). Several experiments have been carried out to avoid PPC completely; one successful attempt being Geopolymer concrete. Ambient cured Geopolymer concrete prepared with fly ash and GGBS arrive at the demandable strength for the mentioned period. Employing such by-products like GGBS and Fly Ash as alternates for cement has multiple benefits including conservation of environment, sustainability of resources and solving the disposal problem of by- products.

2. MATERIALS

For the manufacture of Fly ash based geopolymer concrete, The following materials were used:

1. Fly ash: Fly ash is a byproduct from burning pulverised coal in electric power generating plants. During combustion, mineral impurities in the coal fuse in suspension and float out of the combustion chamber with the exhaust gases. As the fused material rises, it cools and solidifies into spherical glassy particles called fly ash. For this project, Low calcium class-F flyash was used.
2. GGBS: GGBS (Ground Granulated Blast-furnace Slag) is a cementitious material whose main use is in concrete.It is a by-product from the blast-furnaces used to make iron. It is obtained by quenching molten iron slag from a blast furnace in water or steam, to produce a granular product that is then dried and ground into a fine powder. It is used as a direct alternative to ordinary Portland cement. GGBS contains oxides of calcium, silicon, aluminium, and magnesium.
3. Alkaline Activator Solution : It is a combination of solutions of alkali silicates and hydroxides, besides distilled water. The role of AAS is to activate the geopolymeric source materials (containing Si and Al) such as fly ash and GGBS. The most common alkaline activator used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate (Na_2SiO_3) or potassium silicate.
4. Fine Aggregates : In the present investigation, fine aggregate used is obtained from local sources. The sand is made free from clay matter, silt, and organic impurities and sieved on 4.75mm IS sieve. The physical properties of fine aggregate are tested in accordance with IS: 2386 and the used sand is confirmed as Zone II of IS 383-1970.
5. Coarse Aggregates : The crushed angular aggregate of 20mm maximum size from the local crushing plants is used as coarse aggregate in the present study. The physical properties of coarse aggregate such as specific gravity, bulk density, flakiness and elongation index are tested with IS: 2386-1963.
6. Steel Fibres : Flat crimped steel fibres are low carbon, cold drawn steel wire fibres designed to provide concrete with temperature and shrinkage crack control, enhanced flexural reinforcement, improved shear strength, and increase the crack resistance of concrete. Here, flat crimped steel fibres with aspect ratio of 65 were used.
7. Water : clean water was used for the mix.

3. LITERATURE REVIEW

Upon studying several papers in detail, the works of distinguished professionals and established authors were applied into the project. It is reported that CO_2 emissions due to the production activities of GPC are about 9% less than the CO_2 emissions by the production of Portland cement concrete[1]. From the research it is clear that alkaline solutions with more than 8 molarity have given good compressive strengths, for low calcium class F fly ash based GPC[3][4][5].However it is also observed in some papers that addition of GGBS with fly ash resulted in high compressive strength for lower molarity and ambient curing conditions [6].Addition of fibres has shown a marginal increase in compressive strength and increase in fibre content will enhance other hardened properties such as split tensile strength, flexure, shear strength, etc[6][7][8]. The reason for choosing a lower concentration of 5 molar was to evaluate whether a lower molarity would eventually yield a higher strength of the final mix. It was also noted that experiments performed to determine the fatigue behaviour of GPC were conducted on beams. The works which dealt with the 'Fatigue behaviour of fibre reinforced GPC' concluded that the fatigue life is directly proportional to the compressive strength of the geopolymer concrete[9][10][11]. These were the several deductions we were able to make from the literature review and successfully take advantage of, in the project of studying fatigue properties of fibre reinforced geopolymer concrete.

4. TESTS PERFORMED ON GPC

4.1 Slump Test

Slump cone test is performed to determine the workability or consistency of the mix prepared at the laboratory or the construction site during the progress of the work. The concrete slump test measures the consistency of the fresh concrete before it sets. It is performed to check the ease with which the concrete produce flows. It can also be an indicator of an improperly mixed batch. The test is popular due to the simplicity of apparatus used and simple procedure. The slump test is performed as per the procedure in IS: 1199.

Table -1: Slump test results

TYPE OF MIX	Trial 1	Trial 2	Trial 3	Avg slump value (mm)
Plain GPC	97	107	100	102
GPC 0.5% FIBRES	44	35	46	43
GPC 1% FIBRES	17	19	18	22

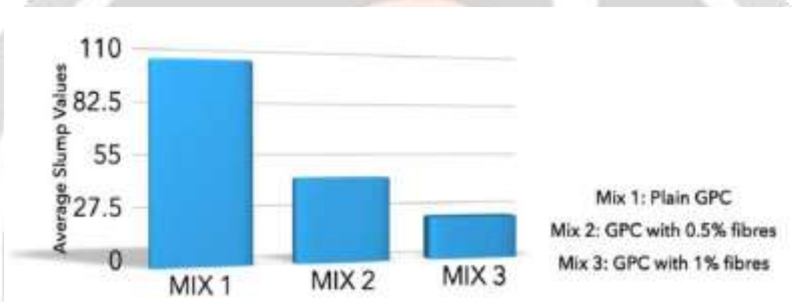

Chart -1: Average Slump Values

4.2 Compressive Strength

The compression test measures concrete strength in the hardened state. The Compressive strength of a material is determined by the ability of the material to resist failure in the form of cracks and fissure. In this test, the push force applied on the both faces of concrete specimen and the maximum compression that concrete bears without failure is noted. Field concrete samples are prepared, cured and tested according to standard procedures. Specimens are prepared from concrete taken from different construction sites. Compression test can be performed on cubes or cylinders. Here, we have performed on cubes of size 100*100*100mm.

A compression testing machine was used to perform this test and the dimension of the specimen was taken to the nearest 0.2 m. The specimen was placed in such a manner that the load shall be applied to the opposite sides continuously at the rate of 140 kg/cm^2/minute till the specimen failed. The cubes were tested on the 3rd, 7th and 28th day to check for their change in compressive strength.

Table -2: Compression test results

Type of Concrete	Trial Cube Number day 3 (mPa)			Average compressive strength (MPa)
	1	2	3	
Plain	22.4	22.3	22.5	22.4
0.5% fibres	22.5	23.5	23.9	23.3
1.0% fibres	25.5	25.5	25.3	25.1

Type of Concrete	Trial Cube Number day 7 (mPa)			Average compressive strength (MPa)
	1	2	3	
Plain	30.3	30.3	30.4	30.3
0.5% fibres	31.0	31.2	31.0	31.1
1.0% fibres	32.0	32.6	32.3	32.3

Type of Concrete	Trial Cube Number day 28 (mPa)			Average compressive strength (MPa)
	1	2	3	
Plain	42.8	42.9	42.8	42.8
0.5% fibres	44.1	44.6	44.5	44.5
1.0% fibres	45.8	46.3	46.3	46.2

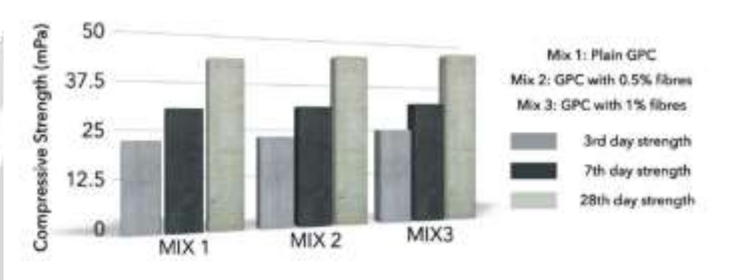

Chart -2: Average Compressive strengths

4.3 Split Tensile Strength

The tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structure. Moreover, the concrete is very weak in tension due to its brittle nature. Hence. it is not expected to resist the direct tension. So, concrete develops cracks when tensile forces exceed its tensile strength. Therefore, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. Furthermore, splitting tensile strength test on a concrete cylinder is a method to determine the tensile strength of concrete. Here, Tensile strength test was performed on cylinders of size 150mm*300mm. A load was continuously applied without shock at a rate within the range 0.7 to 1.4 MPa/min (1.2 to 2.4 MPa/min based on IS 5816(1999)). The breaking load at which the specimen fails was noted for different steel fiber percentage.

Table -3: Tensile test results

Sl. no.	Steel fiber percentage	Load(kN)	Tensile strength (mPa)
1	**0%**	**268.47**	**3.8**
2	**.5%**	**395.64**	**5.6**
3	**1%**	**409.77**	**5.8**

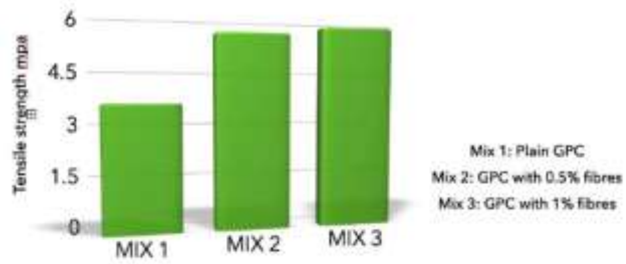

Chart -3: Average Tensile Strengths

4.4 Fatigue Behaviour

Fatigue refers to the phenomenon of rupture under repeated loadings, each of which is smaller than a single static load that exceeds the strength of the material. Fatigue is exhibited when a material fails under stress applied by direct tension or compression, torsion, bending, or a combination of these actions. A fatigue test helps determine a material's ability to withstand cyclic fatigue loading conditions. By design, a material is selected to meet or exceed service loads that are anticipated in fatigue testing applications. Cyclic fatigue tests produce repeated loading and unloading in tension, compression, bending, torsion or combinations of these stresses. Fatigue tests are commonly loaded in tension – tension, compression – compression .

Table -4: Fatigue results

SL. NO.	Beam	Percentage of steel fibres	No. of cycles	Average no. of cycles
1	A	0%	61131	61650
2	B	0%	62150	
3	C	0.5%	136140	135645
4	D	0.5%	135150	
5	E	1.0%	152500	152500

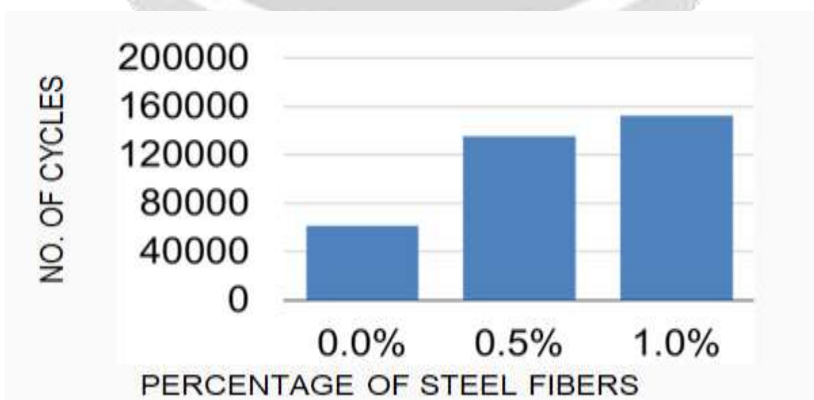

Chart -4: Fatigue Results

5. DISCUSSIONS

For the slump test, It is clear from the graph that increase in volume of steel fibres reduces the workability of the GPC drastically. As addition of more fibre content would make the concrete unworkable, the Fibre content was limited to 1% in the trials. For the compression test, It is evident from the graph that more than half of the desired strength (40MPa) of the GPC is achieved before the 7^{th} day and the required strength is achieved well before the 28th day. It is also clear that the addition of steel fibres increases the compressive strength of the GPC. For the Tensile test, It is clear that the addition of steel fibres increases the tensile strength of the concrete noticeably . It can be observed that the fatigue life of the GPC increases drastically with the addition of steel fibres. The fatigue life of 0.5% steel fiber - GPC was 2.1 times the fatigue life of plain Geopolymer concrete. The rise between 1% steel fiber and .5% steel fiber GPC was observed be 12%.

6. CONCLUSION

From the research, it can be concluded that : The mix design used has successfully yielded M40 grade Geopolymer Concrete. The strength of the GPC increases with age. The workability of GPC decreases with increase in the steel fibre content. The compressive strength increases marginally with the addition of steel fibres. Tensile strength increases significantly with increase in steel fibre content. The number of cycles for the fatigue failure of geopolymer concrete increases largely with the addition of steel fibres.

6. REFERENCES

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