

INVESTIGATION ON INFLUENCE OF GFRP SHEETS PN DEEP BEAMS**Mohammed Junaid Ahmed¹, Mirza Mubashir Ahmed baig², Riyaz Syed³**¹M.Tech Scholar, ^{2,3}Assistant Professor

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Corresponding email id: mohammedjunaidahmed3112@gmail.com**ABSTRACT**

Transfer girders made of reinforced concrete (RC) are widely used in many different contexts, such as foundations, offshore constructions, bunkers, and building load-bearing walls. In order to make doors and windows accessible or to make room for necessary services like HVAC ducts, these beams typically need web holes. Nevertheless, there are substantial safety concerns associated with reducing the beam's shear capacity by increasing the size of these gaps for architectural, mechanical, or functional reasons. There is a dearth of research on the strength and behavior of RC deep beams with apertures, despite the fact that they are common. It is critical to take sufficient steps to reinforce the beams and reduce the impact of the weakening when such expansions are required. Deep beams with apertures are the subject of the current experimental study, which verifies its findings with a Finite Element Method (FEM) model in ANSYS. Without shear reinforcements, five deep beams with apertures were cast and subjected to three-point loading tests. Each test specimen, with a total length of 1200 mm and a cross-section of 150 x 460 mm, had two symmetrical circular apertures positioned in each shear span near the beam's midpoint. Adding externally attached GFRP reinforcement across the holes increased the shear strength of the deep reinforced concrete (RC) beams by 68–125%. The study used finite element modeling in ANSYS to examine RC deep beams with reinforced apertures utilizing GFRP sheets and then compared the results to experimental data in order to determine the efficacy of this strengthening technique.

INTRODUCTION**DEEP BEAM**

To be considered deep, a simply-supported beam must have an effective span (L) to total depth (D) ratio below 2, as per Clause 29 of the Indian Standard IS 456:2000. A ratio lower than 2.5 is used for continuous beams. The effective span is calculated by using the smaller of

the two following measurements: the distance between the supports measured center to center the clear span. When deep beams are mainly loaded as simple beams, a large amount of the load is transferred to the supports by means of compression forces caused by both the applied load and the reaction at the supports.

The design of deep beams causes them to have non-linear strain distribution, which means that shear deformations are more important than pure flexural deformations. This property suggests that shear, not flexure, is typically the limiting factor in deep beam strength. Contrary to expectations based on more conventional models, their shear strength is often higher. They outperform beams of standard size due to their ability to redistribute internal forces prior to failure and their development of novel force transfer mechanisms (Winter and Nelson, 1987). Deep beams are commonly used in various applications such as foundations, bunker walls, load-bearing walls of buildings, raft beams, walls of rectangular tanks, hoppers, floor diaphragms, walls of shear, pile caps, and transfer girders.



Fig. 1.1 Deep Beam without openings

DEEP BEAM WITH OPENINGS

Research on deep beams with apertures is restricted compared to solid deep beams. Buildings typically require large apertures in structural components to accommodate mechanical and electrical cables, doorways, and corridors. Windows, doors, utility lines, and ventilation ducts can all fit through these holes. However, deep beams' structural integrity and shear capacity can be greatly affected by these apertures, thus careful design considerations are needed to guarantee safety and performance under load. Further work is needed to fully understand how apertures impact the behavior and strength of deep beams, even if these designs have practical benefits.

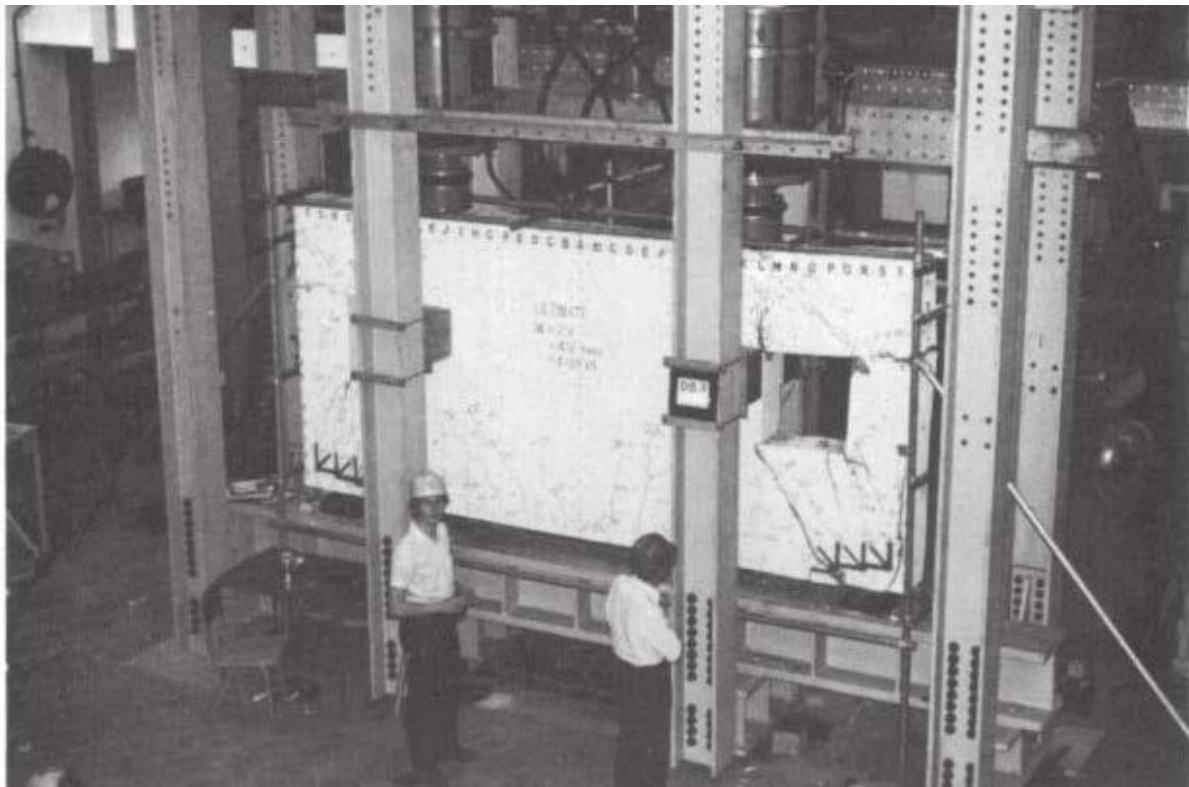


Fig. 1.2 Deep Beams with openings (Source: Google)

FIBRE REINFORCED POLYMER (FRP)

Common forms of fiber-reinforced polymers (FRP) include wires, bars, strands, and grids. The numerous structural uses of FRP have been the subject of substantial research, despite the fact that it is a comparatively new invention.

The use of FRP for structural reinforcement, especially for bridge decks and other similar components, has been successful in the building of bridges. Structural reinforcement and retrofitting of old, weak, or deteriorating buildings is one of the most important uses of FRP.

Lightweight, extremely strong, and highly resistant to corrosion, FRP is a great material to use in structural rehabilitation projects.

Because FRP is also available in thin sheets, it can be installed with minimal alteration to the dimensions of preexisting structural components. This feature improves the overall performance and longevity of the repaired pieces by allowing them to be seamlessly integrated into existing structures without requiring significant adjustments. In sum, FRP's benefits make it a potentially useful material for contemporary building and repair procedures.

OBJECTIVE

The study also intends to see how holes affect the beams' total strength and what happens if the beams are externally strengthened using Fiber-strengthened Polymer (FRP). This research will help shed light on the structural integrity of deep beams with openings and find efficient strengthening ways to reduce the negative effect of openings on shear capacity by methodically evaluating their performance. The research is anticipated to improve design methods and deep beam performance and safety in a range of construction contexts.

REVIEW OF LITERATURE

OVERVIEW

Deep beams, especially those with openings, are often used structural elements in offshore structures, foundation systems, and tall buildings; yet, there is a lack of research on their strength and behavior in the literature. In his experimental work titled "Behaviour of Fibre Reinforced Concrete Deep Beams," A. K. Sachan [21] tried to test 14 different types of concrete deep beams until they failed.

Examining the "Behavior and Performance of RC T-Section Deep Beams Externally Strengthened in Shear with GFRP Sheets," H. K. Lee [24] sought to answer this question. Experimental testing were conducted on fourteen RC T-section deep beams that were intentionally made to be shear deficient, with a shear span-to-effective depth ratio (a/d) of 1.22.

H. S. Kim [25] sought to characterize the behavior of deep reinforced concrete beams subjected to simultaneous axial and bending pressures in his experimental research, "Structural Behaviors of Deep RC Beams under Combined Axial and Bending Force."

We applied axial stresses of 235 kN and 470 kN to specimens with varying shear span-to-depth ratios. When subjected to increasing axial stresses, deep beams with a shear span-to-depth ratio of 0.5 showed a decreasing failure load.

Keun-Hyeok Yang used 21 beam specimens for his study, "Shear Characteristics of High Strength Concrete Deep Beams without Shear Reinforcements" [26]. The study found that beams with lower shear span-to-depth ratios and deeper depths were more likely to break in brittle ways, with big diagonal cracks and fast energy release rates because of size effects. High-strength concrete deep beams showed evidence of brittleness due to size effects.

M. R. Islam [27] examined six concrete deep beams in "Shear Strengthening of RC Deep Beams using Externally Bonded FRP Systems," with one serving as a control and the other five reinforced with carbon fiber grids, strips, and wraps. The results showed that the bonded FRP system decreased the propagation of key diagonal cracks and greatly improved the beams' load-bearing capability.

EXPERIMENTAL STUDY

Beam Casting

Dimensions of the Beam Here are the finalized beam dimensions according to Clause 29 of IS 456:2000: With dimensions of 1.2 m in length, 0.15 m in breadth, 0.46 m in depth, and 0.9 m in effective span, the dimensions are as follows. Following a 28-day curing period, the beam is tested utilizing three-point loading.

Specimen Casting (4.1.2)

The concrete mix proportions chosen for the experimental process were 1:2:4 for cement, fine aggregate, and coarse aggregate, respectively. To make sure everything was mixed evenly, a concrete mixer was used. A 28-day curing period is required after casting for the beam. To find the concrete's compressive strength, three cubes are also cast and evaluated after the same curing time.

Cement Casting Materials: This experiment makes use of Konark Cement's Portland Slag Cement. The specific gravity of the cement is 2.96 and it has been evaluated for physical qualities according to the criteria of the Indian Standard.

Fine Aggregate: Utilized is fine aggregate with a specific gravity of 2.67 that has passed through a 4.75 mm sieve. According to the standards laid out by the Indian Standard, the fine aggregate falls into Zone III.

Two types of coarse aggregate are used: one that passes through a 10 mm sieve and another that passes through a 20 mm sieve. When it comes to the coarse aggregates, their specific gravity is 2.72.

Water: For all of the concrete's proportions, regular tap water is utilized.

The Detailing of Reinforcements

The longitudinal reinforcement is made of High-Yield Strength Deformed bars with diameters of 12 mm and 8 mm, while the stirrups are 6 mm bars in diameter. Tightening the structure are two HYSD bars with a diameter of 12 mm. Furthermore, two HYSD bars with a diameter of 8 mm are included for use as hang-up bars. Figures 4.1(a) and 4.1(b) show the reinforcing details for the beam.



Reinforcement cage

GLASS FIBRES

A fiber-reinforced polymer, fiberglass is composed of a plastic matrix augmented with tiny glass fibers; alternative names for this material include glassfibre and glass-reinforced plastic (GRP).

Fiberglass is easy to work with in a variety of molding methods, and it has weight and bulk strength attributes that are preferable to metals. Glass fibers can have a thermoplastic matrix, a thermosetting matrix (often polyester or vinyl ester), or both. Fiberglass is widely used in many different things, including as boats, cars, water tanks, cladding, casts, pipelines, roofing, and exterior door skins. It is also great for spas and hot tubs.

Properties of Glass Fibres

Typical Properties	E-Glass	S-Glass
Density (g/cm ³)	2.60	2.50
Young's Modulus (GPa)	72	87
Tensile Strength (GPa)	1.72	2.53
Tensile Elongation (%)	2.4	2.9

FORM WORK

While concrete or a similar substance is curing, it is shaped and supported by formwork, which can be either temporary or permanent molds. The precise size and structural soundness of the deep beam depend on the formwork that was specifically built for it in this project. Figure 4.2 shows the formwork that was employed for this project. Formwork is designed and set up in this graphic representation, which emphasizes its role in supporting and shaping the concrete until it reaches an appropriate strength. In order to get the final concrete building to perform as expected, it is crucial to have formwork that is built correctly.



Fig.4.2 Deep beam frame

MIXING, COMPACTION AND CURING OF CONCRETE

To guarantee consistency in quality, concrete is mixed extensively using a mechanical mixer. After the mixture is combined, each specimen is compacted using a needle vibrator. It is important to avoid displacing the reinforcement cage within the formwork during this process. Following compaction, a metal trowel and wooden float are used to level and smooth the concrete surface, resulting in a fine finish.

Concrete must be allowed to cure in order to retain moisture, which is necessary for hydration and, by extension, for the concrete to harden. Curing concrete properly also shields it from drying winds and high temperatures, which can cause it to lose moisture quickly and experience contraction strains before it's ready. To cure the concrete for this job, we sprayed water onto jute bags and placed them over the top of the slab. We left the bags wet for 14 days. This technique keeps the concrete well-hydrated, which is essential for its strength development and longevity.

STNGTHENING OF BEAMS

Before bonding the fibers, roughen the concrete surface with coarse sandpaper and thoroughly clean it with an air blower to remove any dust or dirt. Following the manufacturer's directions, mix Araldite LY 556 (100% by weight) and Hardener HY 951 (10% by weight) in a plastic container to prepare the epoxy resin. After thoroughly mixing the epoxy and hardener, apply the epoxy resin to the concrete surface. Next, we trim the textiles to size. After applying the GFRP sheet on top of the epoxy coating, a roller presses

the resin into the fabric roving. This process ensures that there are no air bubbles between the concrete and fabric or epoxy.

We apply consistent and uniform pressure to the composite surface while the epoxy cures to remove excess resin, ensure proper contact between the fabric, concrete, and epoxy, and complete the job. We maintain room temperature throughout the entire operation. We leave the glass fiber-reinforced concrete beams to cure at room temperature for 24 hours before testing.

A TEST SETUP

The "Structural Engineering" Laboratory at the National Institute of Technology, Rourkela uses a loading frame to test deep beams with holes. Every specimen follows the same testing protocol. We give the beams a thorough sanding after they have cured for 28 days to reveal any hidden surface flaws during testing. Beam testing typically makes use of a single-point loading configuration.

At the beam's midpoint, a load cell and spherical seats transfer the load. We positioned the specimens 150 mm away from the bearing edge of the two steel rollers.

respective beam ends. There is a single dial gauge installed in the beam's center that records the deflection.

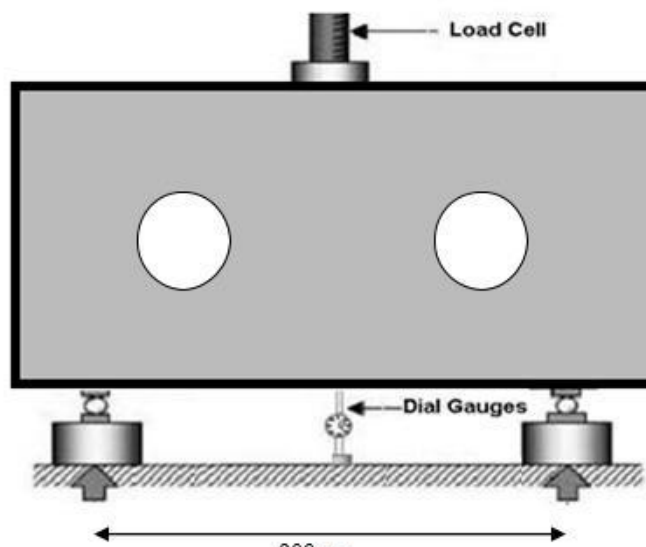


Fig.4.3 Experimental setup

FABRICATION OF GFRP PLATE

Hand lay-up and spray-up are the two main techniques for shaping FRP (fiberglass-reinforced plastic). For FRP boats, the most common and time-honored form of manufacture is hand lay-up. Here, glass fibers are placed to a completed surface with liquid resin. The material is made both strong and lightweight by the resin's chemical reaction, which hardens it. The resin here works as a matrix that bonds the glass fibers, just like concrete does for steel reinforcing rods.

- The following submaterials were employed in the plate fabrication process:
- The composite material is strengthened and reinforced with glass fiber.
- Epoxy is the resin that binds the glass fibers together; it's like a matrix.
- A catalyst that helps the epoxy resin cure faster is the hardener, often known as diamine.
- To make sure the moulded plates can be taken out of the moulds without sticking, polyvinyl alcohol is used as a release agent.
- After going through the manual lay-up process, these elements are mixed to form a long-lasting and versatile FRP product.

To begin the laminating process, a mixture of epoxy and hardener was brushed into the mold to form a gel layer. The main goal of applying this gel coat is to shield the fibers from the weather and create a smooth exterior. During this application, a steel roller was utilized to remove any air bubbles.

After the gel coat was applied, reinforcement layers were added and more gel coat was brushed on. The gel coat was hand-laid until it started to harden. The next step was to apply a second plastic sheet that had been coated with polyvinyl alcohol to act as a release agent. After that, the plate was compressed by placing a hefty, flat, and rigid metal platform on top of it. After at least 48 hours of curing, the plates were transported and precisely cut to test specifications.

Two distinct designs of closely spaced layers of glass fiber were employed in the casting of the plates. One utilized two layers, while the other utilized four layers. Further specimens were generated for testing with 2 layers and 4 layers with wider spacing. Using this method, we were able to compare the plates' mechanical properties.

Table4.2 Size of the specimens for tensile test

No. of layers	Length (cm)	Width (cm)	Thickness (cm)
2(closely spaced)	15	2.3	0.1
4(closely spaced)	15	2.3	0.25
2(largely spaced)	15	2.3	0.3

No. of layers	Length (cm)	Width (cm)	Thickness (cm)
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4(closely spaced)	15	2.3	0.25
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2(largely spaced)	15	2.3	0.3

DETERMINATION OF ULTIMATE STRESS, ULTIMATE LOAD AND YOUNG'S MODULUS

Our specimens underwent a unidirectional tensile test to determine their ultimate stress, ultimate load, and Young's modulus. In Table 4.2, you can find the specimen dimensions in both the longitudinal and transverse cutting orientations. The specimens underwent a polishing process to achieve a flawless finish following their hex saw cutting. The method of cutting could have made use of a hex saw or a diamond cutter.

We used an INSTRON 1195 universal tensile test equipment to extend the specimens at a preset pace and load them until we could no longer calculate the Young's modulus. We first firmly grasped the specimens in the upper jaw of the machine, then moved them to the adjustable lower jaw for a more precise grip. To avoid slippage, it was crucial to measure 50 mm from both sides. The strain started out at zero. During the test, a digital extensometer measured the length of the object, and a load cell assessed the load.

A stress-versus-strain graph was drawn from the data set, with the Young's modulus value provided by the graph's beginning slope. The specimens' failure points were used to determine the ultimate stress and load. According to Table 4.3, which summarizes the main results of the tensile testing technique, the average values for each layer of the specimens examined are displayed.

Table 4.3 Result of the specimens

No.of layers of the specimen	Ultimate stress (MPa)	Ultimate Load (N)	Young's modulus(MPa)
2 Layers(closely spaced)	172.79	6200	6829.9
4 Layers(closely spaced)	209.09	9200	7788.5
2 Layers(largely spaced)	268.6	30890	6158
4 Layers(largely spaced)	271.48	31221	6224.02

4.10 TESTING OF BEAMS

In a sequential test, four of the five beams had fiber-reinforced polymer (FRP) reinforcements, while the fifth beam served as a control without FRP. The testing configuration was identical for all beams. Continuous monitoring of deformation and strain gauge readings occurred throughout the tests, which involved a progressive increase of the load. The readings from the dial gauge allowed for the measuring of the deformation in real-time.

The cracking load was defined as the load at which the crack exhibited its first apparent manifestation. After this realization, the load was increased until the beam finally snapped. Both the GFRP and non-GFRP beams' midpoint deflections were measured and recorded in proportion to the rising load. The appropriate data is shown in the table.

In Chapter 6, we go further into the data gathered from these tests and develop conclusions about the beams' behavior and performance under stress based on what we uncover.

4.10.1 Beam No.1 (Control Beam)



Fig. 4.7 Deep Beam specimen for testing





Fig. 4.8(a) Specimen showing the crack pattern (front)

RESULTS AND DISCUSSIONS

6.1 INTRODUCTION

In this section, we decipher and examine the experimental data for every beam using different kinds of GFRP stacking. We utilize collected data on deflection behavior and ultimate load-carrying capacity to characterize the testing behavior of each beam. We also describe the possible failure situations and crack patterns for each beam in this section. We tested all beams, using Beam-1 as the control beam, to determine their ultimate strengths.

Compared to the beams strengthened externally with GFRP sheets, the control beam had a lower load-carrying capability. A variety of GFRP sheets, applied in varied patterns at clear shear spans, reinforced the other beams, with the exception of the control beam. We used a closely spaced four-layer U-wrap of GFRP to reinforce Beam-3, and a similarly spaced double-layer U-wrap to reinforce Beam-2. We reinforced Beam-5 with a four-layer full wrap of GFRP, generally spacing the layers, and Beam-4 with a double-layer full wrap, mostly spacing the layers. This systematic strengthening approach allows for an in-depth analysis of how different GFRP designs affect the beams' performance.

CONCLUSIONS

7.1 CONCLUSIONS

The current experiment we are doing looks at how shear acts on reinforced concrete (RC) deep beams that have glass fiber reinforced plastic (GFRP) sheet reinforcements built in as holes. We designed all five of the cast RC deep beams to be shear weak, sharing identical reinforcement features, and subjecting them to three-point loading. The calculated strength values allow us to draw several significant conclusions:

Compared to the control beam, the ultimate load-carrying capability of each of the reinforced beams was much higher.

The strengthened beams showed improved performance under loading conditions when the first shear cracks appeared at higher loads.

Beam 3, reinforced with a four-layer (closely spaced) GFRP U-wrap, outperformed Beam 2, which utilized a double-layer (closely spaced) GFRP U-wrap, in terms of load-carrying capabilities.

Beam 5, reinforced with a four-layer full-wrap of GFRP (primarily spaced), showed a higher load-carrying capability than Beam 4, which was reinforced with a double-layer full-wrap of GFRP (largely spaced).

The data showed that applying GFRP in tightly spaced configurations, as opposed to widely separated arrangements, best achieved the load-carrying capability.

At lower load values, the experimental results and the deflection predictions made by the ANSYS models agreed well. Disagreements became more noticeable at higher load values due to the use of a linear finite element model in the ANSYS simulations.

Purpose of Future Projects

Future research could focus on potential areas such as:

One method to reinforce deep beams with holes is to use carbon fiber-reinforced polymer or another kind of FRP.

We are examining the shear behavior of deep beams with holes punched into them at various angles.

We are devising strategies to avert debonding by anchoring the FRP beams with steel plates.

These avenues offer promising new directions for studying GFRP's application to deep beam structural reinforcement.

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