Experimental Investigation on Geopolymer Concrete Slabs of Grade M25

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Abstract- *This study investigates the performance of M25 grade geopolymer concrete (GPC) slabs reinforced with glass fibres (GF). Four slab specimens of size 600 mm× 600 mm × 50 mm were casted and tested under static loading. The mix variations included: (S1) conventional M25 concrete, (S2) M25 + GF, (S3) GPC M25 with 8 Molarity (8M) and (S4) GPC M25 + GF - 8M. Mechanical properties such as compressive strength, flexural strength, and flexural behaviour were evaluated. Among all specimens, the hybrid fibre-reinforced GPC slab (S4) demonstrated the best performance. It showed the highest first crack load, ultimate deflection, and enhanced post- peak behaviour under flexural loading. The static test results for specimen S4 revealed an ultimate load-carrying capacity of 26.61 kN, a ductility index of 8.72, and a toughness index of 30.54. These results indicate that the integration of glass fibres significantly improves the load- bearing capacity and ductility of GPC slabs, making them a viable alternative to conventional concrete in structural applications*

Keywords- Cement, Flyash, GGBS, Fibers, M-sand , Compressive strength, Flexural strength.

I. INTRODUCTION

The construction industry relies heavily on concrete, which typically uses Ordinary Portland Cement (OPC) as a binder. However, OPC production is energy- intensive and generates significant carbon dioxide emissions. The process consumes vast amounts of raw materials and fuel, contributing to resource depletion. Additionally, the calcination process releases substantial CO_2 emissions. In response to these environmental concerns, researchers are exploring sustainable alternatives to traditional OPC, aiming to reduce its use in concrete and promote eco-friendly construction practices. Geopolymer concrete (GPC) is a modern and eco-friendly construction material that serves as a sustainable replacement for conventional Portland cement concrete. It is formed by chemically activating alumino-silicate-based substances such as fly ash, ground granulated blast furnace slag (GGBFS), using alkaline activators like sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). (1) The Experimental on mechanical properties of M25 grade concrete with silica fume and recycled coarse aggregate (RCA). Silica fume enhances concrete performance by filling spaces between cement particles. RCA promotes sustainability by reducing waste and conserving natural resources. Test results show improved compressive strength with silica fume. The combination of RCA and silica fume can create more eco-friendly concrete. The findings support the use of RCA and silica fume in sustainable construction practices, reducing environmental impact while maintaining structural integrity. This approach can contribute to a more environmentally friendly construction industry. Sustainable concrete solutions are crucial for future development. (2) The study explored the effect of glass fibers on the load- carrying capacity of concrete members. Various percentages of glass fibers were added to the mixture, and the results showed that a 1% addition significantly improved flexural strength compared to plain cement concrete. However, further increasing the fiber content to 2% yielded minimal additional benefits. Notably, the workability of the concrete mixture was substantially reduced, even with the use of admixtures. Within a certain range, glass fibers can enhance flexural strength through confinement effects, but excessive fiber content can compromise workability and overall performance. A balanced fiber content is crucial for optimal results.{3} A comprehensive review of geopolymer concrete's mechanical properties was conducted, analyzing existing research to understand the relationships between various properties. The study examined compressive strength, tensile strength, flexural strength, elasticity, and other key characteristics. By evaluating data from previous studies, the review aimed to assess the accuracy of predictive equations and identify trends in geopolymer concrete's behavior. This analysis provides valuable insights into the material's properties, helping to advance its development and application. The findings can inform future research and practical uses of geopolymer concrete, promoting its potential as a sustainable building material. {4} Investigated the punching behavior of two-way reinforced concrete (RC) slabs with multiple openings. Their study, published in Structure, employed a combined experimental, analytical, and numerical approach. This means they likely conducted physical tests on slabs with openings, developed analytical models to predict the punching behavior, and performed computer simulations to further analyze the results. The goal of their research was likely to understand how these openings affect the load-carrying capacity of the slabs and identify potential failure mechanisms. This information is valuable for designing safer and more efficient RC slabs with openings for real-world applications.

II. EXPERIMENTAL INVESTIGATION

The bending test is primarily conducted to evaluate a material's ductility, bending strength, fracture resistance, and overall behavior under flexural loading. It helps determine whether a material can withstand bending forces without failing, which is crucial in structures using ductile materials. In concrete, strength after hardening is a key factor influencing structural behavior and design. Among all properties, strength is often regarded as the most critical, as it provides a reliable indication of concrete quality. This strength is closely linked to the internal structure of the hardened cement paste within the concrete.

III. MATERIALS AND MIXES

Geopolymer concrete (GPC) is produced by activating aluminosilicate-rich industrial by-products using alkaline solutions. The primary binders used are Fly ash (FA), especially Class F, and Ground Granulated Blast Furnace Slag (GGBS), both known for their high silica (SiO_2) and alumina (Al_2O_3) content. The alkaline activator typically consists of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). Aggregates (fine and coarse) are used similarly to conventional concrete, often constituting about 75– 80% of the total mix. The water-to-binder ratio is kept low, while 8M molarity of NaOH solution is used while mixing, it helps to significantly influences strength.

Table -1 : Mortar Mix Designation

Mixes	Designation
MIX 1	M-25
MIX 2	M-25+GF
MIX 3	GPC-8M
MIX 4	GPC-8M+GF

IV. TESTING PROCEDURE

Experimental Set up - Static Testing Machine

As part of the experimental investigation, static load tests were conducted on slab specimens. The testing setup was designed and installed at the Department of Civil Engineering, UVCE, Bengaluru. A manually operated hydraulic jack system, securely anchored to a reinforced concrete (RCC) pedestal foundation, was used for load application. The pedestal extended 1 metre above ground level, including a 0.3-metre-high base. A loading frame, fabricated using an ISMB 250 section, was mounted vertically to a height of 2.5 metres. Another ISMB 250 section was placed horizontally to support the loading mechanism. The test slabs were positioned on a 600 × 600 mm square support frame made of ISHB 160 sections, fixed to the pedestal. During testing, fixed edge boundary conditions were maintained

V. RESULTS AND DISCUSSIONS

5.1 Compressive strength

Compressive strength tests were performed on standard cube specimens of size 150 × 150 × 150 mm for all mix variations. The specimens were tested after curing periods of 3, 7, and 28 days to evaluate the strength development over time. The compressive strength values obtained for each mix at these intervals are summarized in the table below.

Table -2 : Summary of 3, 7 and 28 days Compressive Strength of Test Specimens

Mixes	Compressive Strength in N/mm^2		
	3 days	7 days	28 days
MIX 1	13.25	21.53	33.13
MIX 2	13.86	22.70	33.73
MIX 3	13.71	22.15	33.61
MIX 4	14.24	22.80	34.65

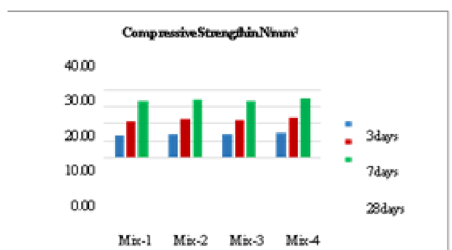

Chart -1: Comparison of Compressive Strength with Age of different concrete matrice

5.2 Flexural strength

Flexural strength tests were conducted on beam specimens with dimensions of 100 × 100 × 500 mm. During testing, the maximum load at failure was recorded for each specimen. Using this data, the flexural strength was calculated in accordance with standard procedures. The flexural strength values obtained for all concrete mixes are summarized in the below table.

Table -3: Summary of 3, 7 and 28 days Flexural Strength of Test Specimens

Mixes	Flexural Strength in N/mm^2		
	3 days	7 days	28 days
MIX 1	1.66	2.69	4.15
MIX 2	1.77	2.80	4.31
MIX 3	1.73	2.77	4.25
MIX 4	1.95	3.12	4.65

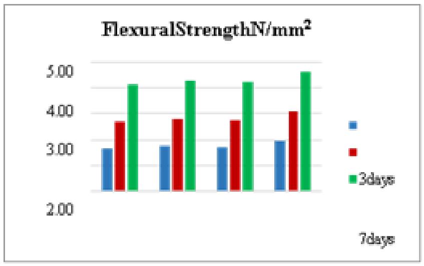

Chart -2: Comparison of Flexural Strength with Age of different concrete matrices

5.3.Results of load deflection curve (P-δ curve)

Load–deflection curves provide critical insight into the structural response of slab specimens under applied loads. They are particularly useful for evaluating behavior within the service load range and identifying the working load limit. For all slab specimens tested in this study, the corresponding load–deflection curves have been plotted and presented in the form of graphs.

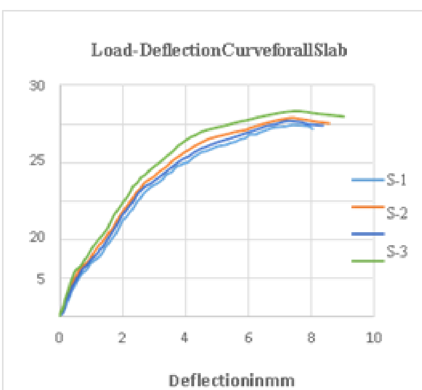

Chart-3: Load - Deflection curve upto Ultimate Load

5.4.First crack load

This is the load at which the first visible crack appears on the surface of the slab to the development of tensile stresses.

Table -4: Experimental and Theoretical values of First Crack Loads.

Designations	**Theoretical first crack load (kN) - T**	**Experimentalfirst crack load (kN) - E**
MIX 1	6.76	7.07
MIX 2	6.82	7.32
MIX 3	6.81	7.17
MIX 4	6.95	7.68

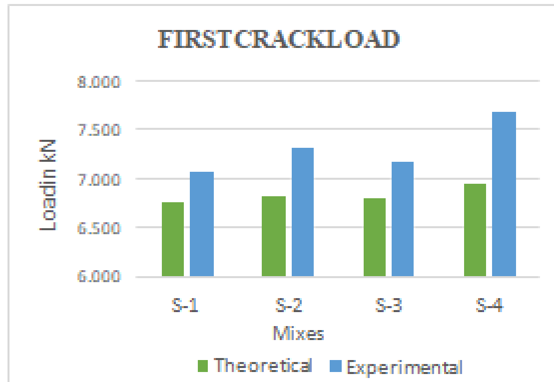

Chart-4: Comparison of Experimental and Theoretical values of First CrackLoads

5.5.Punching Shear

The phrase "ultimate strength" refers, when applied a structural member, to boththe resistance that corresponds to the stage at which actual material rupture begins to occur and the maximum resistance that the member can develop due to internal stresses against external forces.

Table -5: Experimental and Theoretical values of Ultimate Load.

Designations	**Theoretical Ultimate load (kN) - T**	**Experimental Ultimate load (kN) - E**
MIX 1	20.51	24.62
MIX 2	20.70	25.59
MIX 3	20.66	25.31
MIX 4	20.98	26.61

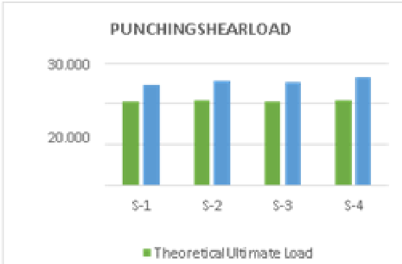

Chart-5: Experimental and Theoretical values of Ultimate load

5.6.DuctilityIndex

Deflection at yield and ultimate loads are noted down through LVDTs and the same are tabulated below Table -6: Ductility Index

Table -6: Ductility Index

Designation	UltimateDeflection(mm)	YieldDeflection(mm)	DuctilityIndex
MIX1	7.02	1.04	6.75
MIX2	7.33	0.93	7.88
MIX3	7.21	0.95	7.58
MIX4	7.42	0.85	8.72

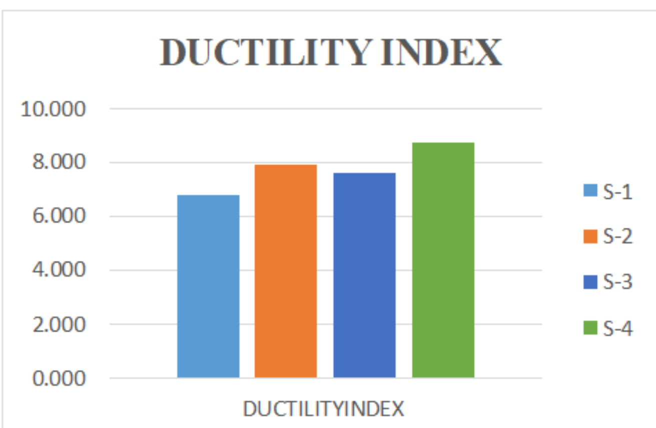

Chart-6.DuctilityIndex

5.7.Energy Absorption Capacity

The specimen's load versus deflection curve may be used to determine the material's energy absorption capability. The energy absorption capacity of various concrete mix slabs under examination was calculated by calculating the area under the load deflection curve.

Table -7 : Energy Absorption Capacity

Designations	Energy Absorption Capacity (kN-mm)
MIX 1	139.53
MIX 2	153.86
MIX 3	147.05
MIX 4	183.00

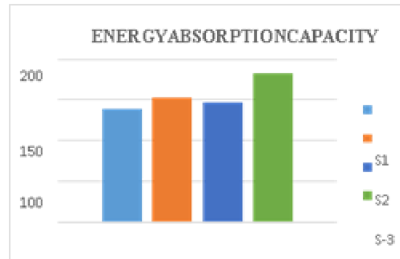

Chart -7. Energy Absorption Capacity

5.8.Toughness Index

Table -8: Toughness Index

Designations	Area under curveupto 0.8 Pu (kN-mm)	Area under curve upto first crackload (kN-mm)	Toughness Index
MIX 1	139.53	5.22	26.73
MIX 2	153.86	5.45	28.23
MIX 3	147.05	5.310	27.69
MIX 4	183.00	5.992	30.54

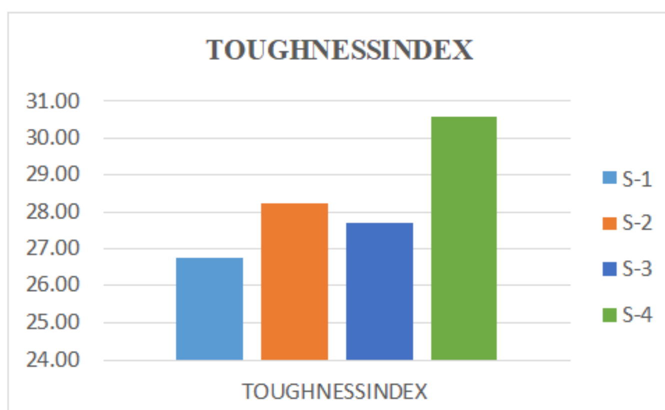

Chart -8. Toughness Index

VI. CONCLUSION

1. The compressive strength of 28 days is highest for GPC-8M+GF (Mix 4) in comparison with other concrete matrices used in this investigation i.e. 4.38% than that of 28 days strength,

2. The flexural strength of 28 days is highest for GPC-8M+GF test specimen in comparison with M25 used in this investigation i.e. 10.75%.
3. It is observed that from experimental results, first crack load for other slabs as achieved up 4.38%, 6.83%, 5.02% & 9.50%, with respect to theoretical values of First Crack Loads..
4. It is observed that from experimental results, ultimate load for other slabs are achieved up to 16.69%, 19.10%, 18.37% & 21.15%, with respect to theoretical values of Ultimate Loads..
5. Ductility is achieved with respect to S-1 by 1.34%, 10.94% & 22.59% for S-2, S-3, & S-4 test slab specimens respectively
6. It is observed from that from Experimental results, energy absorption capacity for S-2, S-3 & S-4 has been achieved up to 9.31%, 5.11% & 23.75% respectively with respect to S-1.
7. Toughness is achieved with respect to S-1 by 5.31%, 3.46%, 12.47%, for S-2, S-3 & S-4 test slab specimens respectively.
8. The percentage change of analytical to experimental ultimate punching shear for S-1, S- 2, S- 3 & S-4 is to 16.69%, 19.10%, 18.37%, 21.15% respectively.

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