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A Study on Structural Failures and Corrective Actions

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Abstract: In the beginning, man lived in shelters made from the abundant natural resources at hand. They learned where to construct their tents to avoid the effects of natural disasters. In the event of a breakdown, they may be fixed using only naturally occurring, low-cost components. Yet, as the world's population rises and new construction techniques emerge, it becomes crucial to understand why certain buildings have structural problems and what can be done to fix them. Materials used in engineering construction may deteriorate over time for a number of reasons, leading to structural failures. This study examines the causes of structural failures such as bad planning, low-quality materials, sloppy construction, bad luck, and extreme weather. Also covered are the different approaches to carrying out the necessary repairs, commonly known as corrective actions.

Keywords: Monuments, Natural Calamities, Engineering Construction, Building.

1. Introduction

Apart for a few of notable landmarks like the TajMahal, the KutubMinar, the Great Wall of China, the White House, etc., all civil buildings are prone to failures in one form or another at some point in time. There are two main categories for construction failures. Both visual and non-physical breakdowns qualify as structural failures. [1]

When buildings suffer structural damage, it not only compromises their integrity but also endangers the lives of the people within. For a concrete structure to be considered structurally flawed, it must fail to provide its intended function. Defects in the brickwork, plasterwork, plumbing, electrical, etc. that do not pose a significant threat to the safety of the building are considered nonstructural failures. [2-3]

Buildings have been falling apart since at least 300 A.D. and the trend shows no signs of stopping. In Figure, we see a towering building in Oogue, Siberia, divided vertically in half. The World Trade Center in New York City is another structure that was destroyed by an accident. As reinforced cement concrete is so long-lasting, it has been used for decades to construct everything from homes to bridges, highways to bridges, and so on. Concrete buildings that are well-planned and constructed with high-quality materials seldom need extensive upkeep or fixing. As a consequence of a severe housing scarcity in the 1960s, concrete's popularity soared. Concrete's poor performance may be attributed to its heterogeneity and the fact that the quality of the material varies depending on its constituent parts. The rising cost of maintenance and repair over the last several years has caused a noticeable shift in the investment for restoration against new construction.[4-6]

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Reinforced concrete beams that have been exposed to repetitive loads are a topic of interest in the area of repair. Rehabilitation treatments have several benefits, including restoring the concrete's strength and functional efficiency, making it watertight, and enhancing its aesthetics. The need for cutting-edge infrastructural support has prompted the introduction of novel, cutting-edge materials and methods. [7-8]

You can't expect perfection from any tool or substance. New technologies will need to be developed and implemented in order to fulfill the expanded roles. Materials used in engineering construction may deteriorate over time for a number of reasons, leading to structural failures. Understanding the issue and finding a solution requires knowledge of the numerous agencies contributing to degradation. Concrete, as we all know, has risen in importance as a construction material in recent years. By paying more attention during design and monitoring, we civil engineers may reduce the frequency and severity of building failures. Although natural processes like weathering and environmental consequences are beyond our control, we may mitigate their impact via technological advancements. [9-10]

2. Material and Methods

The IS Code guides the selection of materials for casting beam.

Cement

These samples were made using OPC 43 cement, which is standard as per IS 8112 -1969. The following tests were performed in accordance with IS: 460 - 1962 to ensure conformance.

Cement Modulus of Fineness, Cement Density (SG), Cement consistency, Early Contextualization Lag, Time of Last Sunset.

Fine Aggregate

This sample's fine aggregate has been put through its paces. The conformance was examined by the following tests are Fine Aggregate Density (SG), Fine Aggregate's Capacity to Soak Up Water, Fineness Modulus in Percentage.

Coarse Aggregate

This sample of coarse aggregate was put through rigorous testing.

The conformance was examined by the following tests:

- Specific Gravity of 20mm Aggregate
- 20mm Aggregate Specific Weight
- Aggregate Size Distribution
- Soaking up liquids
- Indicator of Flakiness
- Index of Prolongedness

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- Affect Aggregate Worth.

Steel

Steel's Young's modulus is measured using a tension test performed in accordance with IS:800.

- **Rehabilitation Materials**

The structural part is rehabilitated using five different techniques (beam). The wrapping techniques require four GFRP. Steel jacketing is the sixth strategy. According to our distributors, all four GFRP Standards are met. IS: 800 standard steel.

- **Specimen Preparation**

The beam's span is 1500mm, and its dimension is 150mm x 200mm. M25 grade concrete and Fe415 TMT bars were used in this project. The beam's water-cement ratio is 0.4, and it was cast using OPC 43 grade cement. Tensile and compressive forces Two dozen 12mm diameter reinforcing rods are supplied, with a single 8mm diameter shear rod placed at a center-to-center spacing of 100mm. Two legs, each 35 millimeters in length, provide shear reinforcement. Figure depicts a typical beam specimen's cross section, whereas Figure depicts the beam's size, reinforcing details, and longitudinal section.

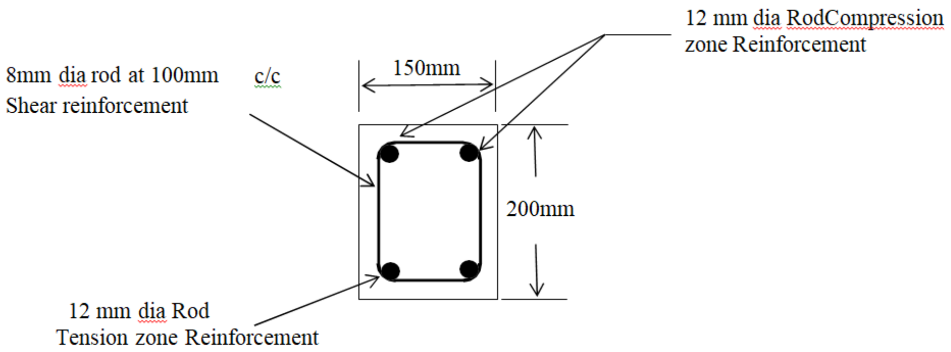

Figure 1: Beam's Radial Cross-Section

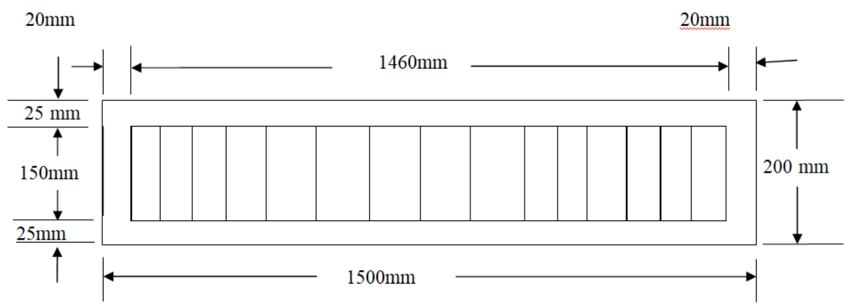

Figure 2: Beam Section along Its Long axis

Testing

Wrapping them with GFRP (225GSM, 400GSM, 300CSM, and Jute Fiber) and steel

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jacketing were the main components of their rehabilitation. When repairs were made, the beams were put through their paces until they failed. In order to verify the accuracy of the experimental results, the ultimate load determined during the experiment is compared with the theoretical calculation performed for the control specimen using the clauses specified in the IS 456-2000 code. The five Retrofitting Techniques were tested, and the results were compared to the Control Specimen in terms of Ultimate Load Carrying Capacity or Deflections at that Load. The conclusion was derived from the findings.

3. Results

Beam moulds of the appropriate size were made to prepare the specimens for this investigation. Three of the beams were saved as reference standards. There are a total of five treatments used, and three beams each treatment. therefore completely A total of 18 beams were cast.

Specimen Detail

Data about the size and shape of the specimen Here are both cross-sectional and longitudinal specifications.

Specimen Detail

The beam's span is 1500mm, and its dimension is 150mm x 200mm. M25 grade concrete and Fe415 TMT bars were used in this project. The beam's water-cement ratio is 0.4, and it was cast using OPC 43 grade cement. Tensile and compressive forces Two rods, each 12mm in diameter, serve as tension reinforcement, while a third, 8mm in diameter, serves as shear reinforcement at a center-to-center spacing of 100mm. Two legs, each 35 millimeters in length, provide shear reinforcement. The specimen data was tabulated below.

Table 1: Specimen Information

Depth	200mm
Width	150mm
Length	1500mm
TensionRod	2No.sof12mmDia.
CompressionRod	2No.sof12mmDia.
ShearRod	8mmDia.rod@100mmc/cdistance
NoofLegs	2Legged(35mmlength)
W/cRatio	0.4
CementGrade	OPC43
ConcreteGrade	M25(Designmix)1:1.8:2.6
SteelGrade	Fe415
CoveronXAxis	20mm
CoveronYAxis	25mm

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Flexural Member Design Requirements

The beams were reinforced in accordance with clause 26.5.1 of the IS 456-2000 code, which specifies the limit state of the design approach to be used. The beam size 150mm X 200mm with a span of 1500mm has been nominally reinforced and evaluated for safety per the requirement. Steel Grade Fe415 is utilized for tension, compression, and shear reinforcement of the beam, and design mix concrete is used for the concrete.

Reinforcement under Stress:

In paragraph, the minimum area of steel necessary for tension reinforcement is specified, and calculations show that this value is 51.92mm2. In addition, specifies 1200mm2 as the maximum allowable steel area. As a result, the area of the stress reinforcement given is 226.19mm2, which corresponds to 2 numbers of 12 mm dia. bar. Hence, the area of steel in the reinforcement given is more than the minimum area of steel called for, but less than the maximum area of steel called for.

Strengthening Under Compression:

The clause 26.5.1.2 specifies 1200mm2 as the maximum area of steel needed for compression reinforcement. Thus, the given compression reinforcement consists of 2 sets of 12mm dia. bar, for a total steel area of 226.19mm2, which is less than the maximum area of steel allowed. Hence, the requirements of IS 456-2000 clause 26.5.1.2 were met.

Spacing and Reinforcement for Shear

According to the formula, the minimum area of steel needed to meet the shear reinforcement requirements set out in clause 26.5.1.6 of IS 456-2000 is 16.62mm2. Bars with a diameter of 8 millimeters and an area of 50.26 millimeter squared were supplied to meet the minimum steel area requirement for shear reinforcement.

According to clause 26.5.1.5 of IS 456-2000, the minimum distance between shear rods must be 126.75mm and the maximum distance between shear rods must not exceed 300mm. As a result, the 100mm c/c distance that has been specified is enough.

- **Controlled Experimental Study**

The ultimate load is determined by first testing controlled specimens. The findings of all the tests performed on the control samples are summarized in Table.NThe results of the Control Specimen Tests Might Be Expressed As:

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Table 2: The Outcomes of the Control Sample Tests

Sl.No	Specimen	InitialCrackingLoad	Average	Deflection	Average	Ultimate Load	Average	Deflection	Average
1	Specimen1	52		5.6		65		14.2	
2	Specimen2	53		5.0		65		14.1	
3	Specimen3	54	53	5.3	5.3	66	65.33	14.0	14.15

The beam has a mean ultimate load bearing capability of 65.33kN. By comparing the theoretical energy of the beam (calculated at 61.60kN) to the actual value, the experimental value is found to be 6% higher. Figure shows the plotted Load vs. Deflection curve for the control Specimen.

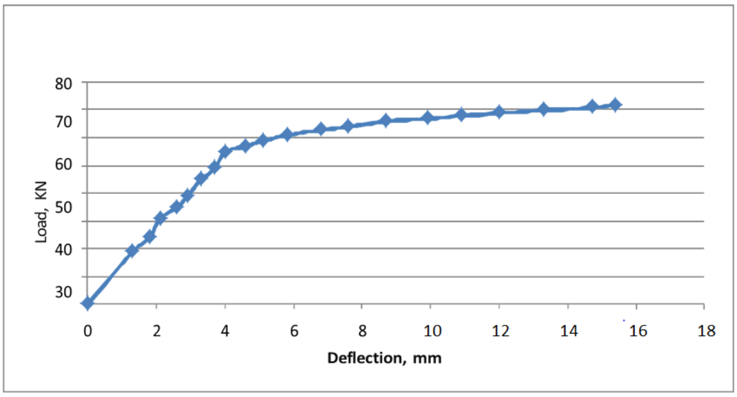

Figure 3: Load-versus-deflection plot - standard specimen

- **Rehabilitation Methods**

Our flexural member may be rehabilitated using five different techniques. In other words, they are three beams were tested each procedure, and the average was determined..

1. Method-1: GFRP Woven Roving–225GSM

GFRP Woven Roving - 225 GSM was used in the rehabilitation process, and three sets of beams were loaded until the first fracture appeared. The polyester resin is the best. The aforementioned work has been wrapped around the beam from end to end. After that, the specimen is cured for a full day. The beams' final load capability is determined after they have cured. Table displays the tabulated results of these analyses.

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Table 3: Data from controlled experiments on specimens restored using 225GSM GFRP woven roving

Sl.No	Specimen	Deflection(mm)	Average(mm)	UltimateLoad(kN)	Average(kN)	Deflection(mm)	Average(mm)
1	Specimen4	5.1	4.7	74	72	15.3	15.4
2	Specimen5	4.4		70		15.4	
3	Specimen6	4.7		72		15.4	

The restored beam can support 72kN, but the control Specimen can only handle 65.33kN. The restored beam has a 10.2% higher maximum load compared to the control Beam.

The ultimate load bearing capacity of the restored beam is 10.2 percentage points higher than that of the control Specimen, while the deflection is only 0.9 percentage points higher (1.27 mm) than that of the control Specimen.

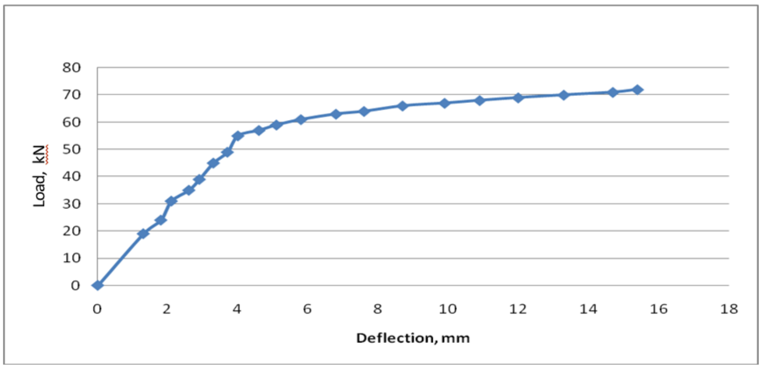

Figure 4: 225GSM GFRP Woven Roving Load Deflection Curve After Rehabilitation

2. Method-2:GFRPWovenRoving–400GSM

Beam rehabilitation begins with loading up to the point of the first crack, at which point the beam is unloaded and the rehabilitation process begins.Glass fiber reinforced polymer (E-Class glass fiber with 400 GSM) is used for rehabilitation of the beam after loading was halted due to the appearance of the first cracking load. The glass fiber is wrapped around the whole beam member.After curing for 24 hours, the maximum load of the beam is determined. Table summarizes the results.

Mathematical Statistician and Engineering Applications
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Table 4: Details of GFRP Woven Roving 400GSM Samples Rehabilitation Experiments

Sl.No	Specimen	Deflection(mm)	Average(mm)	Ultimate Load(kN)	Average(kN)	Deflection(mm)	Average(mm)
1	Specimen7	4.9	4.8	83	85.67	13.7	16.7
2	Specimen8	4.8		89		19.8	
3	Specimen9	4.7		85		16.7	

The restored beam has a mean ultimate load of 85.67kN. There is an increase of 20.33Kn, or 31%, in the ultimate load bearing capability of the beam as compared to the controlled specimen.

The deflection of the refurbished beam is 16.73 millimeters, which is 2.63 millimeters more than the deflection of the control Specimen. Thus, the repaired beam has an increased deflection of 18% and a load capacity of 31% compared to the control specimen. The restored beam's load-versus-deflection graph is shown in Figure.

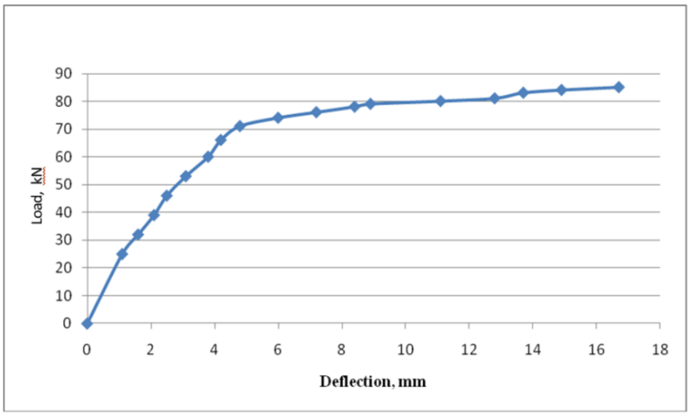

Figure 5: Load vs deflection curve after GFRP woven roving 400GSM rehabilitation.

3. Method–3:GFRPChoppedStrandMat–300GSM

The rehabilitation process involves loading the beam until the first fracture emerges. As soon as the beam showed signs of cracking, the weight was removed. E-Class Glass Fiber Reinforced Polymer, chopped strands mat 300 GSM is used to repair the beam after it has developed cracks.

When the GFRP has been covered, polyester resin is put on top, and the beam is allowed for 24 hours to cure. The beam's final load capacity is determined after curing is complete. Table displays the outcomes of the tests performed.

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Table 5: Data from controlled experiments on specimens treated with GFRP Chopped Strand Mat 300 GSM

Sl.No	Specimen	Deflection(mm)	Average (mm)	Ultimate Load(kN)	Average (kN)	Deflection(mm)	Average (mm)
1	Specimen10	4.7		70		13.7	
2	Specimen11	3.8		72		13.6	
3	Specimen12	4.3	4.27	71	71	12.5	13.27

Rehabilitated individuals, on average, have an ultimate load of 71kN. For the standard Specimen, the maximum load is calculated to be 65.33kN. This comparison allowed the improved ultimate load bearing capacity of the beam to be calculated, which was found to be 5.67kN. As a result, the strengthened beam can support 9 percent more weight than the reference specimen.

Rehabilitated beams had less deflection when compared to both the controlled and rehabilitated beams. The beam's deflection was decreased by 0.83 mm after rehabilitation, from 14.1 mm in the controlled beam to 13.27 mm in the rehabilitated beam. Figure shows a graph of load versus deflection.

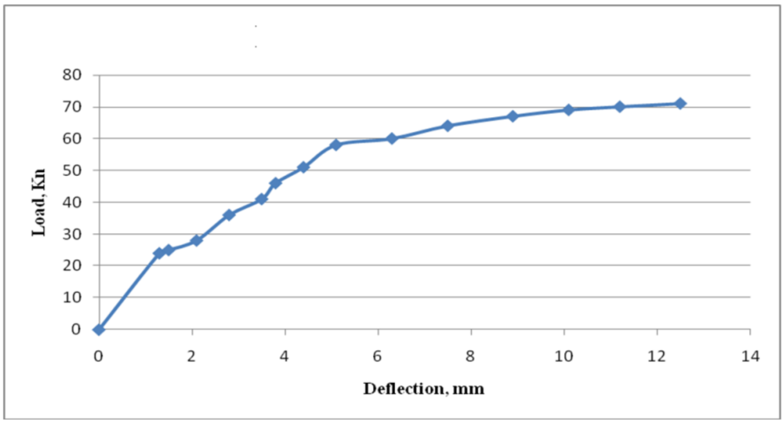

Figure 6:Curve of Load against Deflection after Rehabilitation with 300 GSM GFRP Chopped Strand Mat

4. Method–4:JuteFiber

In order to determine whether or not the beam needs repair, it is subjected to a load until the first fracture emerges. When the first fracture emerges in the beam, the weight is immediately removed. Afterwards, jute fiber is used to complete the restoration process.

Polyester resin is often used for bonding. For curing or hardening purposes, the beam is permitted to sit for 24 hours after application.

Table 6: Rehabilitating Specimens with Jute Fiber: Experimental Details

Sl.No	Specimen	Deflection (mm)	Average(mm)	Ultimate Load(kN)	Average (kN)	Deflection(mm)	Average (mm)
1	Specimen13	4.8	4.93	67	68.33	12.3	12.43
2	Specimen14	5.1		70		13.0	
3	Specimen15	4.9		68		12.0	

The ultimate load of the restored beam is higher than that of the controlled beam. The control specimen's load bearing capability was improved by just 3kN, hence the load increase seems to be negligible. Since the additional ultimate load is just 5% above the regulated beam.

Nevertheless, the deflection is much less in the restored beam than in the controlled beam; whereas the deflection in the control Specimen was 14.1 mm, it was only 12.43 mm in the rehabilitated beam, a reduction of 1.67 mm. As a result, the repaired beam had 14% less deflection than the control Beam. Figure also displays a graph of load vs deflection for the repaired beam.

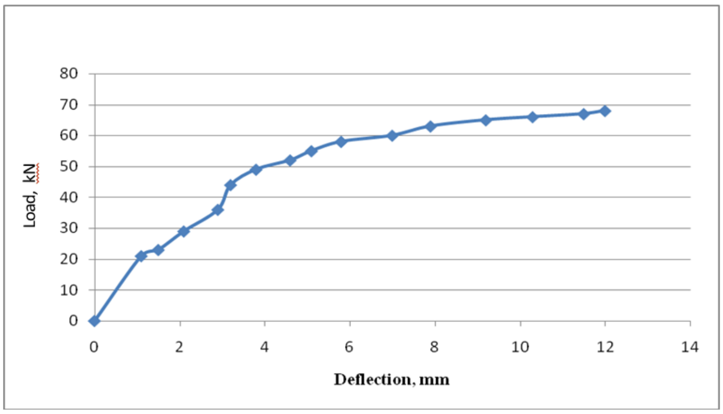

Figure 7: Curve of Load vs Deflection after Jute Fiber Restoration

5. Method–5: Steel Jacketing Method

The cracking load of the beam is first determined, as it is with all other procedures, and then the beam is rehabilitated. As the first break showed up, work halted and steel was used to restore the beam. In this process, steel is employed as a jacket. After repairs have been made, the beam's capacity will be determined. Table displays the measured data from the tests.

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Table 7: Specifics of our experimental work with rehabilitated specimens using the steel-jacketing technique

Sl. No	Specimen	Deflection (mm)	Average (mm)	Ultimate Load(kN)	Average (kN)	Deflection (mm)	Average (mm)
1	Specimen16	5.2	4.73	110	111	12.3	11.9
2	Specimen17	4.8		112		11.6	
3	Specimen18	4.8		111		11.8	

The restored beam has a maximum allowable load of 111kN. The regulated beam can only support a maximum weight of 65.33kN. There is an increase of 44.67Kn in the rehabilitated beam's load bearing capability when compared to the controlled beam's ultimate load. As a result, the load's carrying capacity is boosted by 70% compared to the regulated beam.

The Figure compares the ultimate load & deflection of the controlled beam to those of the repaired beam. Compared to the 14.1mm deflection of the control Specimen, the 11.9mm deflection of the restored beam represents an improvement. The beam's deflection was decreased from 3.2mm to 2.2mm after rehabilitation, an improvement of 16% compared to the control Condition. Figure displays the load vs deflection curve for the repaired beam.

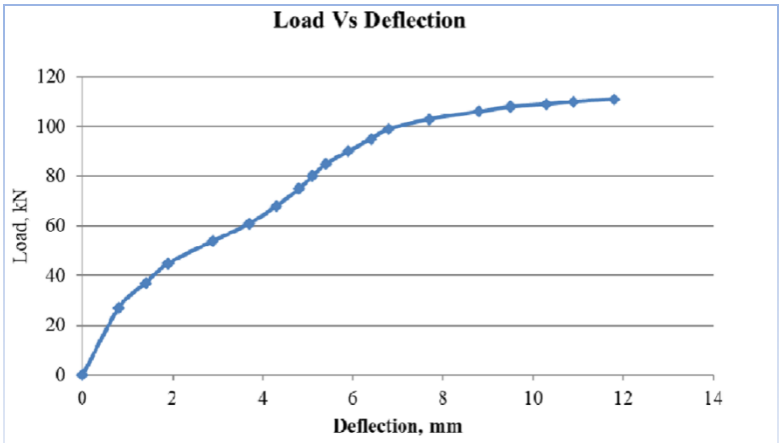

Figure 8: Curve of Load vs Deflection After Steel Jacketing Rehabilitation

- **Analysis of Rehabilitated Beams' Maximum Allowable Loads Based on Different Wrapping Methods**

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Each method of wrapping the restored beam is evaluated based on its final load bearing capability. Glass-Fiber-Reinforced Polymer is utilized in this project for the wrapping methods, and Jute Fiber is the major material. Glass fiber uses several different types of GSM, but all of them are in the Class "E" range. The data clearly shows that the mat made from Glass Fiber Reinforced Polymer - Woven Roving 400 GSM significantly increases the ultimate load bearing capability of the beam. The GFRP - WR - 400 GSM mat has a 31% higher load bearing capability than the controlled beam.

The Effect of Wrapping on the Deflection of Restored Beams

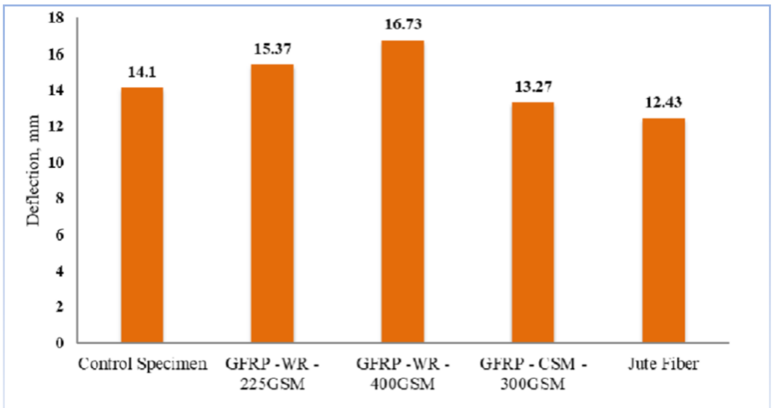

Figure 9: Wrapping Method Deflection: A Comparative.

The accompanying diagram displays the deflection performance of the repaired beam. As compared to other fiber materials, jute fiber performs very well in deflection control. Glass fiber outperforms jute fiber in terms of load bearing; however jute fiber is the only material capable of regulating deflection. As compared to the regulated beam, the jute fiber reduces deflection by 14%. Deflection is not decreased when utilizing glass fiber woven roving material; however it is reduced by 7% when using Chopped Strand Mat. There is merely a 50% decrease in the effectiveness of the jute fiber substance. The pliability of glass fibers is responsible for this property. While both glass fiber and jute fiber can withstand stress, jute fiber is not ductile. In this way, jute fiber is not much more durable than glass fiber, but its deflection may be better managed. As compared to other glass fibers, GFRP - Chopped Strand Mat's deflection of the beam is reduced since the fiber runs in all directions.

4. Conclusion

The results of the GFRP 225 GSM Rehabilitation study are in. The average load required to cause cracking in the control beams is 65.33kN. GFRP 225 GSM has an average Ultimate load rehabilitation value of 72kN. There is a 10% boost to the maximum load. The 9.7 percentage point increase in deflection translates to 15.37mm. Recovery 6.4% Using GFRP 400 GSM The average cracking load for the control beams is 65.33kN. Ultimate load is often calculated to be 85.67kN using this approach. Overall, the burden is 31% higher. Nevertheless, the deflection is now 18.1% larger at 16.73mm. Restoring Function with GFRP 300 GSM The average cracking load for the control beams is 65.33kN. Nonetheless, the typical Maximum load with this technique is 71kN. There is a nine percent rise in the total

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load. The initial deflection of 13.27mm is now just 0.83mm. 6.8 Healing Using Jute Fiber The average load required to cause cracking in the control beams is 65.33kN. Maximum load, on the other hand, averages out to 68.33kN using this technique. The maximum load is now 5% higher. Nonetheless, this has resulted in a 14% drop in deflection, to a mere 12.43mm. 6.7 Steel-Jacketed Technique of Rehab the average load required to cause cracking in the control beams is 65.33kN. Nonetheless, the typical Maximum load with this technique is 111kN. There is a 70 percent increase in the maximum allowable load, and a 16 percent reduction in deflection to 11.9 mm.

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