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Experimental study on hybrid fibre reinforced geopolymer concrete slab under impact load

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Abstract: This study presents a Geopolymer is an eco-friendly binding material alternative for Ordinary Portland Cement (OPC). Geopolymer concrete is produced by mixing fly ash, GGBS, alkaline solution, fibres, fine aggregate and coarse aggregate. Alkaline solution is composed of NaOH and Na2SiO3 solution. This paper deals with the study of impact resistance capacity of geopolymer concrete slabs subjected to impact loading. For this study, ten specimens of size 600 mm (length) × 600 mm (width) × 80 mm (thick) were casted with two different combinations of geopolymer concrete mix using different molar sodium hydroxide solutions and different percentages of mineral admixtures and a normal concrete slab as control slab. The molarity of NaOH solution used was 12M and 14M. The slabs were oven cured at 80C for 24 hours. These slabs were subjected to impact loading by drop weight test method. All the slabs were tested under a drop weight of 75.50 N through a guide pipe from a height of 700mm. The results obtained from this study showed that with the increase in molarity of NaOH solution, the strength characteristics and the impact resistance capacity of the specimen increases. Also increase in percentage of GGBS content as replacement for Fly ash content increases the impact resistance and overall strength characteristics of geopolymer concrete. From the test results, geopolymer concrete slab with 14M NaOH solution using 50:45:5 Fly ash and GGBS and fibres content showed higher impact energy absorption capacity as compared other geopolymer mixes.

Keywords: Geopolymer, Molarity, Impact loading, First crack, Ultimate failure etc…

I. INTRODUCTION

Joseph Davidovits (1999) suggested back in 1978 that we can make binders by mixing alkaline liquids with materials rich in silica and aluminum He called these binders "geo-polymers". They are like zeolites but don't have a defined structure. Instead, they are a mix of different molecules.

According to Paloma et al. (1999), we can mix materials like blast furnace slag with alkaline liquids to make binders. These binders can completely replace regular cement in making concrete. Unlike regular cement concrete, the main part of geo-polymer concrete (GPC) isn't made of calcium-silicate-hydrates (C- S-H). Instead, it's made of a gel made of silicon, aluminum, and oxygen.

GPC has two main parts: the materials we use and the alkaline liquids. The materials need to be rich in silicon and aluminum. They can come from nature, like metakaolin, or they can be leftovers from other processes, like fly ash or GGBS. The alkaline liquids are made of things like sodium or potassium that dissolve in water. The most common mix is sodium or potassium hydroxide mixed with sodium or potassium silicate.

II. OBJECTIVES

- To carry out a mix design for conventional concrete and 12 and 14 Molarity geopolymer concrete.
- To study the physical properties and mechanical properties of material using in geopolymer concrete and conventional concrete.
- To study the behavior of geopolymer concrete slab and conventional concrete under Impact load.
- To carry out a comparative study on results obtained from experimental investigation for conventional concrete and geopolymer concrete.

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III. METHIDOLOGY

1. Geopolymer concrete
2. Materials procurement
3. Basic test for procure materials
4. Admixtures are GGBS, Fly ash and Alccofine
5. Mix Design
6. Mixing
7. Workability Test
8. Casting
9. Oven Curing at different temperature
10. Determination of Mechanical Properties and slab of geopolymer Concrete
11. Results and Conclusion

IV. MATERIALS

4.1 Fly Ash

Fly ash is the most abundantly used mineral admixture as replacement for cement in concrete. It is also the main ingredient for geopolymer concrete due to its active participation in the geopolymerization process. Pozzolanic material exhibits cementitious properties when combined with calcium hydroxide. Fly ash is used as the pozzolana in many concrete applications. Fly ash From Bellary ZINDAL steel plant, Karnataka is used as cement replacement material in this investigation.

4.2 Ground Granulated Blast Furnace Slag

Ground granulated blast furnace slag comprises mainly of calcium oxide, silicon di-oxide, aluminium oxide, magnesium oxide. It has the same chemical constituents as OPC but in different proportions. And the addition of GGBS in Geo-Polymer Concrete increases the strength of the concrete and also curing of Geo-Polymer concrete at room temperature is possible. Ground granulated blast furnace slag from Bellary ZINDAL steel plant, Karnataka is used as cement replacement material in this investigation which confirms to IS: 12089-1987.

4.3 Sodium Hydroxide

Generally, NaOH is available in market in pellets or flakes form with 96% to 98% purity where the cost of the product depends on the purity of the material. The solution of NaOH was formed by dissolving it in water based on the molarity required. It is recommended that the NaOH solution should be made 24 hours before casting and should be used with 36 hours of mixing the pellets with water as after that it is converted to semi-solid state.

4.4 Sodium Silicate

It is also known as water-glass which is available in the market in gel form. The ratio of SiO_2 and Na_2O in sodium silicate gel highly affects the strength of geopolymer concrete. Mainly it is seen that a ratio ranging from 2 to 2.5 gives a satisfactory result. Solution was obtained from the Datta scientific in Bangalore.

4.5 Fine Aggregate

Locally obtained natural river sand is used as the fine aggregate in the concrete mixes. The sieve analysis result indicates that the sand confirms to zone-II as per IS: 383- 1970.

4.6 Coarse Aggregate

Locally available crushed aggregate was been used as coarse aggregate. The aggregate passing through 12.5 mm IS sieve and retained on 4.75 mm IS sieve was used in preparation of reinforced GPC slab specimens. The tests on the coarse aggregate were conducted in accordance with IS 2386- 1963.

V. MIX PROPORTION AND EXPERIMENTAL INVESTIGATION

Mix design samples have shown that the aggregates occupy about 75-80% by mass in Geopolymer concrete. Few assumptions are made in the mix design process as there isn't a standard mix design procedure available as per IS codes. Table below shows the mix design used here.

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mix design proportion for 12M 50% GGBS, 45% Flyash, 5% Alcofine

Material	Quantity (kg/m^3)
GGBS	248.0
Flyash	223.3
Alccofine	24.8
Sodium hydroxide	94.41
Sodium Silicate	236.63
Coarse Aggregate	874.54
Fine Aggregate	687.14
Super Plasticizer	4.96

mix design proportion for 14M 50% GGBS, 45% Flyash, 5% Alcofine

Material	Quantity (kg/m^3)
GGBS	223.2 kg/m^3
Flyash	223.3 kg/m^3
Alcofine	49.6 kg/m^3
Sodium hydroxide	96.26 kg/m^3
Sodium Silicate	240.65 kg/m^3
Coarse Aggregate	875.75 kg/m^3
Fine Aggregate	680.44 kg/m^3
Super Plasticizer	4.96 kg/m^3

A).Preparation of Alkaline Activator Solution

The mixture of Na2SiO3 solution and NaOH solution can be used as the alkaline liquid. The Alkali activator solution has to be prepared before 24 hours of use because at the time of mixing Na2SiO3 and NaOH solution it generates a huge amount of heat and the polymerization takes place by reacting with one another, which will act as a binder in the geopolymer concrete. It should be used within 36 hours of mixing the pellets with water as after that it is converted to semi-solid state. The Sodium hydroxide, available in small flakes, is dissolved in water at different proportions as required molarity of solution.

B).Casting of test specimen

Wooden moulds of size 600 x 600 x 60 mm clear were prepared using plywood boards. The moulds were coated initially with oil so as to enable easy removal of the moulds. The moulds were placed on an even surface. The surface was painted with waste oil. Cover blocks were used to ensure a clear cover of 10 mm. Normal mild steel bars steel bars (nominal diameters 6 mm) were used as the reinforcing material. The steel reinforcement mat with required spacing was placed inside the moulds. The moulds were supported well on all the sides from outside so as to prevent bulging of the specimen once the concrete is poured inside.

Individual materials were batched in an electronic weighing balance. Fly ash and GGBS were mixed separately. Aggregates and cementitious materials were added on to the mixer and thoroughly mixed until a uniform mix was obtained then; required quantity of alkaline solution along with water is added and mixed thoroughly to form uniform concrete mix. Moulds were filled with the concrete and compacted thoroughly.

The wooden moulds, which formed the sides of the slabs, were de-shuttered only after 48 hours to avoid development of handling stresses. The slabs were stem-cured at 600C for a period of 24 hours. White wash was applied to achieve clear visibility of cracks during testing. After respective curing period the slabs were tested. Totally ten slabs were casted out of which one is reference slab and remaining nine slabs are having different molarity of NaOH and different percentages of Fly ash and GGBS.

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C).Test Setup

Drop weight test was used to simulate impact load on the square slabs of 600 mm size and test set up shown in below figure was adopted. It consists of a steel frame supported by two short columns. A steel hammer of mass 7.7 kg was used for impact on the specimen. The height of fall was kept as 700 mm and the rate of impact was 60 blows per minute. The free fall of the hammer at the centre of slab applied the impact load on the slabs. C - clamps were used to prevent the specimen from lifting up during impact. The no. of impact blows required to develop first visible crack was used to calculate the first crack impact strength. Similarly the no. of blows required to achieve ultimate failure was used to calculate the ultimate impact strength.

The energy absorption of the GPC can be calculated using the formula:

E= N x (w x h) joules

Where,

E is the energy absorbed in joules,

w is weight of hammer in Newton,

h is the height of drop in meter and N is the no. of impact blows.

VI. RESULTS AND DICUSSIONS

Strength characteristics of GPC slabs The various strength tests that are to be done are listed as below.

¬ Compressive strength

¬ Split tensile strengthThe cubes of standard size 150 mm were tested in 2000 kN capacity compressive testing machine as per IS: 516-1959 (1999) to get the compressive strength of GPC cubes. The prisms were tested in 100 kN capacity impact testing machine under two point loading for specimens of 100 x 100 x 500 mm at rate of 140 kg/cm2/minute as per IS: 516 1969 (1999) to get the flexural strength of concrete. The cylinders were tested in 2000 kN capacity compressive testing machine at 1.2 N/cm2/minute to 2.4 N/cm2/minute as per IS: 516-1999 to get the split tensile strength of concrete cylinders.

Table 6.1: Compressive strength test results of GPC [12M] at 60°C

TRIAL MIX NO	FIBERS (kg/m³)			COMPRESSIVE STRENGTH (N/mm²)		
	SF	PPF	ARGF	7 DAYS (N/mm²)	14 DAYS (N/mm²)	28 DAYS (N/mm²)
M1	1.0	0.5	-	32.67	33.45	35.68

Table 6.2: Compressive strength test results of GPC [12M] at 80°C

TRIAL MIX NO	FIBERS (kg/m³)			COMPRESSIVE STRENGTH (N/mm²)		
	SF	PPF	ARGF	7 DAYS (N/mm²)	14 DAYS (N/mm²)	28 DAYS (N/mm²)
M1	0.75	0.75	-	39.9	42.99	45.9

Table 6.3: Compressive strength test results of GPC [12M] at 100°C

TRIAL MIX NO	FIBERS (kg/m³)			COMPRESSIVE STRENGTH (N/mm²)		
	SF	PPF	ARGF	7 DAYS (N/mm²)	14 DAYS (N/mm²)	28 DAYS (N/mm²)
M1	0.25	1.25	-	33.34	36.68	37.78

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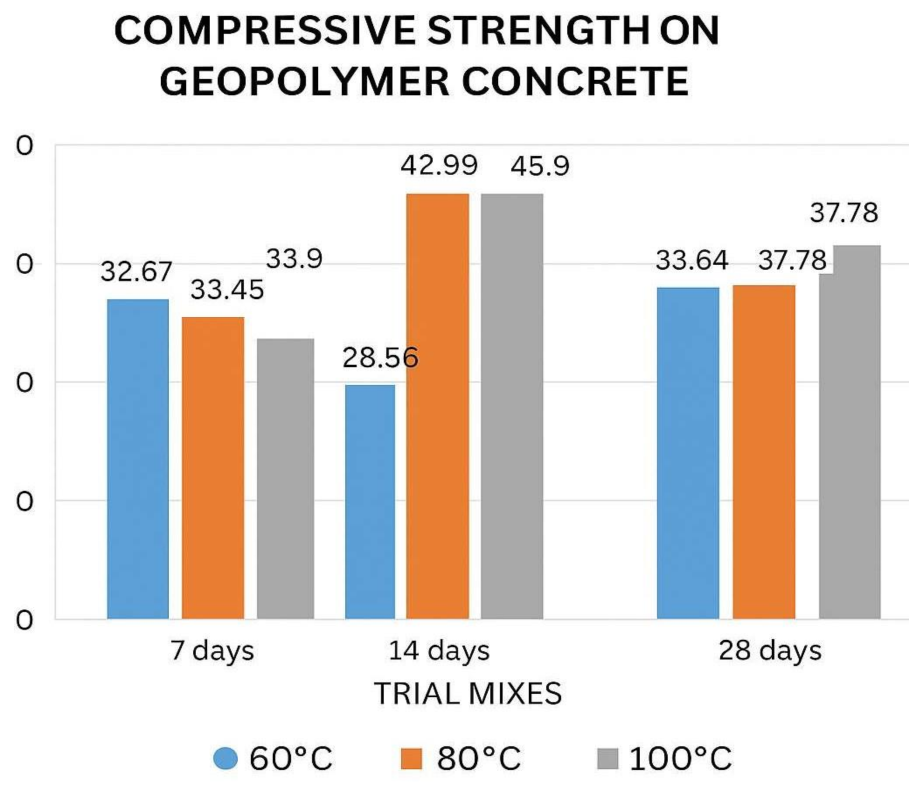

Fig 6.1.: Compressive strength test results of GPC [12M]

Table 6.4: Compressive Strength Test Results of GPC [14M] at 60°C

TRIAL MIX NO	FIBERS (kg/m³)			COMPRESSIVE STRENGTH N/mm²		
	SF	PPF	ARGF	7 DAYS	14 DAYS	28 DAYS
M1	0.5	1.0	-	30.71	33.9	35.36

Table 6.5 Compressive Strength Test Results of GPC [14M] at 80°C

TRIAL MIX NO	FIBERS (kg/m³)			COMPRESSIVE STRENGTH N/mm²		
	SF	PPF	ARGF	7 DAYS	14 DAYS	28 DAYS
M1	0.75	0.75	-	46.9	48.1	49.29

Table 6.6: Compressive Strength Test Results of GPC [14M] at 100°C

TRIAL MIX NO	FIBERS (kg/m³)			COMPRESSIVE STRENGTH N/mm²		
	SF	PPF	ARGF	7 DAYS	14 DAYS	28 DAYS
M1	0.25	1.25	-	33.9	36.8	38.62

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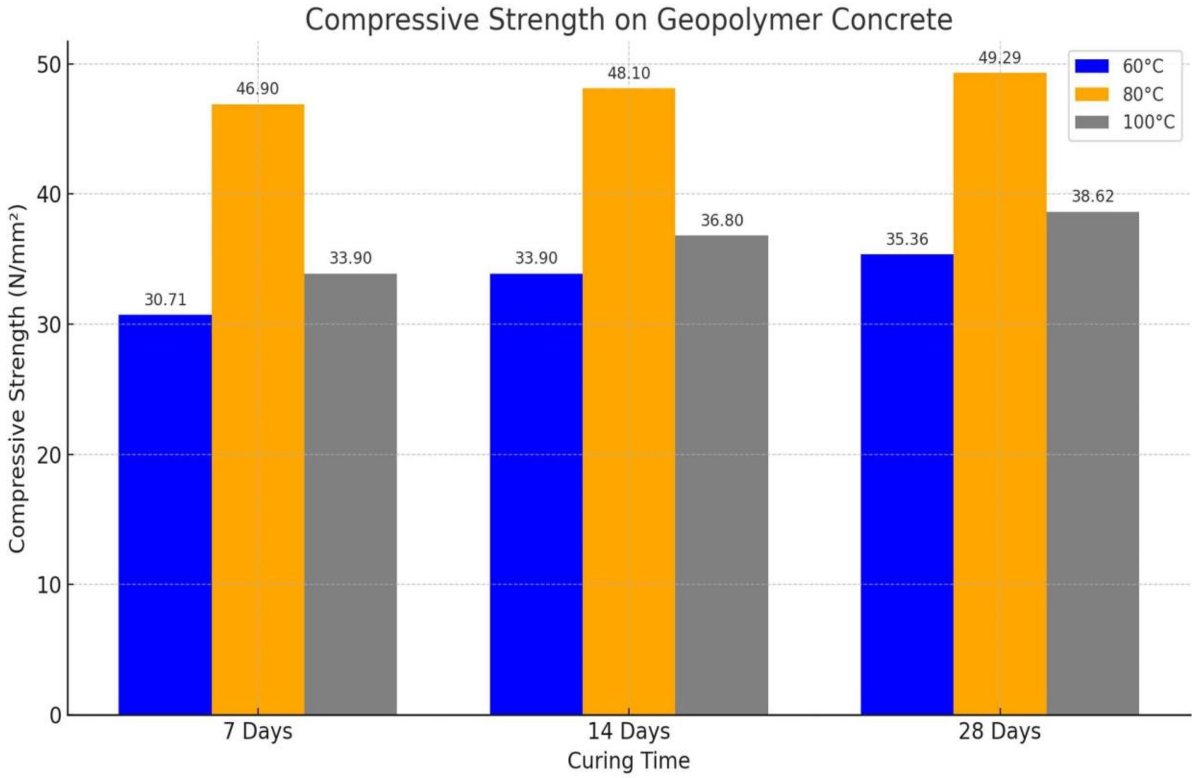

Figure 6.2: Compressive Strength Test Results of Geopolymer Concrete

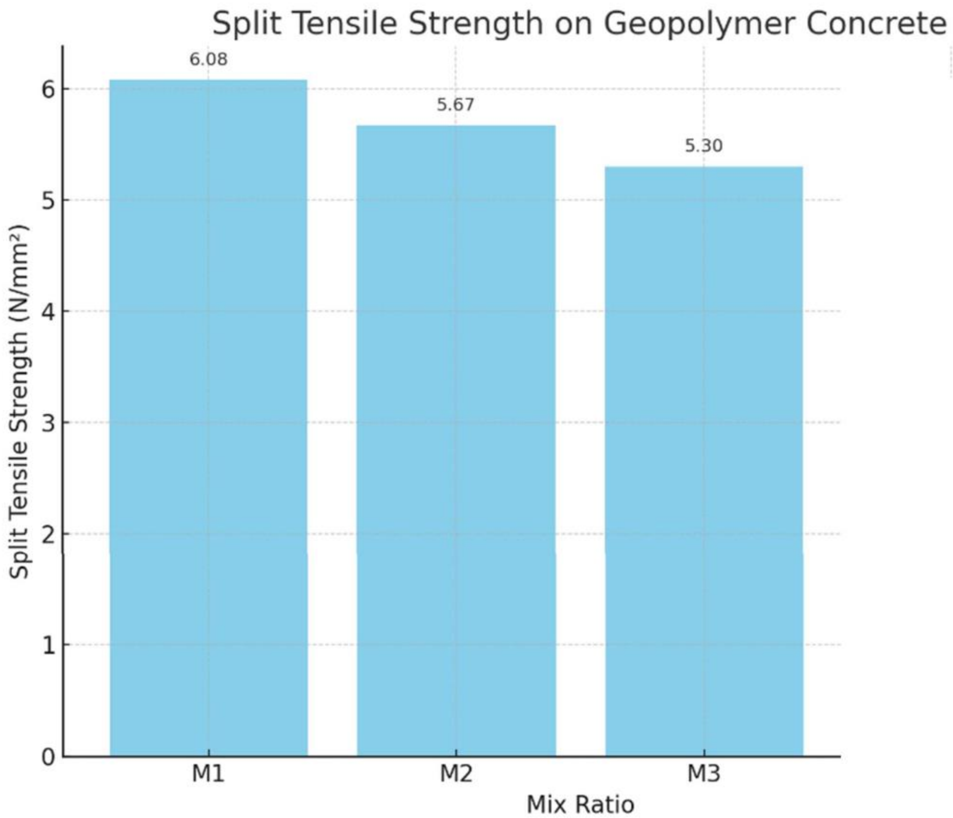

Fig : 6.3 Split Tensile Strength test result of Geopolymer Concrete

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From the test results, it is observed that the compressive strength and split tensile strength of geopolymer concrete is slightly more than the normal M 30 Concrete mix specimens. Also it is observed that as the molarity of NaOH solution used in Geopolymer concrete mix design is increased, the strength characteristics showed better results. Increase in GGBS content as replacement for fly ash showed better results and early strength.

Energy Absorption od GPC slabs

The test results of the normal reinforced concrete slab and GPC slabs with fly ash and GGBS as replacement for cement with steel reinforcement have been tabulated in this section. The test setup was done as explained in the earlier chapter. Initial adjustments were done before the experiment. The first crack impact strength and ultimate crack impact strength of geopolymer concrete slabs are tabulated.

First crack impact energy of GPC slabs without fibres:

Table 6.7: impact Test Results

SL NO	Slabs specimen	No. of blows	First Crack Impact energy in Joules	First Crack Impact Strength in KJ/mm^2
1	GPC (12M) at 80°C	13	1020.24	2.834
2	GPC (14M) at 80°C	17	1334.16	3.706
3	M40	20	1569.6	4.36

Ultimate impact energy of GPC slabs without fibres:

Table 6.8: impact Test Results

SL NO	Slabs specimen	No. of blows	Ultimate Impact energy in Joules	Ultimate Impact Strength in KJ/mm^2
1	GPC (12M) at 80°C	119	9339.12	25.942
2	GPC (14M) at 80°C	124	9731.52	27.032
3	M40	125	9810	27.25

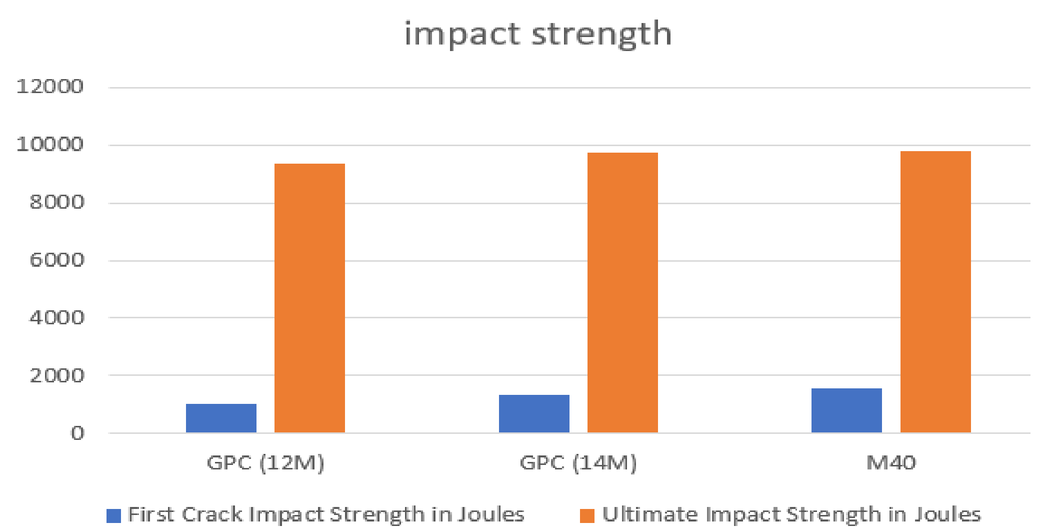

Fig : 6.4: impact test result of Geopolymer Concrete without fibres

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First crack impact energy of GPC slabs with fibres:

Table 6.9: impact Test Results

SL NO	Slabs specimen	No. of blows	First Crack Impact energy in Joules	First Crack Impact Strength in KJ/mm^2
1	GPC (12M) at 80°C	15	1177.2	3.27
2	GPC (14M) at 80°C	16	1255.68	3.488
3	M40	22	1726.56	4.796

Ultimate impact energy of GPC slabs with fibres:

Table 6.10 impact Test Results

SL NO	Slabs specimen	No. of blows	Ultimate Impact energy in Joules	Ultimate strength in KJ/mm^2
1	GPC (12M) at 80°C	1122	9574.56	26.596
2	GPC (14M) at 80°C	125	9810	27.25
3	M40	127	9966.96	27.686

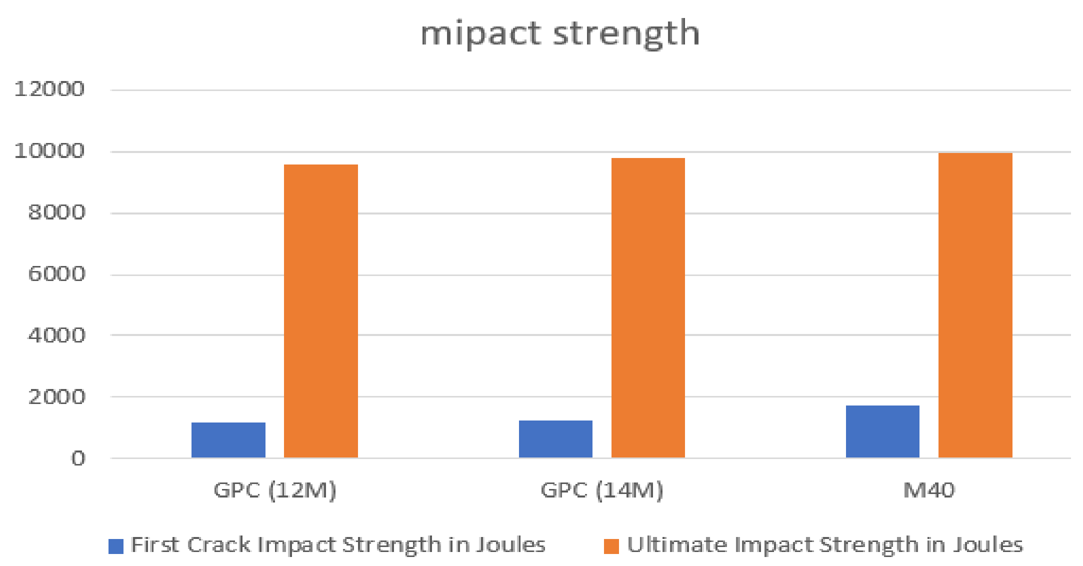

Fig: 6.5 impact test result of Geopolymer Concrete with fibres

VII. CONCLUSIONS

- The study investigated the strength performance of fiber-reinforced geopolymer concrete (GPC) mixes M1, M2, and M3, with M3 used as the reference mix.
- Each mix included 0.25% steel fiber (SF), 0.5% polypropylene fiber (PPF), and 0.25% alkali- resistant glass fiber (ARGF).
- The strength was evaluated for both 12M and 14M concentrations of alkaline activator at different curing temperatures (60°C, 80°C, and 100°C).

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- M1 consistently delivered the highest compressive and tensile strengths across all curing temperatures and molarity levels.
- 80°C proved to be the most effective curing temperature for maximizing strength performance.
- The 14M alkaline concentration yielded better results than 12M.
- The combination of steel, polypropylene, and glass fibers enhanced mechanical strength, although it slightly reduced workability due to increased water absorption.
- Conventional concrete shows the highest energy absorption.
- Geopolymer concrete at 14M performs almost as well as conventional concrete, showing promise for structural application.
- The increase from 12M to 41M improves energy absorption by about 2.46% making 14M geopolymer to conventional concrete in terms of energy absorption.

REFERENCES

[1]. Madheswaran C K, J K Dattatreya, P S Ambily & Karansingh P R, Investigation on behavior of reinforced geopolymer concrete slab under repeated low velocity impact loading International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 3, pp. 10775-10786, March 2014

[2]. S. Nagan and R. Mohana, Behaviour of geopolymer ferrocement Slabs subjected to impact IJST, Transactions of Civil Engineering, Vol. 38, No. C1+, pp 223-233, 2014.

[3]. Dr. Abdulkader Ismail Al-Hadithi, Dr.Khalil Ibrahim Aziz and Mohammed Tarrad Nawar Al-Dulaim, Behavior of ferro-cement slabs modified by polymer under low velocity impact Advanced Materials Research Vol. 925 (2014) pp 3-7.

[4]. Madheswaran C. K, Gnanasundar G, Gopalakrishnan. N Effect of molarity in geopolymer concrete by international journal of civil and structural engineering Volume 4, no 2, 2013.

[5]. Zhang P, Gao Z, Wang J, Guo J, Hu S, Ling Y. Properties of fresh and hardened fly ash/slag based geopolymer concrete: a review. J Clean Prod 2020; 270:122389.

[6]. Wasim M, Ngo TD, Law D. A state-of-the-art review on the durability of geopolymer concrete for sustainable structures and infrastructure. Constr Build Mater 2021; 291:123381.

[7]. Elemam WE, Tahwia AM, Abdellatief M, Youssf O, Kandil MA. Durability, microstructure, and optimization of high-strength geopolymer concrete incorporating construction and demolition waste. Sustainability 2023; 15:15832.

[8]. Shaikh FUA. Review of mechanical properties of short fibre reinforced geopolymer composites. Constr Build Mater 2013; 43:37–49.

[9]. Zhang X, Chiu YW, Hao H, Cui J. Free water effect on the dynamic compressive properties of mortar. Cem Concr Compos 2021; 118:103933.