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STRENGTHENING OF CYLINDRICAL CONCRETE SPECIMENS USING CFRP SHEETS

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ABSTRACT:
FRP materials provide lightweight, corrosion-resistant alternatives for infrastructure and aerospace, enhancing sustainability. CFRP (carbon fiber reinforced polymer) sheets, featuring carbon fiber and epoxy resin, offer high strength and stiffness, extensively used in reinforcing concrete structures. Widely applied in civil engineering, aerospace, and automotive sectors, CFRP sheets ensure superior performance, particularly in repair and rehabilitation projects.

The present study is conducted on how a deteriorated concrete regains its strength when CFRP sheets wrapped around.Cylinder specimens were used for this experiment. the weight of the specimens has been recorded. The compressive strengths of the specimens were assessed using rebound Hammer (NDT Test). The 12-cylinder specimens were split into two halves of 6 specimens each and one half is tested in the UTM machine for their respective compressive strengths. After that cleaning all the specimens with sand paper and apply the epoxy resin on the specimens. cut the CFRP sheets and apply them on the concrete after curing test the specimens again.

KEYWORDS: CFRP sheets, Adhesive, Strength re-gaining ratio.

1.INTRODUCTION:

Strengthening of concrete using FRP (Fiber-Reinforced Polymer) sheets involves applying layers of composite material made of fibers (such as carbon, glass, or aramid) embedded in a polymer matrix to enhance the structural performance of existing concrete structures. FRP sheets can improve the strength, stiffness, and durability of concrete elements, providing a cost-effective solution for reinforcing and rehabilitating deteriorated or underperforming structures. The process typically includes surface preparation, application of adhesive, and affixing the FRP sheets to the concrete surface, resulting in a stronger and more resilient structure.

Strengthening of concrete using Fiber Reinforced Polymer (FRP) sheets is a widely adopted technique in the field of civil engineering. FRP sheets are composed of high-strength fibers, such as glass, carbon, or aramid, embedded in a polymer matrix, typically epoxy resin. When applied to the surface of concrete structures, these FRP sheets enhance the structural performance and durability of the elements.

Uses of FRP sheets:
1.Increased strength and durability of concrete structures.
2.Reduced maintenance and repair costs.
3.Improved fire resistance and safety.
Types of FRP sheets:
Fiber-Reinforced Polymer (FRP) sheets come in various types, each with specific properties and applications based on the type of fiber used and the polymer matrix. The main types of FRP sheets include:

1. **Carbon Fiber-Reinforced Polymer (CFRP) Sheets.**
2. Glass Fiber-Reinforced Polymer (GFRP) Sheets.
3. Aramid Fiber-Reinforced Polymer (AFRP) Sheets.
4. Basalt Fiber-Reinforced Polymer (BFRP) Sheets.
5. Hybrid Fiber-Reinforced Polymer Sheets.

2.OBJECTIVES:
1.To develop the Experimental Analysis using carbon fiber-reinforced polymer (CFRP) sheets to strengthen reinforced concrete.
2.To develop a cost-effective and efficient methodology for applying FRP sheets to improve strengthening techniques for RCC buildings.
3.METHODOLOGY:
3.1Data collection:
After the collection of data about different types of FRP sheets, Ultimately CFRP is one of the best FRP sheet that's available in the market.
Properties of the CFRP sheet are mentioned below:

- CFRP sheets are made of carbon fibers embedded in a polymer matrix, typically epoxy.
- Carbon fibers provide excellent tensile strength, stiffness, and resistance to high temperatures.
- CFRP also has a high resistance to being deformed without permanent effects, Also has resistance to tension
- It also has low thermal conductivity.

CFRP sheets are commonly used for strengthening and rehabilitating structures due to their high strength-to-weight ratio.
3.2Material collection:
1.Carbon Fiber Reinforced Polymer (CFRP) sheets are a game-changer in the world of construction and engineering. Made from carbon fibers mixed with a special type of resin, these sheets are incredibly strong and versatile. This introduction aims to explore the essence of CFRP sheets, their various applications, and their crucial role in repair and rehabilitation projects.
One of the most significant roles of CFRP sheets is in repair and rehabilitation projects. When structures become damaged or weakened over time, CFRP sheets can be applied to strengthen and restore them to their original condition. By strategically bonding CFRP sheets to compromised surfaces, engineers can enhance load-bearing capacities, fortify against environmental challenges, and extend the lifespan of structures. This makes CFRP sheets invaluable in maintaining and prolonging the service life of infrastructure assets.
CFRP sheets represent a revolutionary material in construction and engineering, offering unmatched strength, versatility, and durability. Their usage spans various industries, and their role in repair and rehabilitation projects is crucial for ensuring the longevity and safety of structures worldwide.
2.12 Nos of 100 mm dia. x 200 mm ht. cylinder specimens were used for this experiment.
3. Epoxy resin used as an adhesive for the application of CFRP to the concrete specimen.

Fig 1 Specimens

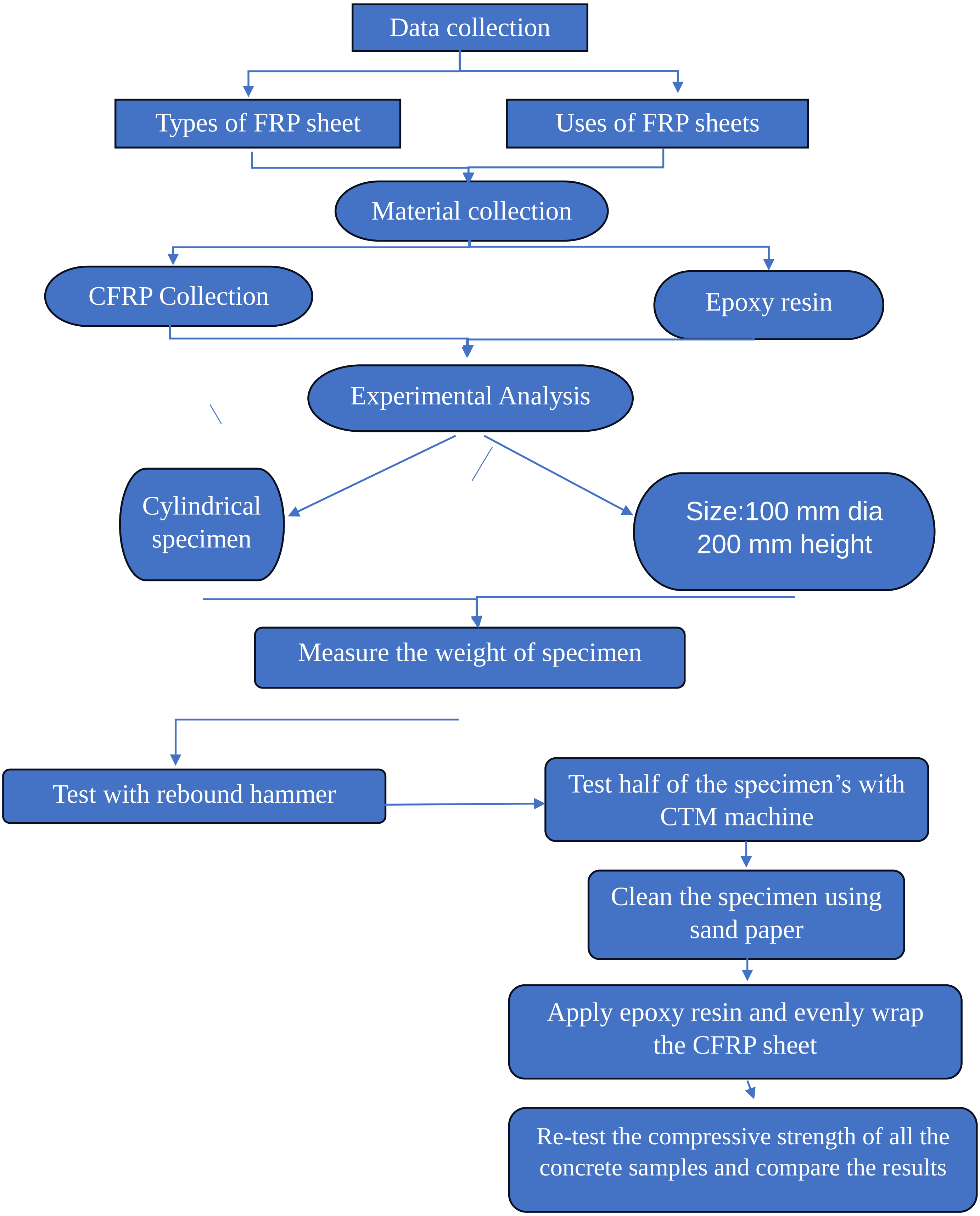

Fig 2 Step by step process of methodology

4. Results & Discussions:

4.1 Weight Assessment:

After Collecting the 12 random specimens, we recorded the unit weight of each sample by weighing machine and noted the weights of the specimens.

Fig 3 weight assessment

4.2 NDT Testing:

Rebound Hammer test is a Non-destructive testing method of concrete which provide a convenient and rapid indication of the compressive strength of the concrete. The rebound hammer is also called as Schmidt hammer that consist of a spring-controlled mass that slides on a plunger within a tubular housing. rebound hammer is used to test the strength of the specimens. each specimen is tested three times and took the average strength value.

Fig 4strength test using rebound hammer

4.3 Strength test using CTM (Compression Testing Machine):

1.After recording the compressive strengths of specimen using rebound hammer, again the specimens are tested by using CTM (Compression Testing Machine) to break the concrete samples.

2.After testing with CTM we recorded the strength at which, the specimen was broken.

Fig 5 Strength test using CTM

3.Now using the sandpaper clean the specimen and make the surface of specimen dust free.

4.After the cleaning of specimen now we have to cut the CFRP sheet according to the size of specimen.

Fig 6Cutting of CFRP sheet

5.Apply the epoxy resin to the specimen using paint brush and stick the CFRP sheet to the specimen.

Fig 7Epoxy resin mixing

S.No	Weight (kg)	Rebound no			Compressive Strength (PSI)			Compressive Strength (N/mm^2)			Mean strength (N/mm^2)
		T-01	T-02	T-03	T-01	T-02	T-03	T-01	T-02	T-03	
1	4.6	34	30	34	4500	3500	4500	31	24.1	31	28.77

2	**4.54**	**28**	**30**	**27**	**3100**	**3500**	**3000**	**21.4**	**24.1**	**20.6**	**22.06**
3	**4.5**	**22**	**24**	**25**	**2200**	**2500**	**2600**	**15.16**	**17.2**	**17.9**	**16.77**
4	**3.94**	**26**	**22**	**25**	**2800**	**2200**	**2600**	**19.3**	**15.1**	**17.9**	**17.45**
5	**4.4**	**23**	**22**	**21**	**2400**	**2200**	**2000**	**16.54**	**15.1**	**13**	**13.8**
6	**4.36**	**25**	**26**	**25**	**2600**	**2800**	**2600**	**17.9**	**19.3**	**17.9**	**18.4**
7	**3.82**	**25**	**23**	**22**	**2600**	**2400**	**2200**	**17.9**	**16.5**	**15.2**	**16.53**
8	**4.42**	**24**	**25**	**26**	**2500**	**2600**	**2800**	**17.25**	**17.9**	**19.3**	**18.15**

Specimen Number	**Compressive strength before wrapping(N/mm^2)**	**Compressive strength after wrapping(N/mm^2)**	**Strength regain ratio %**

9	**3.48**	**25**	**26**	**24**	**2600**	**2800**	**2500**	**17.9**	**19.3**	**17.2**	**18.15**
10	**4.22**	**26**	**24**	**27**	**2800**	**2500**	**3000**	**19.3**	**17.2**	**20.7**	**19.13**
11	**4.42**	**20**	**23**	**22**	**1800**	**2400**	**2200**	**12.4**	**16.5**	**15.2**	**14.73**
12	**4.54**	**28**	**26**	**30**	**3100**	**2800**	**3500**	**21.36**	**19.3**	**24.1**	**21.67**

Table:1 Compressive strength using rebound hammer

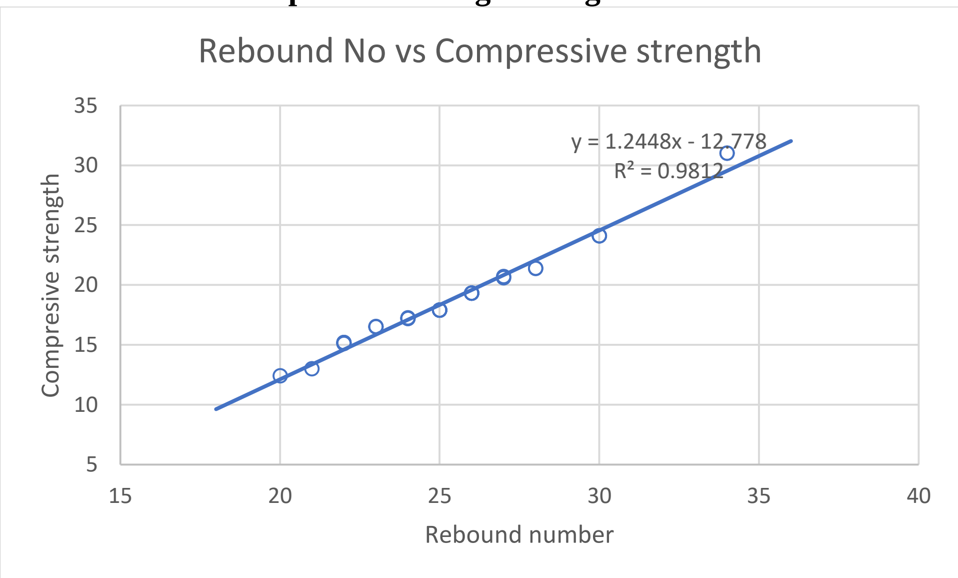

Fig 8 Graphical representation of rebound number vs compressive strength

1	28.77	83.39	289.85
2	22.06	87.21	395.33
3	16.77	71.3	425.16
4	20.37	70.03	343.79
5	13.8	57.29	415.14
6	22.91	73.85	322.35
7	12.73	46.47	365.04
8	24.83	53.47	215.34
9	18.15	70.03	385.84
10	19.13	68.75	359.38
11	17.82	45.83	257.18
12	22.28	56.02	161.67

Table:2 Compressive strength before and after wrapping

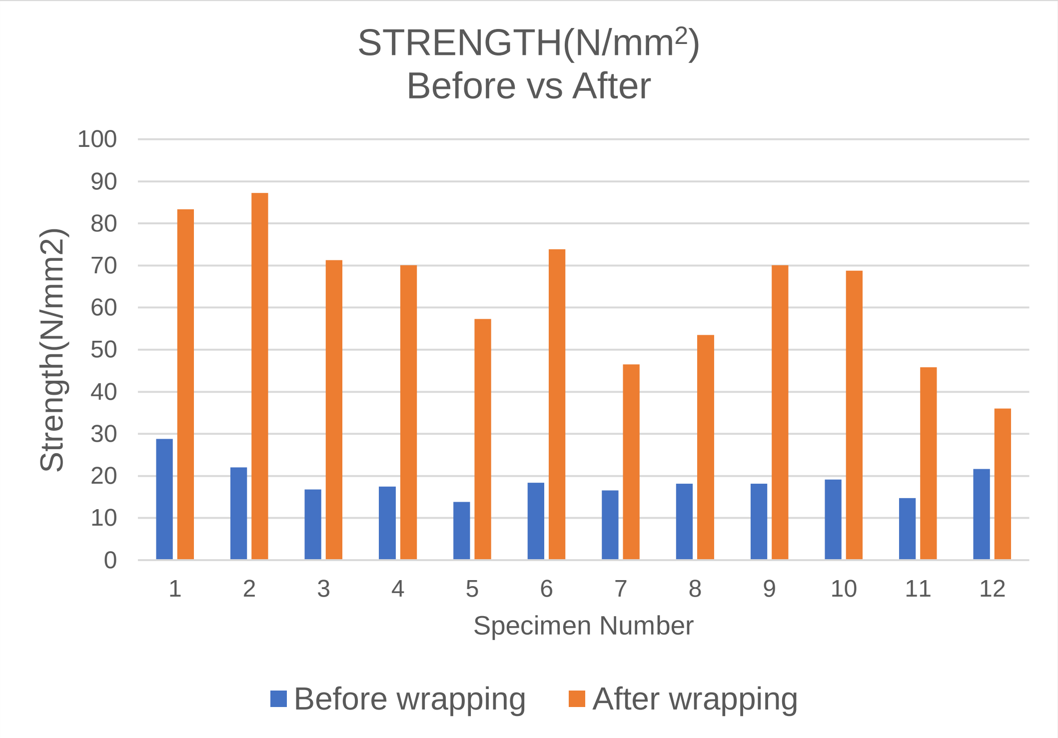

Figure 9 Compressive strength before and after wrapping CFRP sheet

Specimen number	Axial stress $\sigma_x = \frac{F}{A}$ (MPa)	fck=$f'ck - 1.65 \times S$ N/mm^2	E = 5000× $\sqrt{fck}$ MPa	Axial strain $\epsilon_x = \frac{\sigma_x}{E}$
1	**83.39**	**22.17**	**23542.51**	**0.0035**
2	**87.21**	**15.46**	**19659.6**	**0.0044**
3	**71.3**	**10.99**	**16579.35**	**0.0043**
4	**70.03**	**11.68**	**17084.34**	**0.0041**
5	**57.29**	**8.025**	**14164.22**	**0.0040**
6	**73.85**	**12.625**	**17765.84**	**0.0042**
7	**46.47**	**10.755**	**16397.41**	**0.0048**
8	**53.47**	**12.375**	**17589.06**	**0.0030**
9	**70.03**	**12.375**	**17589.06**	**0.0039**
10	**68.75**	**13.355**	**18272.24**	**0.0037**
11	**45.83**	**8.955**	**14962.45**	**0.0031**

12	**36.02**	**15.07**	**19410.05**	**0.0029**

Table:3 Stress and strain on each specimen

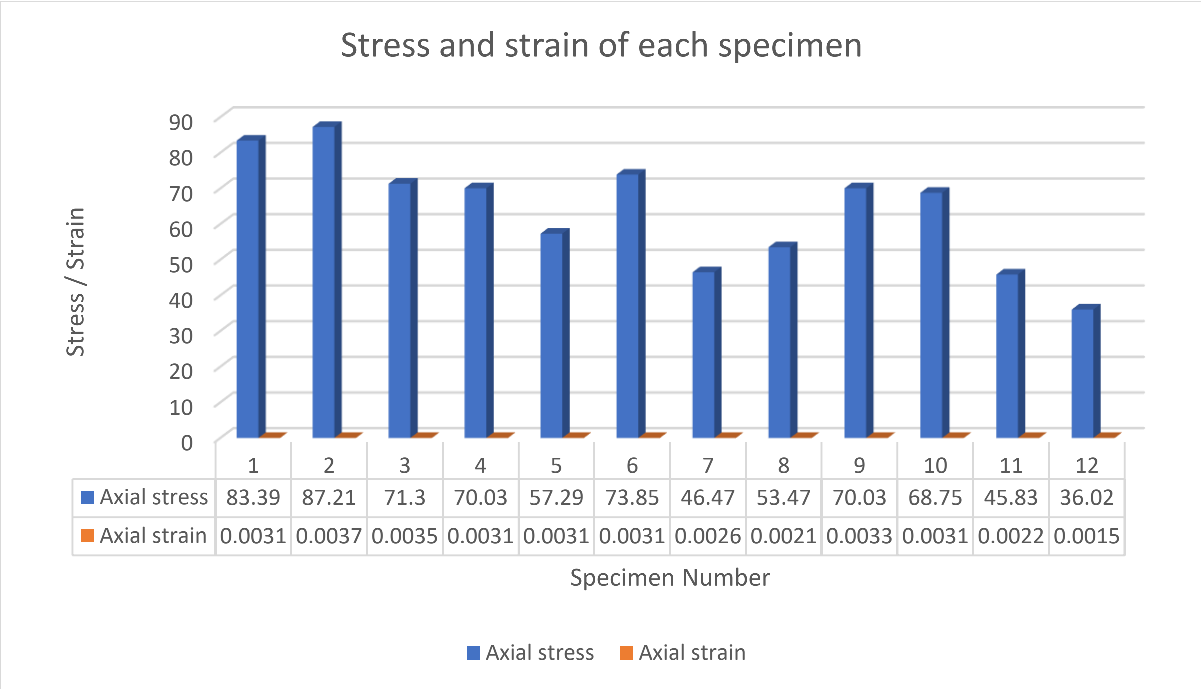

Figure 10 Stress and strain of each specimen

4.4 Discussion

1. The compressive strength of the specimen showed a significant improvement after wrapping, increasing from 28.77 N/mm² to 83.39 N/mm². This enhancement corresponds to a strength regaining ratio of 289.85%. The axial strain of the specimen was measured at 0.0035. Additionally, adhesive failure was observed, as evidenced by traces of concrete attached to the CFRP laminates. This suggests that the bond between the concrete and the CFRP was sufficiently strong, indicating that the reinforcement effectively contributed to the overall structural integrity of the specimen.

Fig 9 specimen 1 after testing

2. The specimen's compressive strength experienced a remarkable increase after wrapping, rising from 22.06 N/mm² to 87.21 N/mm². This improvement represents a strength regaining ratio of 395.33%. The axial strain was recorded at 0.0044. Additionally, cohesive failure was observed, with chunks of concrete adhering to the CFRP laminates. This indicates a robust bond between the

concrete and the CFRP, demonstrating that the reinforcement significantly enhanced the overall structural integrity of the specimen.

Fig 10 specimen 2 after testing

3. The compressive strength of the specimen saw a significant enhancement after wrapping, increasing from 16.77 N/mm² to 71.3 N/mm². This improvement translates to a strength regaining ratio of 425.16%. The axial strain was measured at 0.0043. Additionally, cohesive failure was observed, indicated by chunks of concrete adhering to the CFRP laminates. This demonstrates a strong bond between the concrete and the CFRP, highlighting that the reinforcement significantly bolstered the specimen's overall structural integrity**.**

Fig 11 specimen 3 after testing

4. The compressive strength of the specimen exhibited a substantial increase after wrapping, rising from 20.37 N/mm² to 70.03 N/mm². This enhancement corresponds to a strength regaining ratio of 343.78%. The axial strain was measured at 0.0041. Additionally, adhesive failure was observed, with traces of concrete remaining attached to the CFRP laminates. This indicates a strong bond between the concrete and the CFRP, demonstrating that the reinforcement significantly improved the overall structural integrity of the specimen.

Fig 12 specimen 4 after testing

5. The specimen's compressive strength experienced a notable increase after wrapping, rising from 13.8 N/mm² to 57.29 N/mm². This significant improvement corresponds to a strength regaining ratio of 415%. The axial strain recorded was 0.0040. Furthermore, cohesion failure was observed, with chunks of concrete attached to the CFRP laminates. This indicates that the bond between the concrete and the CFRP was very strong, showing that the reinforcement effectively enhanced the specimen's structural integrity.

Fig 13 specimen 5 after testing

6. The application of Carbon Fiber Reinforced Polymer (CFRP) wrapping significantly enhanced the compressive strength of a structural element from 22.91 N/mm² to 73.85 N/mm², demonstrating a remarkable improvement in structural integrity with a strength regaining ratio of 322.48%. Although the axial strain of 0.0042 indicates that the wrap maintains acceptable flexibility, the presence of adhesive failure—evidenced by concrete residues on the CFRP laminates—raises concerns about the bonding quality. It is crucial to address and optimize the adhesive techniques to ensure the longevity and effectiveness of the CFRP reinforcement.

Fig 14 specimen 6 after testing

7 The CFRP wrapping significantly increased the compressive strength of the structural element from 12.73 N/mm² to 46.47 N/mm², marking a substantial enhancement with a strength regaining ratio of 365%. The recorded axial strain of 0.0048 remains within typical limits for reinforced structures, suggesting an effective balance between strength and flexibility. However, the occurrence of cohesive failure, indicated by chunks of concrete adhering to the CFRP laminates, suggests issues with the concrete's internal integrity. This type of failure necessitates a closer examination of the concrete quality and the interface between the concrete and the CFRP to ensure the reinforcement's durability and effectiveness**.**

Fig 15 specimen 7 after testing

8.The CFRP wrapping significantly boosted the compressive strength of the structural element from 24.83 N/mm² to 53.47 N/mm², achieving a strength regaining ratio of 215.34%. This indicates a marked improvement in the structural resilience and load-bearing capacity. The recorded axial strain of 0.0030 is well within acceptable parameters, which suggests that the enhancement has not compromised the element's flexibility. However, the presence of adhesive failure, highlighted by traces of concrete on the CFRP laminates, points to potential issues in the bonding process. Addressing these adhesive failures is crucial for maximizing the long-term effectiveness and reliability of the CFRP reinforcement.

Fig 16 specimen 8 after testing

9 The application of CFRP wrapping to the structural element resulted in a substantial increase in compressive strength from 18.15 N/mm² to 70.03 N/mm², with a strength

regaining ratio of 385.84%. This impressive improvement highlights the effectiveness of CFRP in enhancing structural capacity. The axial strain of 0.0039 suggests that the increase in strength has been achieved while maintaining a degree of flexibility. However, the occurrence of adhesive failure, indicated by traces of concrete on the CFRP laminates, suggests issues with the bond quality between the CFRP wrap and the concrete. Addressing these adhesive issues is crucial to ensure the durability and effectiveness of the reinforcement over time.

Fig 17 specimen 9 after testing

10. The CFRP wrapping significantly enhanced the compressive strength of the structural element, elevating it from 19.13 N/mm² before wrapping to 68.75 N/mm² after, demonstrating a notable strength regaining ratio of 359.38%. This improvement confirms the effectiveness of CFRP in reinforcing structural integrity. The axial strain measured at 0.0037 suggests adequate flexibility has been retained post-reinforcement. However, the presence of adhesive failure, as indicated by traces of concrete on the CFRP laminates, highlights potential issues with the bonding interface. To ensure long-term performance and reliability, it's essential to address and resolve these adhesive bonding concerns**.**

Fig 18 specimen 10 after testing

11. The implementation of CFRP wrapping on the structural element resulted in a significant increase in compressive strength, escalating from 17.82 N/mm² to 45.83 N/mm². This improvement represents a strength regaining ratio of 257.18%, underscoring the effectiveness of CFRP in bolstering structural resilience. An axial strain of 0.0031 was also observed, indicating that the enhancement in strength has been achieved without

compromising flexibility. Despite these gains, the noted adhesive failure, evidenced by traces of concrete on the CFRP laminates, suggests issues with the bonding effectiveness. Addressing this bonding challenge is essential for ensuring the durability and optimal performance of the CFRP reinforcement.

Fig 19 specimen 11 after testing

12. The application of CFRP wrapping to a structural element resulted in a notable increase in compressive strength, rising from 22.28 N/mm² before wrapping to 56.02 N/mm² afterward. This change represents a strength regaining ratio of 161.66%, clearly demonstrating the effectiveness of CFRP in enhancing structural robustness. The observed axial strain of 0.0029 indicates that the structure retains flexibility despite the significant increase in strength. However, the presence of adhesive failure, as indicated by traces of concrete on the CFRP laminates, raises concerns about the bonding quality. Addressing these issues is crucial for ensuring the long-term durability and reliability of the CFRP reinforcement.

Fig 20 specimen 12 after testing

4.4 Conclusion:

- The utilization of CFRP sheets on the cylindrical specimen has yielded impressive results, demonstrating its capacity not just to restore but to exceed the original strength of the specimen. This can be helped in the upcoming projects as well to develop a cost-effective and efficient methodology for applying FRP sheets to improve strengthening techniques for RCC buildings as well.

- On an average (of 12 specimen) 328% of compressive strength was increased before and after wrapping of CFRP sheet.

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