IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Experimental Investigation On Flexural Behaviour Of Rc Beam Wrapped With Carbon Fibre Reinforced Polymer Sheets

[1]G.SRIKANTH, [2]Dr.KHAJA FAREEDUDDIN, [3]SUMAIAH AMREEN

[1]Assistant Professor, [2]Professor ,[3]M.E Student

[1]Civil Engineering,

[1]Lords Institute of Engineering & Technology, Hyderabad, Telangana

Abstract: Due to excessive loading, construction errors and improper maintenance strengthening of concrete structures becomes critical. Fibre reinforced polymer brings improvement in load bearing capacity, improved ductility and reduces damages due to deterioration.

The researchers are seeking new and innovative ways of strengthening of beams as conventional methods of reinforcement encountered certain limitations which are required to overcome. The technique of wrapping a Reinforced Concrete (RC) beam with composite material becomes popular and has been widely adopted in the structural applications due to their superior properties. FRP consumes relatively a less labour cost and also easy way to strengthen the structures to give effective solution.

The experimental work has been done for both conventional and CFRP strengthening sheets and calculated compressive, Split-tensile strength & flexural strength sheets with various intervals such as CFRP wrapped with 50mm interval, CFRP wrapped without interval

Key Words: Reinforced Concrete (RC) Beams, Carbon Fibre Reinforced Polymer (CFRP) ,Structural Strengthening,

Compressive Strength, Split-Tensile Strength, Flexural Strength , FRP Wrapping Technique , Load Bearing Capacity,

Ductility Improvement, Interval Wrapping (50mm / Continuous Wrapping)

I. INTRODUCTION

The reinforced Concrete Structures is also known as Reinforced cement concrete (RCC) which is relatively low tensile strength, as opposed to ductility by adding high tensile or dilute reinforcement. Although reinforcement is not usually required, steel reinforcement bars (rebar) are usually passively embedded in the concrete before the concrete is set.

Traditionally, reinforced concrete structures (such as columns, beams and other structural elements) require a slow and deteriorating process to replace poor quality or damaged concrete or steel bars with new, stronger materials. Asa composite made of fiber-reinforced polymer (FRP), concrete elements can now be easily and effectively reinforced with externally bonded FRP composites.

In many cases, FRP concrete structures provide a more economical and technically superior choice than traditional methods because they have higher strength, lighter weight, lower corrosion resistance, higher fatigue resistance and Minimal changes in structure geometry. Ability to create shapes and forms that are difficult or impossible to manufacture with traditional steel.

Although the fibres and resins used in FRP systems are more expensive than standard reinforcing materials, the labour and equipment costs associated with installing FRP systems are reducing the costs. FRP wrapping canbe used in places where traditional techniques are impractical, such as in construction with limited access. However, due to a lack of proper knowledge about the structural behaviour of reinforced concrete structures with fibre reinforced polymers (FRP) composites, the use of these materials for existing concrete structures falls short of expectations. Successful FRP remodelling of concrete structures necessitates extensive knowledge, readily available user-friendly technologies, and one-of-a- kind guidance.

1.1 FLEXURAL STRENGTHENING OF BEAMS

For flexural support, there are a few techniques, for example, area extension, plate holding, and outside post-strain framework, surface mounted (NSM) framework, and remotely fortified (EP) framework. Albeit numerous strategies for fortifying constructions are accessible, reinforcing structures by outside holding of cutting,edge fiber-built up polymer composites (CFRPs) has gotten extremely famous around the world. Absurd decade, their utilization in this field has been expanding because of the notable advantages of mixtures (CFRP) over different items. Therefore, a lot of test and hypothetical exploration has been led on the conduct of supported cement (RC) structures. In such manner, the arising innovation for the utilization of carbon fiber built up polymer (CFRP) to fortify RC radiates has been joined lately.

1.2 ADVANTAGES OF CFRP

FRP materials have higher last strength and lower thickness contrasted with steel. Taken together, these properties can prompt fiber composites that sometimes have a more grounded/heavier proportion than steel plate. The lower weight of FRP makes connection and taking care of fundamentally simpler than steel. These properties are particularly significant when introducing in bound spaces. Different works, for example, the development of extension surfaces and floor pieces, are done from human access destinations as opposed to from the whole platform. We as a whole realize that the steel plate requires hard work gear, the cement acquires its solidarity, and bolts are fitted to the parent concrete through the steel plate on the side of the plate when the cement fixes. Then again, the utilization of FRP range or sheet material is like the utilization of backdrop; It can be left unsupported once deliberately moved to eliminate air and abundance gum that has entered. Here, bolts are not needed; indeed, the bolt application material will debilitate if the extra cover plates are not fortified. Additionally, since there is no compelling reason to penetrate bolts or other mechanical anchors into the construction for fix, there is no danger of much harm to the current support. Fiber amalgams are accessible in extremely long lengths, while the steel plate is ordinarily 6 m.

1.3 NEED FOR THIS STUDY

- This study compares about the strength parameters like flexural strength test, split tensile strength test,compressive strength test and RC beam test when beam is wrapped with carbon fibre reinforced polymer at various intervals
- To design and proportion the concrete mix for M25 grade concrete as per the recommendations of IS:10262:2009
- Economical method and less labour consumption

1.4 SCOPE OF THE STUDY

- This study focuses on the strengthening of reinforced concrete (RC) beams using Carbon Fibre Reinforced Polymer (CFRP) sheets.
- The research evaluates mechanical properties such as compressive strength, split-tensile strength, and flexural strength under different strengthening techniques.
- Two strengthening patterns are considered:
    1. CFRP wrapped at 50 mm intervals
    2. CFRP wrapped without interval (continuous wrapping)
- The scope extends to identifying the effectiveness of CFRP wrapping compared to conventional beams in terms of load-bearing capacity, ductility, and crack resistance.
- It provides a comparative assessment to determine the optimum wrapping method for practical applications.
- The study will serve as a reference for engineers and researchers in the field of structural rehabilitation, retrofitting, and durability enhancement of concrete structures.

II.METHODOLOGY

Methodology is a systematic approach to conduct research, Methodology describes the complete procedure from surveying of literatures to comparison of results of conventional mix and mixes with partial replacement of feldspar and quartz as fine aggregate.

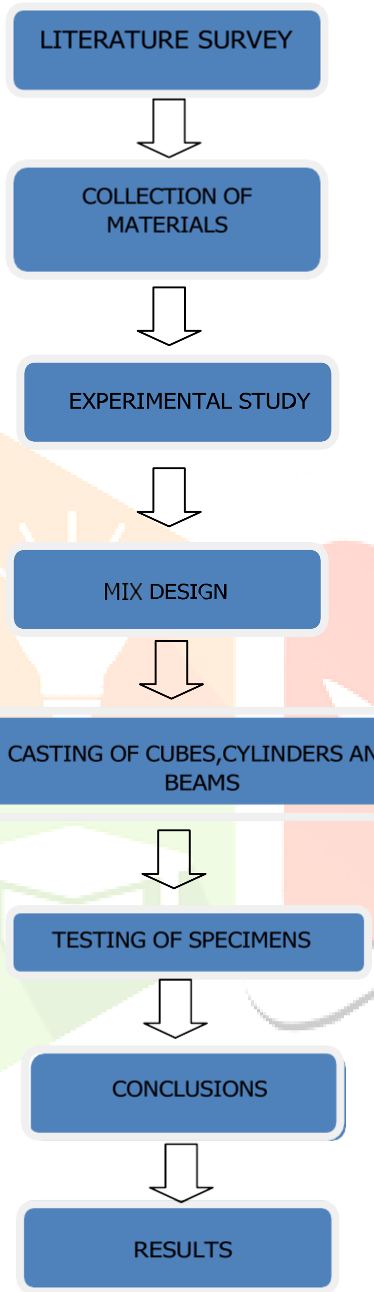

Fig.2.1 Flowchart of methodology

III. COLLECTION OF MATERIALS & MIX DESIGN

3.1 Collection of raw materials

Material testing includes tests on cement, coarse aggregate, fine aggregate and beam compression strength and flexural strength. This chapter contains these experiments and their results and observations.

3.1.1 Cement :

Ordinary Portland Cement (OPC) is the most commonly used binder in concrete production. In this study, locally available Penna OPC 43 grade cement, conforming to IS 269:2015, was utilized, as illustrated in Fig. 1. Due to its cost-effectiveness, OPC is extensively adopted in the construction sector. It is suitable for a wide range of applications including high-rise buildings, roads, bridges, dams, flyovers, and is also used in the preparation of mortars and grouts. Its versatility makes it an ideal choice for both residential and industrial structures. The physical and chemical properties of the cement were examined according to IS 4031:1988 and IS 4032:1985 standards.

Fig 3.1 Cement

3.1.2 Fine Aggregates

Manufactured sand (M-sand) obtained from SS Crusher, Cheyyur, conforming to IS 383:2016, was used as fine aggregate, as illustrated in Fig. 4.2. This sand is produced by crushing hard granite rock into cubical particles with smooth edges. It is then washed and properly graded to meet construction standards. The particle size of manufactured sand is less than 4.75 mm, making it suitable for use in concrete and mortar applications. This crushed fine aggregate is derived from parent rock materials that possess the required strength, durability, and appropriate shape characteristics for structural use.

Fig 3.2 M Sand

3.1.3 Coarse Aggregates

Crushed stone aggregates sourced from SS Crusher, Cheyyur, and meeting the specifications of IS 383:2016, were utilized as coarse aggregates in this study, as depicted in Fig. 4.3. In concrete production, gravel and crushed stone make up the bulk of the coarse aggregate portion. Coarse aggregates serve multiple functions in construction — most prominently as a key component in concrete mixes. Additionally, they are used beneath slabs to create a moisture barrier, and in base layers for driveways and roadways. These aggregates consist of larger-sized stones that provide strength and stability within the concrete matrix.

12.5 mm

20 mm

Fig 3.3 Coarse aggregate

3.1.4 Mixing

The object of mixing is with alkaline activators to blend all the ingredients of concrete into a uniform mass. Though mixing of the materials is essential for the production uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in color and consistency. In this study the process of hand mixing was adopted.

Figure 3.4 Mixing of concrete

3.1.5 Casting of specimen

The cube specimen is of size 150*150*150mm. Before placing the concrete in the mould, its interior surface and base plate were lightly oiled to prevent the unevenness of the specimen. The mixed concrete is placed in the oiled mold in layers, each layer of having 5cm thick. After placing each layer it is pampered 30 times using a slandered tampered rod. The strokes penetrated into the underlying layer and the bottom layer was ridded throughout its depth.

3.1.6 Curing of specimen

Providing adequate moisture, temperature, and time to allow the **concrete** to achieve the desired properties for its intended use. . When these recommendations are properly specified and performed in the field
As soon as the concreting is completed, the mould is stored in a rapid curing at 101 c for 4 hours. Later the specimen is placed at room temperature until taken for testing.

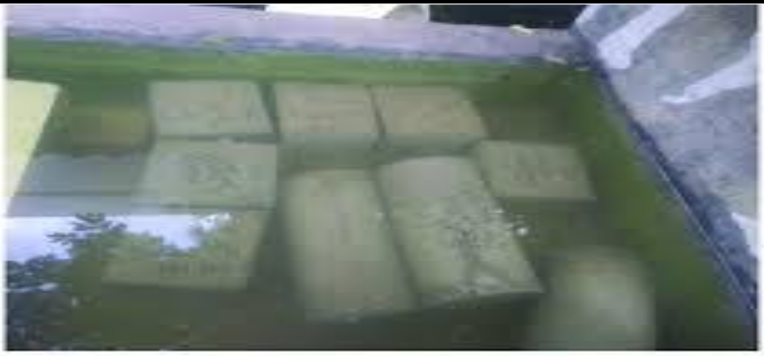

Figure.3.4 Curing of specimen

IV. MIX DETAILS

The mix proportion chosen for this study is 1:1.89:3.0 with water/cementratio of 0.4 shown in table 4.5. M25 concrete is used.

Table 4.1 Mix proportion of concrete

Water	Cement(kg/m3)	Fine aggregate	Coarse aggregate
192	413	859.3	964.2
0.4	1	2.0	2.5

V. EXPERIMENTAL INVESTIGATION

5.1 NUMBER OF SAMPLES

Cubes - 9 nos Size-(150mmX150mm)

- 3 cubes of 7 days curing
- 3 cubes of 14 days curing
- 3 cubes of 28 days curing

Cylinder - 6 nos Size (300mmX150mm)

- cylinder of 7 days curing
- cylinder of 28 days curing

Prism – 9 nos Size (100mmX100mm X500mm)

- prism of 7 days curing
- prism of 28 days curing
- Conventional beam
- **Beam Wrapped with CFRP at 50 mm Interval**
- **Beam Fully Wrapped with CFRP (No Interval)**

VI.TESTS ON CONCRETE

6.1 Compressive strength

The results of the mechanical properties obtained based on the specimenstested as per Indian standard test procedures (as per IS: 516) are discussed. M25 grade of concrete with their three different ages of curing are the variables of investigation. The details of the compressive strengths of M25 grade are shown in Table 6.1

Fig 6.1: Compressive strength test

Table: 6.1 Compressive strength of M 25 grade for 7,14 & 28 Days

MixType	7Days N/mm^2	14Days N/mm^2	28Days N/mm^2
M25	16.25	23.50	26.51

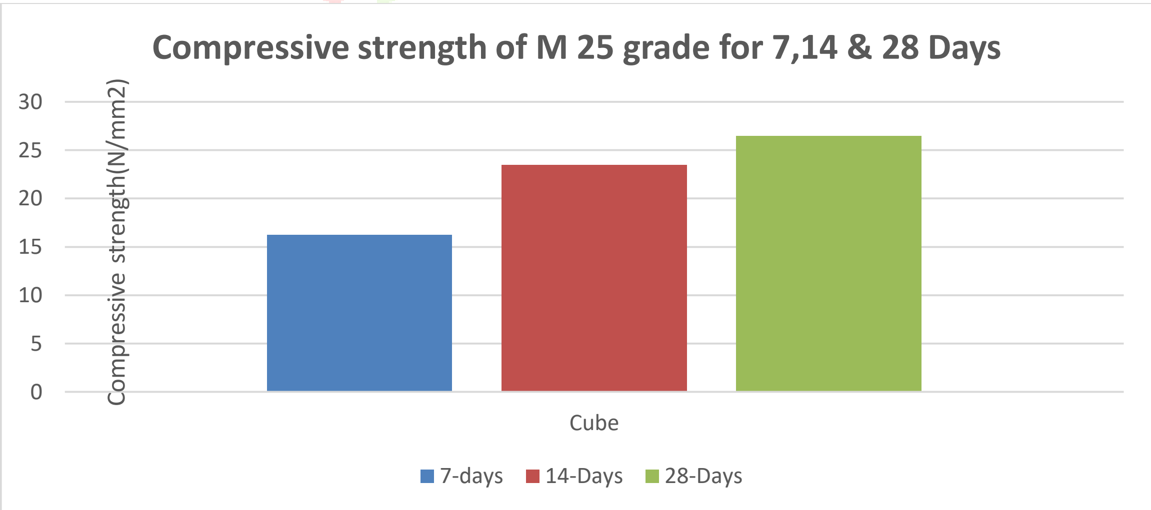

Figure: 6.1 Compressive strength of M 25 grade for 7,14 & 28 Days

6.2 Split tensile strength

The splitting tensile strength are presented. For a mix three cylinders were tested for split tensile strength. The results from the tensile test are presented in Table 6.2.



FIG: 6.2 Split Tensile Strength Test

Table: 6.2 splitting tensile strength of M 25 grade for 7,14 & 28 Days

Mix Type	7Days N/mm^2	14Days N/mm^2	28 Days N/mm^2
M25	2.28	3.20	3.71

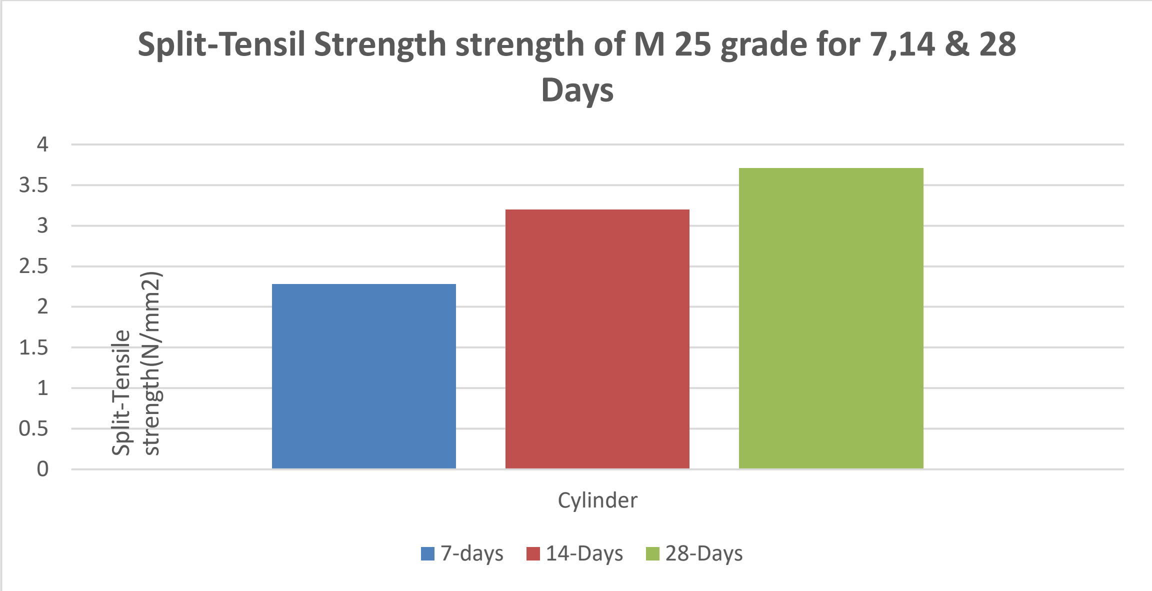

Figure: 6.2 Split-Tensile Strength of M 25 grade for 7,14 & 28 Days

6.3 Flexural strength

The Flexural strength are presented. For a mix three prisms were tested for split tensile strength. The results from the tensile test are presented in Table 6.3.

Figure 6.3.1 Flexural Strength

Table: 6.3.1 Flexural strength of M 25 grade for 7,14 & 28 Days(Conventional Concrete)

Mix Type	7Days N/mm^2	14Days N/mm^2	28Days N/mm^2
M25	2.13	2.98	3.42

Figure: 6.3.2 Flexural strength of M25 Beam

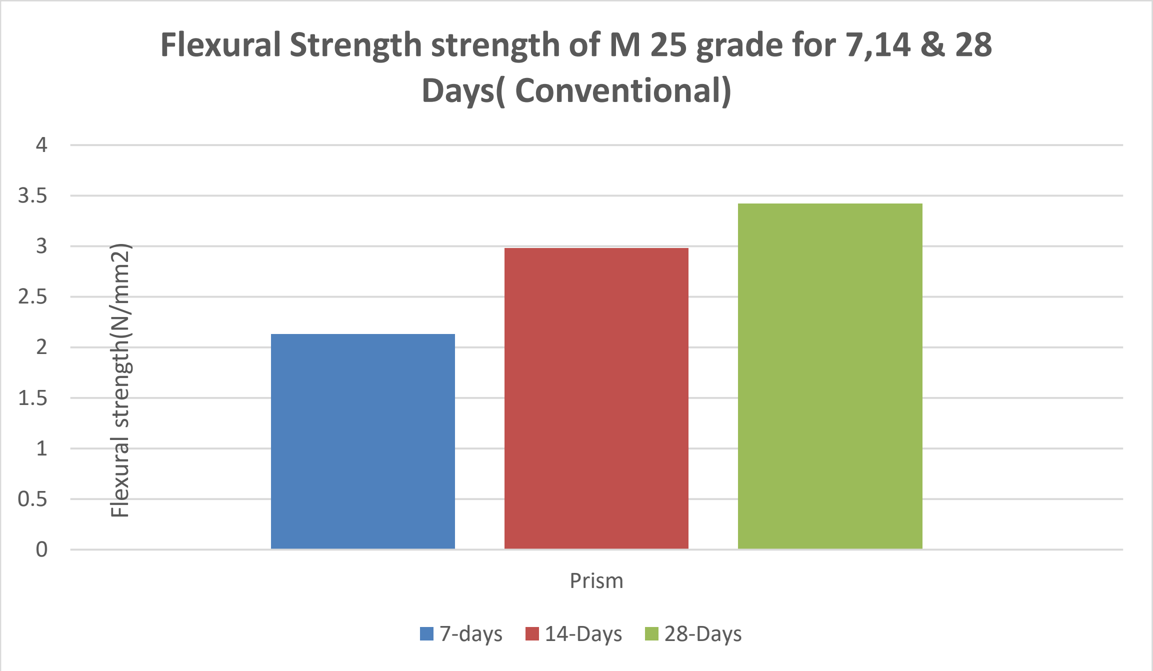

Figure: 6.3.3 Flexural Strength of M 25 grade for 7,14 & 28 Days

Table: 6.3.2 Flexural strength of M25 Beam Wrapped with CFRP at 50 mm Interval (Average strength of 3 prisms)

Mix Type	7 Days (N/mm²)	14 Days (N/mm²)	28 Days (N/mm²)
M25 (with CFRP @ 50 mm interval)	**2.30**	**3.28**	**3.83**

Figure: 6.3.4 Flexural strength of M25 Beam Wrapped with CFRP at 50 mm Interval (Average strength of 3 prisms)

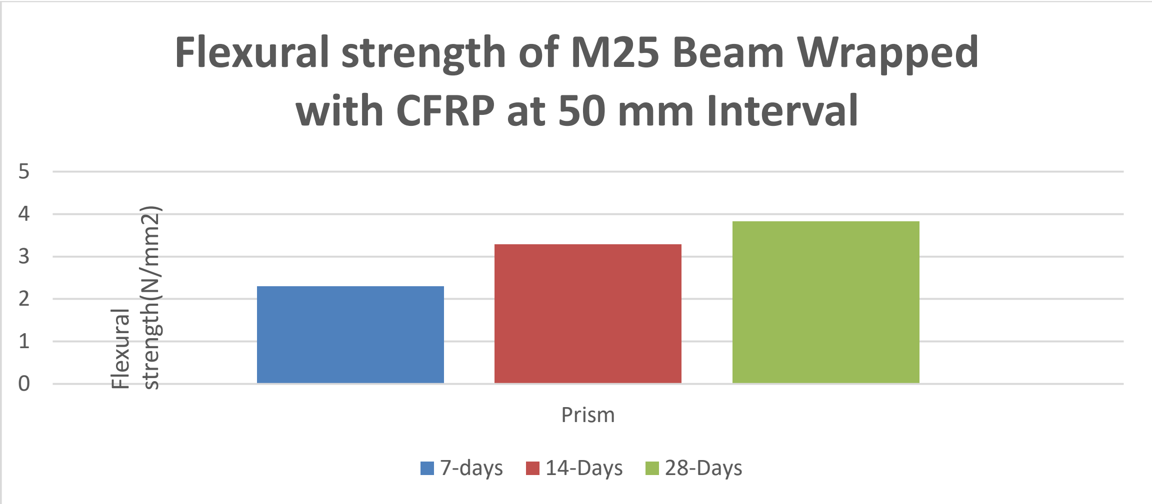

Figure: 6.3.5 Flexural strength of M25 Beam Wrapped with CFRP at 50 mm Interval (Average strength of 3 prisms)

Table: 6.3.3 Flexural strength of M25 Beam Fully Wrapped with CFRP (No Interval) (Average strength of 3 prisms)

Mix Type	7 Days (N/mm²)	14 Days (N/mm²)	28 Days (N/mm²)
M25 (with CFRP, fully wrapped)	**2.39**	**3.43**	**4.04**

Figure: 6.3.6 Flexural strength of M25 Beam Fully Wrapped with CFRP (No Interval) (Average strength of 3 prisms)

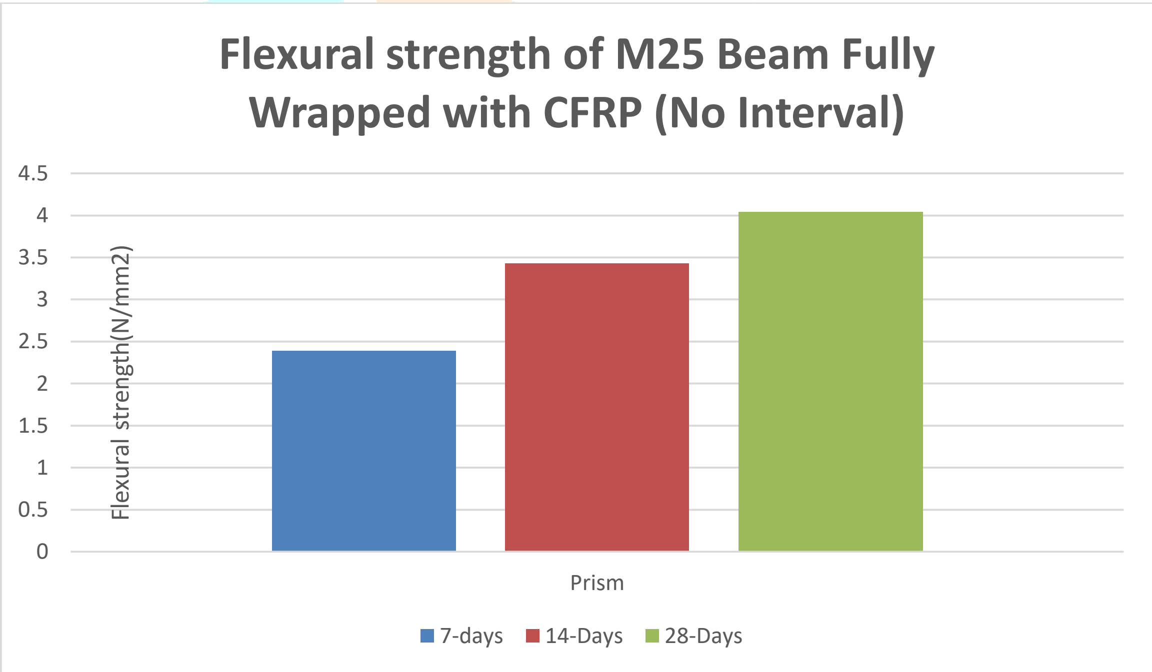

Figure: 6.3.7 Flexural strength of M25 Beam Fully Wrapped with CFRP (No Interval) (Average strength of 3 prisms)

VII. CONCLUSIONS

1. Compressive Strength (Table 5.2.2.4)

- The compressive strength increases with curing age:
  - **7 Days:** 16.25 N/mm²
  - **14 Days:** 23.50 N/mm²
  - **28 Days:** 26.51 N/mm²
- The 28-day strength reaches **~26.5 N/mm²**, which is close to the target M25 characteristic strength.

- The rate of strength gain is **rapid up to 14 days** and then **slows down** till 28 days.

2. Splitting Tensile Strength (Table 5.2.2.4)

- The tensile strength increases gradually with curing:
  - **7 Days:** 2.28 N/mm²
  - **14 Days:** 3.20 N/mm²
  - **28 Days:** 3.71 N/mm²
- At 28 days, the value is in the expected range (≈ 10–15% of compressive strength).
- This shows good development of bonding and microstructure in concrete with age.

3. Flexural Strength – Conventional Concrete (Table 5.2.3.4)

- Flexural strength values:
  - **7 Days:** 2.13 N/mm²
  - **14 Days:** 2.98 N/mm²
  - **28 Days:** 3.42 N/mm²
- The values fall in the typical range (≈ 0.7√fck to 1.0√fck).
- This serves as a baseline for comparison with CFRP-wrapped beams.

4. Flexural Strength – CFRP Wrapped with 50 mm Interval (Table 5.2.3.5)

- Strength values:
  - **7 Days:** 2.30 N/mm²
  - **14 Days:** 3.28 N/mm²
  - **28 Days:** 3.83 N/mm²
- Compared with conventional beams, the increase is **~5–12%** across curing periods.
- Indicates that **partial CFRP confinement enhances flexural capacity**.

5. Flexural Strength – Fully Wrapped with CFRP (Table 5.2.3.6)

- Strength values:
  - **7 Days:** 2.39 N/mm²
  - **14 Days:** 3.43 N/mm²
  - **28 Days:** 4.04 N/mm²
- Compared to conventional beams, improvement is **~10–18%**.
- Fully wrapped beams show the **maximum flexural strength** among all cases.

6. Overall Conclusions

1. **Compressive strength** develops steadily and meets the M25 requirement at 28 days.
2. **Splitting tensile strength** increases proportionally with compressive strength, confirming healthy concrete bonding.
3. **Flexural strength of conventional concrete** is within the expected theoretical range.
4. **CFRP wrapping at 50 mm interval** provides noticeable improvement in flexural performance.
5. **Fully wrapped CFRP beams** give the **highest flexural strength**, proving the effectiveness of continuous CFRP confinement.
6. The improvement trend clearly shows that **extent of CFRP wrapping directly influences strength enhancement**.
7. Thus, **CFRP wrapping is an efficient retrofitting and strengthening technique** for RC beams.

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