Investigation on Flexural Performance of Concrete Beam with Replaced of Cement using WGP

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Abstract –The Glass is a clear substance made by tender a combination of ingredients, including silica, lacking causing representation. The Glass is a material that is utilized extensively in day life in industrialproperties like space tubing, glassware, sheet glass, andbottles. The quantity of glass garbage has been steadily rising in recent years, with the majority of it ending up in landfills. Glass waste should not be land filled because it is not biodegradable. Therefore, leftover glass can be incorporated into concrete to create an affordable and environmentally sustainable building. Cement, aggregates, admixtures and waterare the ingredients of concrete. Using a variety of waste resources, including GGBS, silica fume, and PFA, numerous studies are currently being conducted on the usage of substitutes for Portland cement. Similar to PFA and GGBS, WGP is also employed as a filler material and a partial substitute for cement, which undergoes some reaction during hydration.In this investigation, the automatic qualities such as flexural strength, compressive andsplit tensile strengthdetermination be tested using waste GP in place of cement, the material used in concrete. In order to assess the impact of adding GP at different percentages to the concrete mix (5%, 10%, 15%, and 20%), GP with a particle size of 75 microns was employed.

Key words: Silica Fume,WGP (Waste Glass Powder), PFA, GGBS

1 INTRODUCTION

The production of cement contributes to carbon dioxide emissions together with the burning of fossil fuels and the clearing of forests. The primary cause of global warming is emissions of greenhouse gases. into the atmosphere, such as CO2. CO2 is about 65 percent of all greenhouse gases that cause global warming. Approximately 7% of earth's atmosphere andgreenhouse gas emissions are caused by the global cement industry. Alternative binders for concrete need to be developed in order to mitigate the environmental effects of cement manufacture.Regardless of the kind of items they produce, almost every industry generates garbage. It will be difficult to properly dispose of these garbage in the future [1-5]. Both industrial wastes (silica fume, fly ash, blast furnace slag, etc.) and other wastes (solid waste, waste plastics, waste glass, waste tiles, and other agricultural wastes) contribute to

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environmental pollution. One of the challenging tasks facing engineers is the efficient and safe disposal or recycling of these waste materials, which were formerly used as land fill for low-lying areas. Waste creation and garbage disposal are unsustainable practices.

These industrial wastes are being utilized by the concrete industry to some extent in the manufacturing of concrete[12]. Concrete gains strength via the pozzolanic process, which also reduces the amount of cement needed. Consequently, blast furnace slag, silica fume and fly ash are now used as pozzolana by the cement industries to replace a portion of cement[14-18]. Globally, it is believed that several million tons of waste glass are produced each year. Waste containers, medicine bottles, bulbs,window glasses, alcohol bottles,window screens, tube lights, electronic equipment, etc. are the main sources of used glasses. This waste glass can only be recycled in part.Nothing can be done with the leftover trash glass[19]. However, recent studies have demonstrated that leftover glass can be employed in material as a glass aggregate or glass pozzolana, either fine or coarse. When the leftover glass is pulverized into an exceptionally fine ash, it exhibitionscertainpozzolanicabilities. As a result, the GP can partially substitute for cement and aid in the development of strength.Glass is created by mixing various inorganic minerals; it can be categorized into many different types depending on its makeup, but the most common kind is soda-lime glass[20]. The average glass has about 70% silica in it. Although it takes that excellently crushed glass organizes not subsidise to alkali-silica response, the presence of alkali now glass might produce the alkali-silica response and modification in volume[22]. GP, being a pozzolana, offers a higher volume of hydration products and a more even distribution.The structure of the cement paste changes when GP is added to a concrete mixture. Compared to regular cement pastes, the resultant paste has a higher concentration of the potent C-S-H and a lower concentration of the weaker, more readily Ca(OH)2. The glue that keeps the system composed and provides the majority of the strength in concrete is the calcium silicate hydrate that forms.The slight glass powder particles are excellent in penetrating and obstructing concrete's capillary pores, resulting in fewer and smaller pores and denser concrete[23].

2 COLLECTION AND TESTING OF MATERIALS

2.1 Glass Powder

Glass is a clear substance made by melting a combination of elements at a high temperature, including silica, soda ash, and CaCO3. Then, the mixture is cooled, allowing solidification to occur without crystallization, and the composition of chemical GP as displayed in Table 1. The use of glass items has been increasing completed the previouslimited years, which consumes led to a broadmindedgrowth in the amount of waste glass. The majority of used glasses have ended up in landfills. Thus, as Figure 1 illustrates, we use leftover glass with concrete to create affordable and environmentally beneficial building.

Fig 1. WGP and Cement

Table 1. Chemical configuration of GP

S.No.	Properties	Waste GP
1	Al2O3 (%)	1.63
2	Na_2O (%)	15.31
3	MgO (%)	-
4	SiO2 (%)	70.41
5	Fe_2O_3 (%)	0.54
6	CaO (%)	11.20
7	SO_3 (%)	-
8	Loss of ignition	0.8
9	K_2O (%)	-
10	Cl (%)	-

2.2 Ordinary Portland Cement

The chemical and physical composition of cement is examined using normal Portland cement 53 evaluation through a 3.15 of specific gravity as indicated in Table 2. It is a finely ground material that serves as a binding medium for the various components by having cohesive and adhesive properties. It is made by partially fusing, at a high temperature (about 1450 0C). The mixture is burned together in a certain proportion. Clinker, also known as nodules with a diameter of 5 to 25 mm, is the by-product of burning that is ventilated and crushed to the necessary quality to create cement. Because it generated a substance that resembled pebble from the mines near Portland, England, as it set, Joseph Aspin, the product's developer, gave it the name Portland cement.

Table 2. Cement-Chemical Configuration

S.No.	Oxide	Percentage
1	CaO	64%
2	SiO_2	23%
3	Al_2O_3	5.9%
4	Fe_2O_3	2.9%
5	MgO	2.5%
6	SO_3	1.6%
7	K_2O, Na_2O	0.49%

Table 3. Cement - Physical Possessions

S.No.	Characteristics	Values
1	Standard constancy	54
2	CementFinenesstaken on 90 ms	3%
3	setting time starting	30 min
4	Specific gravity	3.2

2.3 Fine Aggregate

Sand, or fine aggregate, is a collection of mineral particles that are left over after rocks break down. The best for business use are silica sands, which are frequently more than 98% pure. Beach sands are often devoid of organic debris and smooth, spherical to protect the grains from the rough impact of breakers and waves. The bleached shore sands are used to excerpt different fundamentals; they are mostly composed of silica, but they can also contain garnet, zircon, monazite, and other minerals. Sand is utilized in manufacture of concrete and mortar, in sandblasting and polishing. In foundries, gravels with a slight quantity of clay are used to kind molds. Clear sands are used to filter water. Sand is sold in tons (0.91 metric tons) and cubic yards (0.76 m3) and is shipped by weight. Depending on the grain's size and composition, its weight capacity series from 1540 to 1839 kg/m3. For this experimental program, fine gravel free of various organic contaminants was collected from the Kavery River bed. The fine combined had a 2.66 of specific gravity and 4.75 mm screen. Allowing to ISS, zone II was the fine aggregate is a grading zone. Table 4 below provides a list of fine aggregate's physical characteristics. Table 5 displays the findings of the sieve analysis.

Table 4. Fine Aggregate - Physical Possessions

S.No.	Characteristics	Experimental value
1	Modulus Fineness	3.03
2	Specific gravity	2.6
3	Zone of fine aggregate	Zone II

Table 5. Fine Aggregate -Particle Size (Wt = 1000 grams)

Sieve dimension	Weight retained (grams)	Percentage weight retained	Cumulative percentage retained	Cumulative percentage passing
4.8mm	20	2	2	98
2.4mm	20	2	4	96
1.2mm	90	9	13	87
600µ	150	15	28	72
300µ	410	41	69	31
150µ	180	18	87	13
Pan	130	13	100	0

2.4 Coarse Aggregate

When creating concrete, coarse aggregate—crushed stone—is utilized. The stone used for commerce is graded, crushed, and quarried. The most common types of crushed stone utilized are trap rock, limestone, and granite. The last phrase is used to describe many dark-colored, fine-grained igneous rocks, such as diorite, gabbro, and basalt. Typically, graded crushed stone is shattered with sharp edges and only contains one type of rock. Higher dimensions may be utilized for enormous concrete aggregate, however the sizes assortment after 0.25 to 2.5. Coarse aggregate was made of angular granite broken stone that was machine crushed. Granite is an igneous rock with coarse grains and an even texture. The most significant building stone is granite. Because granite does not absorb moisture like sandstone and limestone do, it is incredibly robust and does not weather or split like these stones do. Typically, the colours are grey, green granite can take a pink or lavender background with dark mottling, or it can have a dark green related with pink, reddish mottling and yellowish. Table 6 below lists the coarse aggregate's physical characteristics.

Table 6. Coarse Aggregate - Physical Possessions

S.No.	Characteristics	Values
1	Specific gravity	2.8
2	Nominal size of aggregate	20 mm

2.5 Water

For mixing and curing, potable water is utilized. The final hardened concrete stands visually preciousthrough the excellenceof liquidutilized in the concrete mixing process. Water impurities might hinder the cement's ability to set, which will reduce the concrete's strength and longevity when combined with steel slag. The specimens are cast and cured in fresh, pure water that meets criteria and is devoid of organic debris, silt, oil, and acid material.

3 Mix Design

The process of designing a concrete mix involves calculating the ratios of the raw materials to produce a minimum amount of strength and durability in the most cost-effective manner. The expenses of labor and materials are the two types of costs associated with producing

concrete. For both poor and good concrete, the labor costs for form work, batching, mixing, transporting, and curing are almost equal. Because strength and durability are required, the mix design attempts to choose as little cement as feasible. The Mix ratio, as indicated in Table 7, is –M 30 (kg/m3).

As indicated in Table 8, five distinct mix proportions were selected for this investigation. The control mix (without GP) was the first.

Table 7. Mix ratio –M 30

Water	Cement	Fine Aggregate	Coarse Aggregate
197	448	655	1158
0.44	1	1.4	2.5

Table 8. Mix proportion for various percentage of glass power

Mix	Symbol (GP)	Cement (Kg)	F.A (Kg)	C.A (Kg)	GP (Kg)	Water (litre)
CONT	0%	448	655	1157	0	197
MIX1	5%	425.6	655	1157	22.4	197
MIX2	10%	4032	655	1157	44.8	197
MIX3	15%	380.8	655	1157	67.3	197
MIX4	20%	3584	655	1157	89.6	197

3.1 Slump Test

The topmost layer was flipped and the mold was lifted vertically without affecting the concrete cone in any way. The slump is the millimeter-scale subsidence of concrete.True slump refers to the concrete that slumps uniformly throughout following the test. One side of the cone may slide down the other in extremely lean concrete, a phenomenon known as a shear slump, or it may collapse in extremely moist concrete. Only concretes with medium to high workability are appropriate for this test. Nonetheless, it has been discovered that, in field conditions, the slump test is helpful in guaranteeing consistency across several batches of purportedly same concrete. The workability test results of waste GP concrete are displayed in Table 9. If the percentage of waste GP increases, the value of slump growths as well. As a outcome, it container be realised that employing waste GP will increase workability to concrete after compared to control mix.

Table 9. Slump value

S.No.	Percentage of GP	Slump value(mm)
1	0	25
2	5	26
3	10	26.5
4	15	28
5	20	29

3.2 Compressive Strength

The specimens were demolded and allowed to cure in water after a full day. Cubes were collected and left to dry before being examined in a compression difficult equipment subsequently 28 times of curative. As seen in Figure 2, the specimens were tested in accordance with IS 516-1964, and the ultimate load was recorded.

$$\text{Compressive strength} = \frac{\text{load}}{\text{Area}} \quad (N/mm^2)$$

Fig 2. Compression test on cube

3.3 SPLIT TENSILE STRENGTH

This test is generally used to indirectly evaluate the tensile metier of concrete. Up until the cylinder fails along the vertical diameter, a strong and consistent compressive force is delivered along the cylinder's length. Because of its fragile nature and poor tensile strength, concrete is typically not expected to withstand direct tension. To ascertain the load on the concrete associatescan fracture. Tension failure is the source of the cracking. Figure 3 illustrates the split tensile tests that were performed on a 150 mm by 300 mm cylinder specimen at the phase of 28 existences using a compression testing machine in accordance with IS: 5816-1970. Readings were recorded after the specimen split under the imposed stress. The following formula has been used to regulate the splitting tensile metier.

$$\text{Split tensile strength} = \frac{2P}{\Pi D L} \quad (N/mm^2)$$

Where;
P = Max.load
D = Restrained diameter
L = restrained length

Fig. 3. Split Tensile Test on Cylinders

3.4 DETAILS OF BEAM

Five RC beams in all were cast. The first mix was the control mix, which contained no GP. Before the concrete was poured, the wooden mold was cleaned and oiled. The lengths of the reinforcing bars were determined. By using binding wires, the fastened to one another at the proper interval. After that, the steel bars were linked and placed inside the mold using a cover block that measured 25 mm by 25 mm by 25 mm. To guarantee even mixing, a duration of 3 to 5 minutes was specified for mixing. Following mixing, the concrete was poured into the mold, and air pockets were sealed out through compaction. The samples underwent a 24-hour demoulding process and a 28-day curative period. Following the curative period, they kept dry for a full day. After that, all filth and grime were removed from the specimens using sand paper cleaning. After that, white washing was applied to each specimen from all sides. To make it easier to identify the spread of cracks, white washing was done.

Flexural design of beam

Concrete Grade	M30
Steel Grade	Fe 415
Beam Length	1.10m
Length	1.00m
Beam Breath	100mm
Beam Depth	150mm

Reinforcement details

Figure 4. shows the reinforcement details of beam and Figure 5. Shows the casting of beam

- Main reinforcement – 2 Numbers of 10 mm Φ on top and bottom.

- Shear reinforcement – 8 mm Φ @ 100 mm near the support and – 8 mm Φ @ 140 mm in middle of the beam.
- Cover – 25 mm.

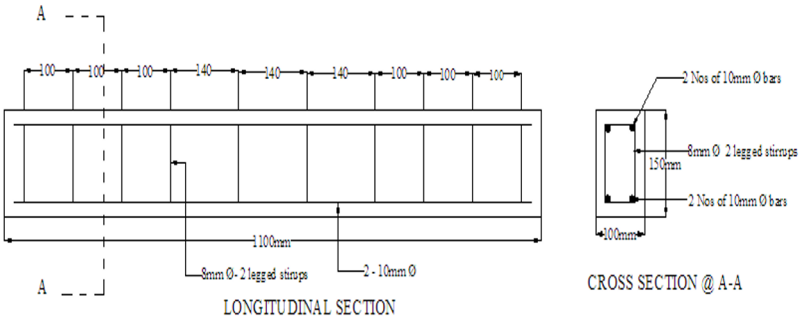

Fig 4. Reinforcement details of beam

Fig 5. Casting of beam

4 Experimental Setup

Under a 100kN load frame, Flexural strength to the each beam was examined. Under 2 point loading, these beams were evaluated under basicallymaintained conditions completed an actualdistance of 1000 mm. Using an LVDT, deflections under the mid span were measured. Every 2 kN load increment was followed by the recording of the crack patterns. The investigational setup is depicted in Fig. 6 and 7.

Fig 6. Experimental setup

Fig 7. Tested specimen

5 RESULT AND DISCUSSION

5.1 Compressive Strength Test

After twenty-eight days, the compressive strength of fifteen cube specimens made of concrete was examined. Figure 8 and Table 10 display the cubes' compressive strength. When waste glass is ground to an extremely fine powder, SiO2 reacts chemically with the cement's alkalis to generate cementitious products, which aid in the development of strength. Another possibility is that the GP successfully filled in the spaces, creating a dense concrete. The alkali-silicate reaction causes weak pockets to form in the concrete when there is an excess of GP present but not enough calcium for the reaction to occur. This weakens the concrete.

Comparing the compressive strength to the control specimen, replacing GP in cement by 5%, 10%, 15%, and 20% enhances it by 5.37%, 9.13%, 11.441%, and 8.76%, respectively.

Table 10. Cubes - Compressive Strength

Mix	7 days		14 days		28 days	
M30 grade	Failure load (KN)	Compressive Strength (N/mm^2)	Failure load (KN)	Compressive Strength (N/mm^2)	Failure load (KN)	Compressive Strength (N/mm^2)
CONT	480	21.35	580	25.76	729	32.41
MIX1	439	19.50	539	23.96	768	34.15
MIX2	446	19.84	498	22.12	796	35.36
MIX3	455	20.22	504	22.39	813	36.12
MIX4	415	18.45	520	23.14	801	35.58

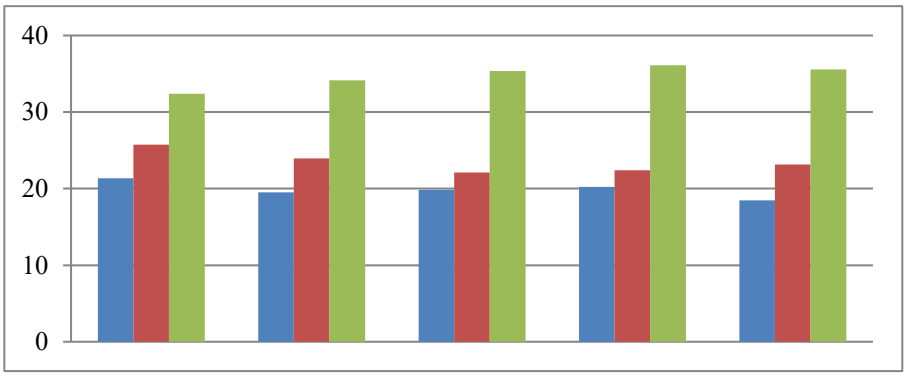

Fig 8. Compressive Strength

5.2 Split Tensile Strength Test

Later the concrete's twenty-eight-day split tensile strength test, a total of 15 cylinder specimens were cast. The STS of the cylinders is displayed in the Table 11 and Figure 9.

Comparing the compressive strength to the control specimen, replacing GP in cement by 5%, 10%, 15%, and 20% enhances it by 7.1%, 11.45%, 18.2%, and 33.03 percent, respectively.

Table 11. Split tensile strength of cylinder

MIX	7 days		14 days		28 days	
M30 Grade	Failure load (KN)	Split tensile strength (N/mm^2)	Failure load (KN)	Split tensile strength (N/mm^2)	Failure load (KN)	Split tensile strength (N/mm^2)
CONT	145	2.05	177	2.52	229	3.25
MIX1	134	1.9	171	2.42	246	3.48
MIX2	150	2.12	184	2.61	256	3.61
MIX3	151	2.13	182	2.58	271	3.84
MIX4	160	2.28	186	2.63	307	4.35

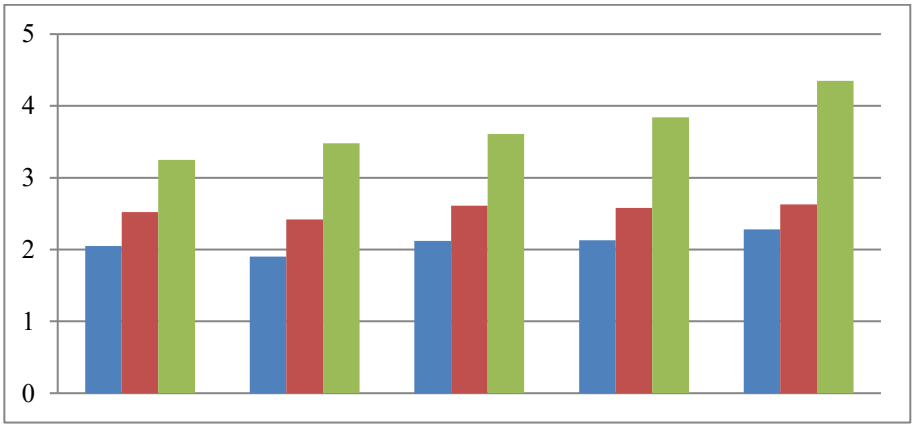

Fig 9. Split tensile strength

5.3 Flexural Strength Test

In comparison to the control specimen, which is depicted in Table 12 and Figure 10, the specimen with a 15% substitution of cement by GP has a higher load carrying capacity.

Table 12. Flexural Strength Results

S.No.	Percentage of GP	Ultimate load (kN)	Deflection (mm)	Energy absorption (kN-mm)	Ductility factor	Stiffness kN/mm
1	0	44	4.6	151	1.31	8.57
2	5	46	5.3	160	1.61	9.5
3	10	50	6.4	180.5	1.73	11
4	15	54	6.7	195	1.86	13.18
5	20	46	5.6	156	1.6	5

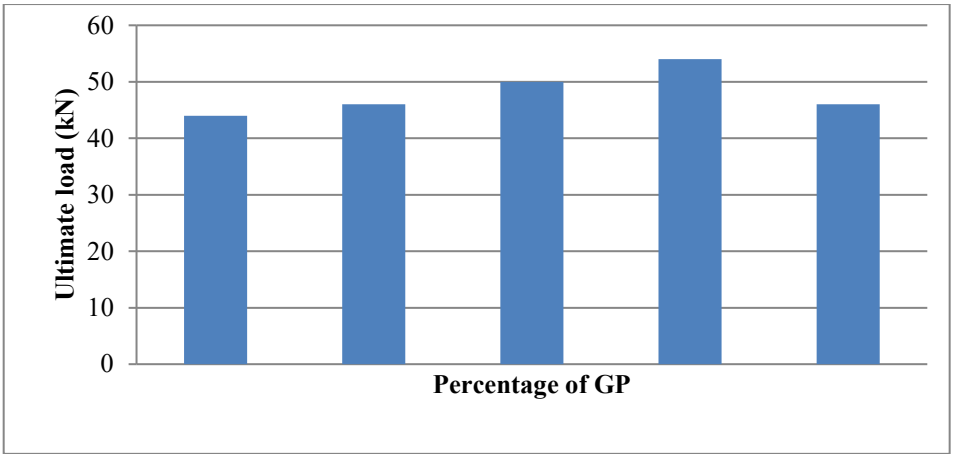

Fig 10. Flexural Strength

5.4 Load Vs Deflection Curve

All beams had load deflection curves generated, and Figures 11, 12, 13, and 14 compare the load deflection behavior of the various types of beams. In comparison to the control specimen, the test result demonstrates that 15% of the GP specimens have an ultimate load and experience less deformation.

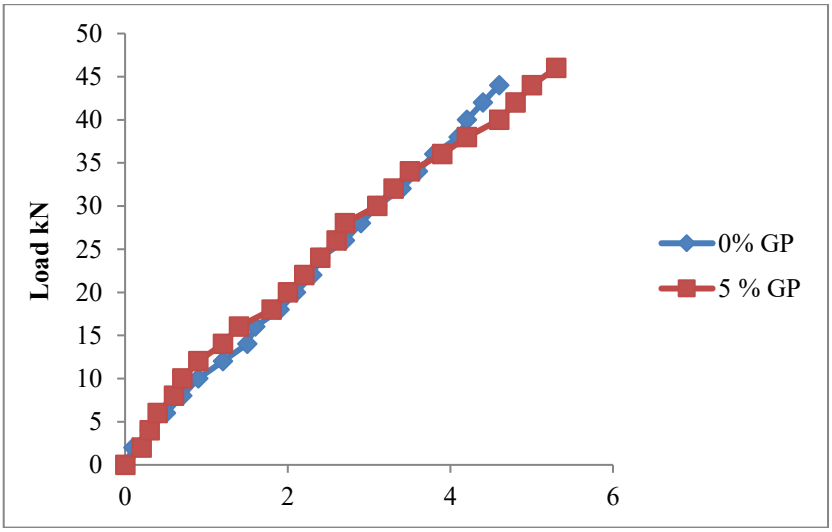

Fig 11. Load deflection curve for 0% GP+ 5% GP

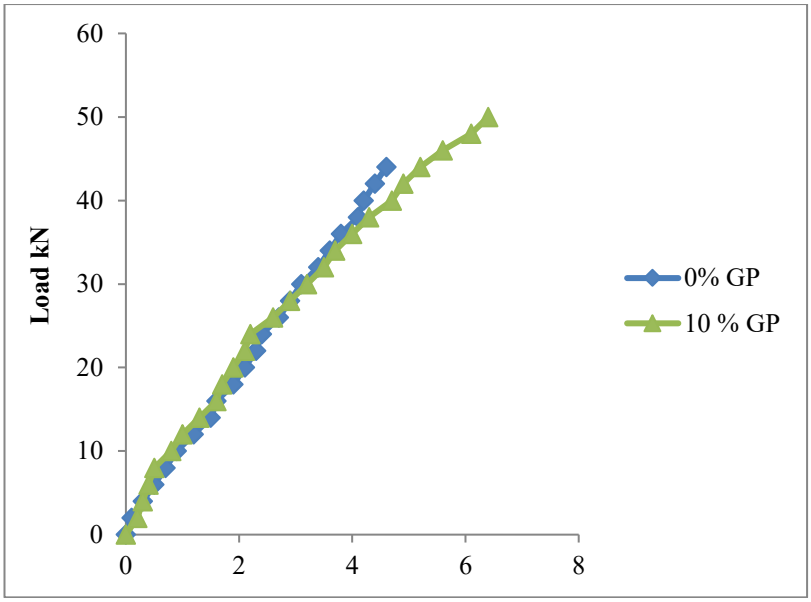

Fig 12. Load deflection curve for 0% GP + 10% GP

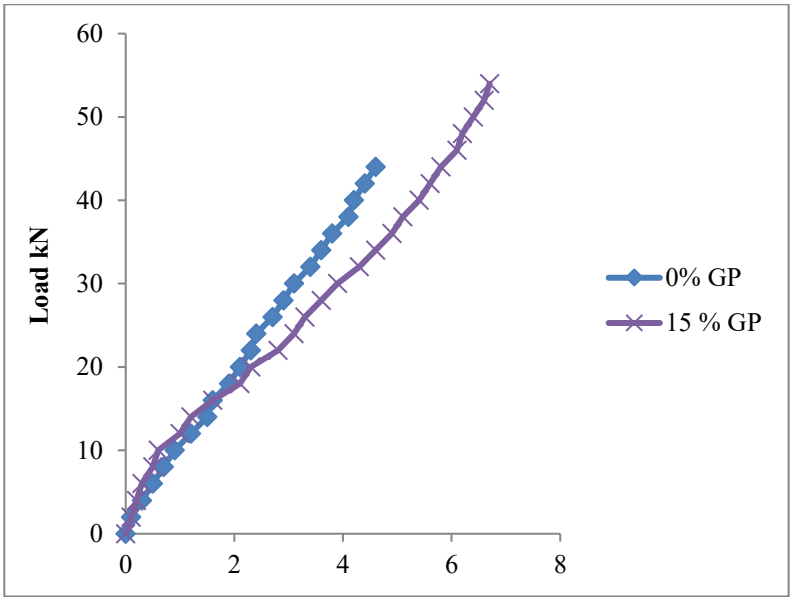

Fig 13. Load deflection curve for 0% GP + 15% GP

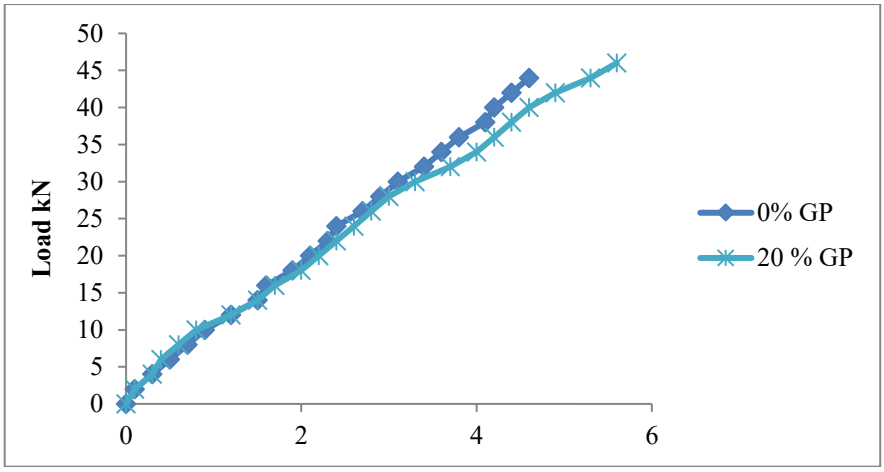

Fig 14. Load deflection curve for 0% GP S+ 20% GP

5.5 Energy Absorption Capacity

The load deflection curve may generally be used to determine a material's energy absorption capacity. Figure 15 shows the difference in energy captivation capacity for each beam. When associated toward controller specimen, the specimen with a 15% cement replacement by GP had a higher energy absorption capability.

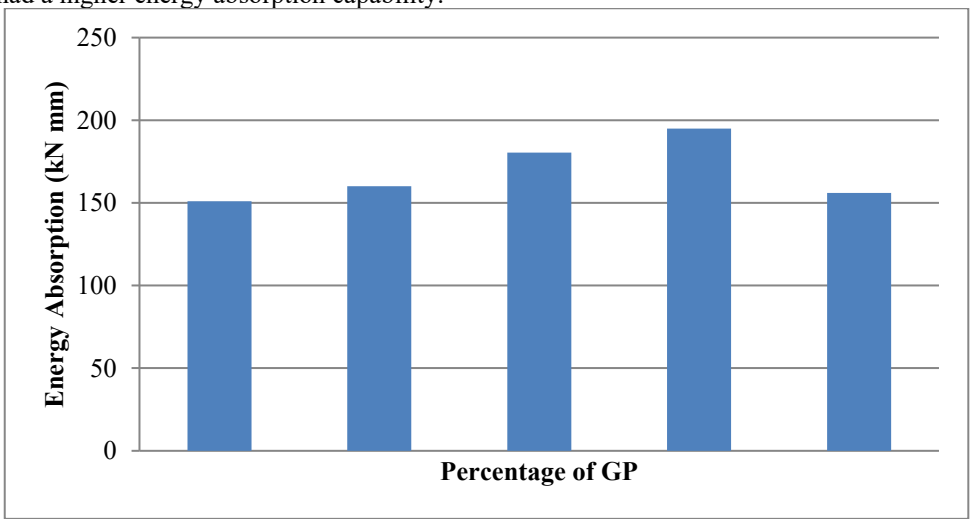

Fig 15. Energy absorption of specimens

5.6 Stiffness

The load essential to cause a unit refraction of the cylinder is recognised as stiffness. The curve at load P= 0.75Pu, where Pu is the cycle's maximum load, has a tangent drawn on it. The tangent's slope, as illustrated, indicates the cylinder's stiffness [40-45]. Figure 16

displayed the variation in stiffness characteristics for each of the cylinders. In comparison to the control specimen, the specimen with a 15% cement substitution by GP exhibits increased rigidity.

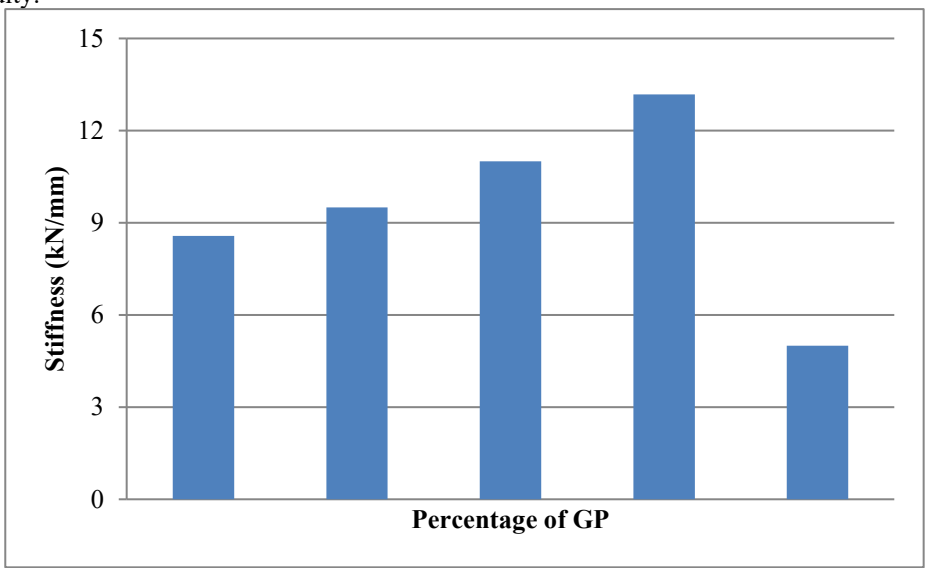

Fig 16. Stiffness of specimens

Ductility Factor

The ratio of deflections at the final load to those at the beginning of yielding is known as ductility. When compared to the control specimen, as depicted in Figure 17, the specimen with a 15% substitution of cement by GP has a higher ductility factor.

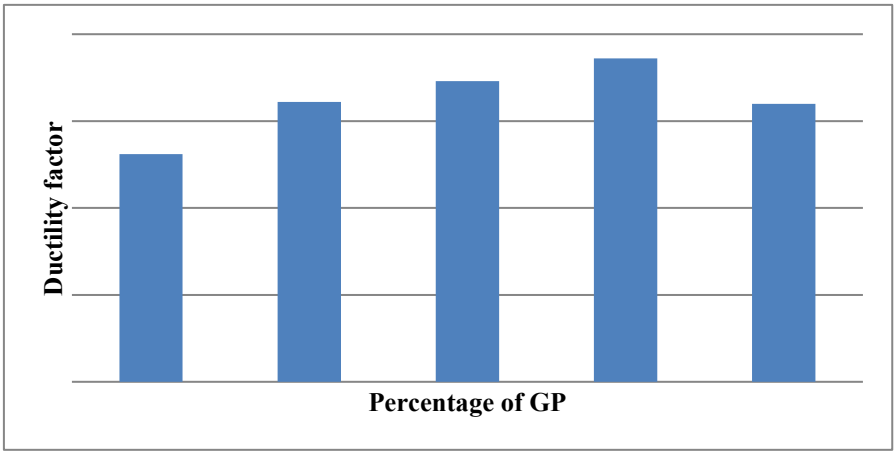

Fig 17. Ductility factor of specimen

6 CONCLUSION

In this investigation, GP is used in place of some of the cement. Replacement is carried out in the M30 concrete mix in increments of 5%, 10%, 15%, and 20%. On both freshly laid and hardened concrete, numerous tests were conducted. Compressive strength was determined to have improved by up to 11.5% based on test findings. Up to 33% more split tensile strength was discovered. It was shown to enhance flexural strength by up to 23%. The strength of the members was found to be decreasing after 15% of replacement, which was done gradually up to 20%.According to the study, 15% is the ideal amount of excess glass to substitute in cement. The initial rate of strength gain after adding GLP is low, but after 28 days, it reaches the required design strength. Concrete gains strength when GLP is added

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