

EXPERIMENTAL AND ANALYTICAL INVESTIGATION ON FLEXURAL BEHAVIOUR OF CARBON FIBRE REINFORCED POLYMER-WRAPPED REINFORCED CONCRETE BEAM

Submitted in partial fulfilment of the requirements for the award of

Master of Engineering Degree in Structural Engineering

by

GEETHA J (39380006)



**DEPARTMENT OF CIVIL ENGINEERING
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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APRIL 2021



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of
GEETHA J (39380001) who carried out the project entitled **“Experimental and analytical
investigation on flexural behaviour of carbon fibre reinforced polymer-wrapped
reinforced concrete beam”** under my supervision from November 2020 to April 2021

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Submitted for Viva voce Examination held on_____

Internal Examiner

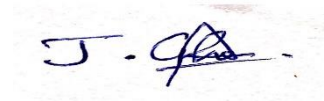
External Examiner

DECLARATION

I **GEETHA J** hereby declare that the Project Report entitled “**Experimental and analytical investigation on flexural behaviour of carbon fibre reinforced polymer-wrapped reinforced concrete beam** ” done by me under the guidance of **Dr. R Padma Priya** at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** is submitted in partial fulfilment of the requirements for the award of Masters of Engineering degree in Structural Engineering.

DATE:

PLACE: CHENNAI

A handwritten signature in blue ink, appearing to read 'J. Geetha', is written on a light-colored rectangular piece of paper.

SIGNATURE OF THE CANDIDATE

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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 and analytical work has been done for both conventional and CFRP strengthening with various intervals such as CFRP wrapped with 100mm interval, CFRP wrapped with 200 mm interval, CFRP wrapped without interval, in which showed better results in deformation and stress analysis. All the experimental results were compared with analytical values calculated. The usage of CFRP on beam increases the strength, load bearing capacity and ductile behaviour.

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LIST OF SYMBOLS AND ABBREVIATIONS

f_{ck}	Characteristic Compressive strength of concrete in N/mm^2 f'_{ck}
f_y	Yield strength of steel in N/mm^2
kN	kilo newton
kg/m^3	kilo gram per meter
cube IS	Indian standard
mm	Millimeter
w/c	Water cement ratio

CHAPTER 1

INTRODUCTION

1.1 GENERAL

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. As a 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 can be 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..

Beams are highly stressed members in all types of structures, including those which bend, twist, and cut. Columns, from the other side, are used as various main components subject to axial load, bent / without bending, and they are used in all types of structures from building to bridge as ships or apartments.

Worldwide, extensive research has been carried out on the use of glass fiber reinforced composite materials for exterior wall cladding to transform concrete beams and columns. Among these members, many researchers have also used carbon fiber-rich polymer (CFRP)/glass fiber-rich polymer (GFRP) composite materials in reinforced concrete poles and columns.

FRP fix is a straightforward technique to increment both the strength and plan life of a construction. Because of its high strength and erosion protection from weight proportion, this maintenance strategy is ideal for solid designs that have decayed because of openness to de-icing salts and other ecological factors by joining solid individuals.

FRP secures against existing salts and other ecological components. It is critical that the greater part of the disintegration harm on numerous scaffolds happened on the external edges. Destructive impacts incorporate direct impacts of surface openness, water splashing, de-icing specialists and ecological impacts. Fixing these ropes delays the plan life as well as shields the individuals from surface assaults.

FRP is an adaptable material. FRP can be utilized for a wide scope of arrangements. The FRP sheet can be sliced and effortlessly attached to any solid part. This is a significant expense impact technique for keeping up or overhauling existing designs.

Fast application brings about less interruption and more limited contact periods. Explanations behind fortifying constructions incorporate moving up to oblige higher burdens (like burdens), loss of augur weight on existing support, or weakening of designs (for example consumption of support). The procedure may take into consideration proceeded with utilization of designs or

offices while supporting works.

Column wrapping with FRP may be an alternative to jacketing additional reinforced concrete or as a complete replacement of structures, with apparent savings in the material energy. This increases the capacity by minimizing dead loads on the structure. The materials are easy to carry and do not require lifting gear. Easy to use at height. This increases the ability to work with limited access to difficult areas (e.g. tunnels and foundations). This technique is relatively quick with reduced interruption and installation time.

1.2 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.

1.3 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.

1.4 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

CHAPTER 2

LITERATURE SURVEY

2.1 GENERAL

In this chapter, the literature studies of RC beams strengthened with FRPs has been described.

2.2 REVIEW OF JOURNAL PAPERS

Sharif et.al (1994), explored the impacts of different fix plans utilizing FRP plates on at first stacked RC radiates. The plate thickness was shifted to evaluate the inception of untimely disappointment at the plate diminishing zone. Diverse fix and securing plans were led to take out such unwanted disappointments and to guarantee pliable conduct. The creators talked about the conduct of fixed pillars as far as burden avoidance bends and diverse disappointment modes. They inferred that I-coat FRP plates gave the best mooring framework; fixed shafts gave sufficient malleability showing the adequacy of FRP plates; the shear and typical anxieties at the plate closes expanded with expanding plate thickness prompting plate partition and solid sham. ACI Committee 440 (1996) introduced a best in class report on FRP for solid designs. The report covered valuable data concerning the utility of FRP for support (interior and outer) purposes alongside rules for plan and execution.

Arduini and Nanni (1997), conducted a parametric study of beams with externally bonded FRP reinforcement. The parameters considered in the analysis were stiffness, strength and adhesive stiffness. The authors reported that the bonded length of FRP should be as high as possible and the adhesive should have high ultimate elongation.

Norris et.al (1997), introduced a test and scientific investigation on the conduct of harmed solid bars retrofitted with CFRP sheets concerning shear and flexure. The shafts were pre-broken and retrofitted with three diverse CFRP framework. The creators noticed various methods of disappointment and gain in extreme strength dependent on the direction of the strands.

Ross et.al (1999), introduced exploratory and logical examinations concerning the flexural fortifying of RC radiates by outer holding of FRP covers. The creators directed a nonlinear limited component investigation and an inelastic area examination for anticipating the heap removal reaction of the retrofitted radiates. They inferred that critical strength improvement can be acquired in flexure in delicately built up radiates and that the bond strength between the composite plate and cement influenced the pillar reaction extensively.

Beauty et.al (2002), considered the flexural conduct of RC radiates reinforced with different kinds of FRP overlays. They analyzed the impact of various number of FRP layers, kind of epoxy and fortifying example on the bar conduct. They examined the impacts of reinforcing on redirection, disappointment load, disappointment mode, strain and malleability. The creators presumed that a mix of vertical and level sheets along with an appropriate epoxy can fundamentally upgrade a definitive burden conveying limit of the bars and that every one of the fortified shafts experienced delicate disappointment governing a higher factor of wellbeing in plan.

Ferrier et.al (2003), led an examination on mechanical conduct of RC radiates supported by remotely fortified CFRP sheets. The proficiency of remotely fortified CFRP in fortifying debased solid constructions has been analyzed. The fundamental impact under assistance stacking was the decrease of break widths. The creators reasoned that the presence of a leftover break width influences the break development of the reinforced pillars.

Henrik Thomsen et.al (2004), directed an investigation on the disappointment mode examination of Reinforced Concrete pillars fortified in Flexure with remotely fortified Fiber-Reinforced Polymers. A non-direct built up solid bar component model and the FRP plate was utilized to concentrate how the disappointment instruments of the just upheld supported RC radiates were influenced by the boundaries, for example, Plate length, Plate width, Plate solidness and stacking type. The parametric examinations submitted the tentatively noticed outcomes as per which the most regularly noticed disappointment mode because of loss of composite activities was influenced by

the plate calculation and material properties. at last, they presumed that conveyed burdens may not be as touchy to plate debonding in the locale of most extreme bowing second as are radiates exposed to point loads.

Huang Yue-lin et.al (2005), introduced a trial concentrate on fortifying of supported solid pillars utilizing prestressed glass fiber-built up polymer (PGFRP). The heap conveying limit and the redirections of reinforced RC radiates utilizing GFRP and PGFRP sheets were tried and analyzed. They detailed that the bars reinforced with PGFRP sheets can withstand bigger extreme burdens than radiates with GFRP sheets. The avoidances of bars with PGFRP sheets were more modest than those with GFRP sheets under similar outside loads. The pliability of the hardened pillars was particularly more modest.

Lee et.al (2005) Presented a mathematical report on the remedial and building up execution of splashed FRP. Ongoing test outcomes outline the advantages of utilizing compounds in a more creative manner, utilizing compounds in a splash weapon, reinforcing and restoring structures. The outcomes showed that the splashed fiber built up polymer (SFRP) was able to do generously expanding the malleability, and burden conveying limit of solid constructions. The creators addressed the aftereffects of mathematical examinations led on harmed RC pillars and scaffold superstructures covered with SFRP. An expected model was created by executing a harm constitutive model in a limited component code to foresee the presentation of SFRP retrofitted solid designs during administration.

Tarek Almusalam (2006), contemplated the heap diversion conduct of Reinforced Concrete shafts fortified with GFRP sheets exposed to various ecological conditions. 84 shaft examples were ready for this examination altogether. They were constrained by lab climate, outside climate, wet-dry antacid water climate and second classification covered with security paint against bright beams. Every class comprised of un-fortified and reinforced pillars. The examples of different wet-dry conditions were presented to a period pattern of about fourteen days inside the arrangement and fourteen days outside the arrangement. The tests were completed following 6, 12 and two years of openness to various ecological conditions. The creator inferred that none of the

previously mentioned natural conditions affect the flexural strength of the shafts.

Pannirselvam et.al (2008), introduced a logical investigation on neural organization for execution assessment of glass fiber built up polymer plated RC radiates. They introduced General Regression Neural Network (GRNN) based computational model for foreseeing the yield load, extreme burden, yield load redirection, extreme burden avoidance, diversion malleability and energy flexibility of GFRP reinforced RC radiates. The forecasts of the model firmly conceded with test results.

Al-Rousan and M. Issa (2017), concentrated how evolved pressure can fundamentally affect the perpetual redirection in the center, reallocating the anxieties prompting an unexpected drop in solid pressure ses and causing a slight expansion in steel and CFRP sheet stresses as the weakness life is exhausted. It likewise expressed that no huge distinction in applying low recurrence of weariness cycles. An expansion in the quantity of CFRP layers and the contact space of the CFRP with the solid outcomes in a huge abatement in the moderate lasting redirection and an increment in firmness and last burden. It shows that under weariness cyclic stacking, a decrease in the solidness of shaft bring about extreme perpetual distortions, which lead to serious usefulness issues.

Sattainathan Sharma A et.al (2019), Steel Fibres are used in most of the water retaining structures. From this it shows the variation in volume fraction of steel fibres also improve the ductility performance of RC beams. The flexural strength, deflection of Steel Fibre beams with Glass Fibre overlay is greater with respect to the conventional beam. compared with Crimped GFRP beam.

2.3 SUMMARY OF LITERATURE REVIEW

The writing accessible on FRP plated RC radiates gives adequate data on the heap avoidance conduct and study boundaries included strength, diversion and pliability of RC radiates. Most specialists proposed models for RC radiates fortified with FRP covers. A few scientists introduced numerical displaying for foreseeing the examination boundaries of FRP reinforced RC primary individuals. Scarcely any analysts directed unwavering quality investigation for FRP fortified solid bars. there have been colossal quantities of studies on radiates with FRP fortifying and thus, further examination is important to comprehend the association between the heap conveying limit, redirection and pliability of CFRP fortified supported solid shafts. The most widely recognized techniques for fortifying is FRP wrapping in order to build the flexural conduct and firmness of the bar. The heap conveying limit of the bar is additionally expanded with the CFRP reinforcing techniques. The proficiency of remotely reinforced CFRP in fortifying corrupted solid constructions has been inspected. The fundamental impact under help stacking was the decrease of break widths. Further examination must be accomplished for the simple comprehension of FRP materials and their conduct.

CHAPTER 3

SCOPE AND OBJECTIVES

3.1 AIM

To determine the flexural behaviour of the carbon fibre reinforced polymer wrapped reinforced concrete beam

3.2 OBJECTIVES

- To determine the mechanical properties of the concrete such as compressive strength, flexural strength, split tensile strength
- To determine the flexural behaviour of RC beam experimentally.
- To determine the flexural behaviour of RC beam analytically.
- Comparison of result on experimental work and analytical work.

3.3 SCOPE

- To increase the load carrying capacity of the specimen by strengthening with CFRP
- To decrease the cracks in the terms of crack width and deflection control.
- One of the savvy techniques for reinforcing which gives greater solidness and most functional answers for fixing and retrofitting constructions to oppose higher plan loads and other toughness issues can be cultivated CFRP

CHAPTER 4

MATERIALS AND METHODOLOGY

4.1 GENERAL

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.

4.2 CEMENT

OPC 53 Coromandel concrete is utilized in this examination. The amount needed for this work is evaluated and the whole amount is bought and put away appropriately in the projecting yard. The accompanying tests are led as per IS principles

- Specific gravity
- Consistency
- Initial & Final setting time
- Fineness

The results of the tests on sample are listed in table 4.1

Table 4.1 Tests on Cement

1.	Specific gravity	3.15
2.	Standard consistency	32%
3.	Setting time	
	(i) Initial setting time	345 minutes
	(ii) Final setting time	510 minutes
4.	Fineness	3%

4.3 COARSE AGGREGATE

In the current examination, locally accessible squashed blue rock stone total of size 20mm and down, is utilized and the different tests are completed on the total are given underneath. The accompanying tests are directed as per IS

principles.

- Sieve analysis
- Specific gravity
- Water absorption

The results of tests on coarse aggregate is given in table 4.2

Table 4.2 Tests on Coarse aggregate

1.	Fineness modulus	7.12
2.	Specific gravity	2.85
3.	Water absorption	0.3%

4.4 FINE AGGREGATE

Fine total bought from a close by smasher. The particles meeting the necessities of the details with explicit gravity 2.54 is utilized as fine total. The accompanying tests are led as per IS principles.

- Sieve analysis
- Specific gravity
- Water absorption

The results of tests on fine aggregate are given in table 4.3

Table 4.3 Tests on fine aggregate

1.	Specific gravity	2.54
2.	Fineness modulus	2.636
3.	Water absorption	2.62
4.	Bulk density	
	(i) Loose state	1537.96 Kg/m ³
	ii) Rodded state	1778.609 Kg/m ³

4.5 WATER

In the present investigation, portable water is used as per IS 10500 (2012)

4.6 CFRP PROPERTY

The property of CFRP are shown in table 4.4

Table 4.4 CFRP Property

Material	Density kg/m³	Modulus of Elasticity Mpa	Poisson ratio
CFRP (UDC) 1mm (Tk)	49823	234500	0.28

4.7 METHODOLOGY

It describes about the workflow of the project as follows:

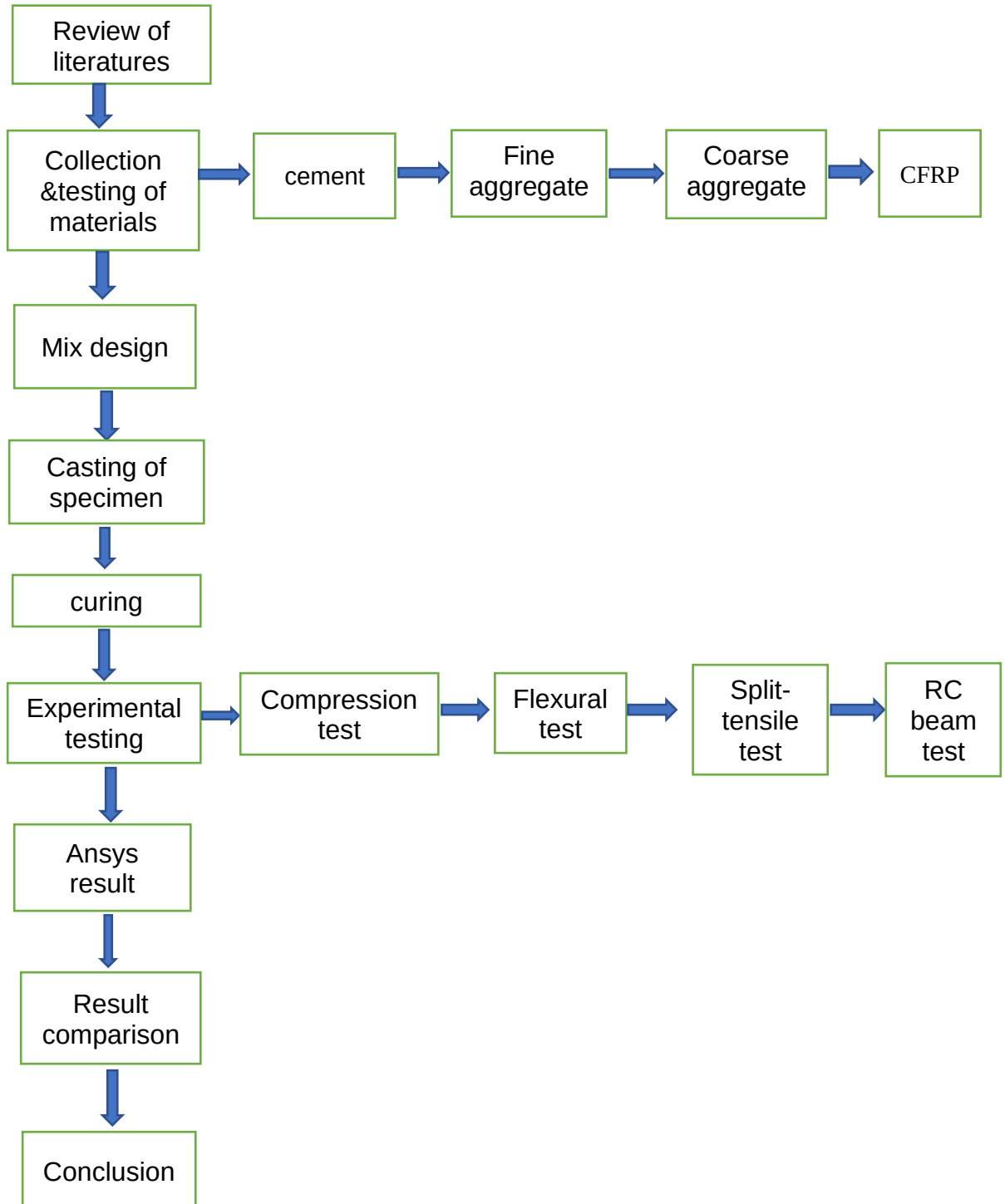


Fig. 4.1 Methodology Flowchart

4.8 MIX DESIGN

4.8.1 INTRODUCTION

The fundamental point of this undertaking is to give general blend plan to M25 evaluation of cement so this venture contains the blend plan for M25 evaluation of concrete according to IS 10262:2009. In this venture the blend will be intended to create the necessary evaluation of cement having the planned functionality and trademark compressive strength, which won't be not exactly the fitting qualities according to IS 10262:2009.

4.9 MIX DESIGN FOR M₂₅ GRADE CONCRETE

4.9.1 SPECIFICATIONS FOR MIX DESIGN

Grade of cement	: OPC53
Type of exposure	: Medium
Size of coarse aggregate	: 12.5 mm
Specific gravity of cement	: 3.15
Specific gravity of Fine aggregate	: 2.54
Specific gravity of coarse aggregate	: 2.85

(i) Target strength for mix proportion

The target of compressive strength mean at 28 days is given by

$$f'_{ck} = f_{ck} + 1.65S$$

From IS 10262:2000 $S = 5 \text{ N/mm}^2$ (S – Standard Deviation)

$$\begin{aligned} f'_{ck} &= 25 + (1.65 \times 4) \\ &= 31.6 \text{ N/mm}^2 \end{aligned}$$

(ii) Selection of water cement ratio

From IS456:2000 table 5

Exposure condition: Moderate

W/C ratio = 0.4

Maximum water cement ratio = 0.5

Adopt 0.45

$0.45 < 0.5$ (hence ok)

(iii) Selection of water content

From IS 10262:2009 table 2

Aggregate size = 20 mm (25 - 50mm slump)

From IS456 - Page 17

Reinforced wall-medium (slump 50 - 100, 75 - 100)

Adopt 75mm (slump)

$$\begin{aligned}\text{Estimated water content for 100mm slump} &= 186 + ((3/100) \times 186) \\ &= 191.58 \text{ liters}\end{aligned}$$

(iv) Cement content

$$\text{W/C ratio} = 0.45$$

$$\begin{aligned}\text{Cement content} &= 186/0.45 \\ &= 413.4 \text{ Kg/m}^3\end{aligned}$$

IS 456:2000 table 5

$$\text{Minimum cement content} = 360 \text{ Kg/m}^3$$

From IS 456:2000 cl.8.2.4.2

Cement content is limited to 450 Kg/m³

$$\begin{aligned}\text{Cement content} &= 360 \text{ Kg/m}^3 < 413.4 \text{ Kg/m}^3 < 450 \\ &\text{Kg/m}^3\end{aligned}$$

(v) The Proportion of volume of coarse aggregate and fine aggregate content

From IS 10262:2009 table 3

- Volume of coarse total comparing to 20 mm size and fine total (zone II) for water concrete proportion of 0.5 = 0.60.
- In the current work water concrete proportion is 0.45. Therefore volume of coarse total is needed to be expanded to diminish the fine total substance. As the water concrete proportion is lower by 0.05 the extent of volume of coarse total is expanded by 0.01 (at the pace of + 0.01 for each + 0.05 change in water concrete proportion).
- Therefore, right extent of volume of coarse total for the water concrete proportion of 0.4 = 0.5.
- Volume of coarse total for water concrete proportion of 0.4 = 0.5
- Proportion of volume of FA = 1 - 0.5 = 0.5

(vi) Mix calculation

- a) Volume of concrete = 1 m³
- b) Volume of cement = (Mass of cement)/((sp.gravity of cement)×(density of cement))
= 413.4/(3.15×1000)
= 0.1314 m³
- c) Volume of water = (Mass of water)/((sp. gravity of water)×(density of water))
= 191.58 /(1×1000)
= 0.192 m³
- d) Volume of all in aggregate = a - (b + c)
= 1 - (0.1314 + 0.192)
= 0.6766 m³
- e) Mass of coarse aggregate = e × Volume of coarse aggregate × Specific gravity of coarse aggregate × 1000
= 0.6766 × 0.5 × 2.85 × 1000
= 964.2 kg.

4.10 MIX DETAILS

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

Table 4.5 Mix proportion of concrete

Water	Cement kg/m ³	Fine aggregate kg/m ³	Coarse aggregate kg/m ³
192	413	859.3	964.2
0.4	1	2.0	2.5

4.11 EXPERIMENTAL INVESTIGATION

4.11.1 INTRODUCTION

This part presents the subtleties of exploratory examinations did on the test examples to contemplate the strength attributes of pillar in various wrapping. The test is led on test examples to determine the strength related properties, for example, 3D shape compressive strength, chamber split rigidity, crystal flexural strength and RC pillar flexural strength. Three examples are tried, and the normal

is accounted for each blend for each test. Every one of the tests are led according to Indian guidelines. In view of the strength test aftereffects of 3D shape and chambers the ideal rate is shown up. After 7,14&28 days restoring, the examples are tried for compressive, Tensile and flexural strength.

4.11.2 SIZE OF TEST SPECIMEN USED

In the wake of testing the fulfillment of the new properties of the solid blend, in cubic tomahawks of size 150 mm x 150 mm, shaft tomahawks with measurements of 100 mm x 100 mm and barrel shaped tomahawks with a distance across of 300 mm stature x 150 mm. The molds were manufactured with steel sheets. It is not difficult to gather and eliminate the form test without harm. The molds were additionally provided with base plates with a smooth surface. The shape is filled without spillage. No holes were dealt with.

4.11.2.1 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)*
 - 3 cylinder of 7 days curing*
 - 3 cylinder of 28 days curing*
- ▶ *Prism – 6 nos Size (100mmX500mm)*
 - 3 prism of 7 days curing*
 - 3 prism of 28 days curing*
- ▶ *Beams – 4 nos Size(230mmX230mmX1500mm)*
 - 1. Conventional beam*
 - 2. Carbon frp wrapped beam without interval*
 - 3. Carbon frp wrapped beam with 100mm interval*
 - 4. Carbon frp wrapped beam with 200mm interval*

4.11.3 CURING OF TEST SPECIMENS

24 hours of projecting, the examples were taken out from the moulds and quickly absorbed clean new water. The examples were relieved for 7 days,14 days and 28 days separately relying upon the necessity required for restoring. The new water tanks used to fix the examples were purged, cleaned and topped off once every fortnight. All lowered examples were in every case very much positioned submerged, and in any event 15 cm of water tests could be seen over the example. Test formats as demonstrated in Figure 4.2.

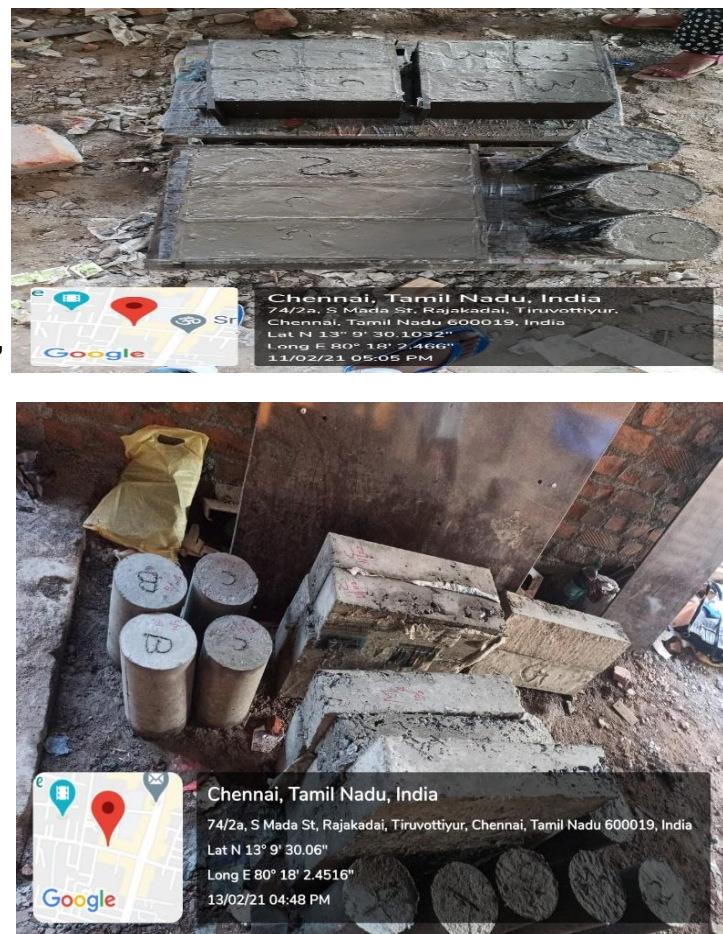


Fig.4.2 Specimen Casting

4.11.4 TESTS ON HARDENED CONCRETE

Testing of hardened concrete plays an important role in controlling and confirming the quality of self-compacting concrete.

4.11.4.1 COMPRESSIVE STRENGTH

The example is portrayed as the assessment of the homogeneous compressive pressing factor achieved when the article thoroughly misfires. In this test, strong shape models of 150 mm x 150 mm x 150 mm are attempted according to IS: 516 - 1969 [Test method for concrete strength]. Taken a stab at a test machine with a constraint of 300 tons. The machine has an office to control the stacking rate with the control valve. The machine has been changed as per the essential rules. The plates are cleaned; The oil level was checked and organized in all respects for testing.



Fig.4.3 Compressive strength test setup

Following 28 days of reestablishing, the square tests were taken out from the assuaging tank and cleaned to clear surface water. The models were moved to the spinning top of the machine, for instance used as the stack place. The smooth surfaces of the model are determined to the bearing surfaces. The upper plate was in contact with the model by turning the handle. The oil pressure valve was closed and the engine worked.

A uniform stacking speed of 140 kg/cm²/min was kept up. The most limit trouble for frustration is exhibited when the model starts to move behind the wrecked pointer. The test was repeated for every one of the three models and the mean worth was taken as the mean strength. The set test is showed up in Figure 4.3.

In the current assessment, pressure strength testing has been done on concretes with different sorts of coarse sums. M25 grade fiber - Reinforced self-compacting concrete attempted at 7,14 and 28 days.

4.11.4.2 FLEXURAL STRENGTH

Flexural strength test was finished on 100 mm x 150 mm x 500 mm transmits according to IS:516:assuming the material is homogeneous. The columns were attempted at 400 mm ranges for every 100 mm test using two identical weights put at the third points. To get these stacks, a center point load is applied on a shaft maintained on steel rollers put at the third point as shown in Figure 4.5. The stacking rate is 1.8 kg/min for 100 mm models. Additionally, the pile was extended until the column fizzled. Contingent upon the sort of frustration, break and break load, the flexural versatility of the model was evaluated.

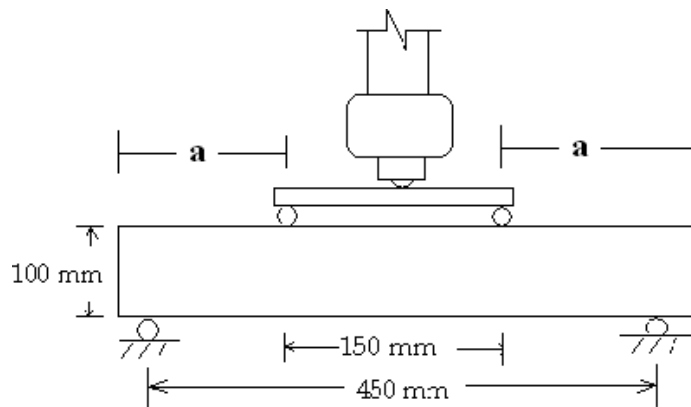


Fig.4.4 Schematic diagram for flexure test setup



Fig.4.5 Flexural strength test

4.11.4.3 SPLIT TENSILE STRENGTH

This is additionally once in a while alluded as "Brazilian Test" as this test was created in Brazil in 1943. This goes under roundabout pressure test techniques. The test was completed by putting a tube shaped example on a level plane between the stacking countenances of a pressure testing machine and the heap was applied until disappointment of the chamber, along the vertical width as demonstrated in Fig.4.6. A solid chamber of size 150mm breadth and 300mm tallness was exposed to the activity of a compressive power along two inverse edges. The chamber was exposed to pressure close to the stacked district and the length of chamber is exposed to uniform malleable pressure.



Fig.4.6 split tensile strength test

4.11.4.4 RC BEAM TEST

A beams with an effective span of 1700 mm are tested under two point loading by using hydraulic jack with the distance between the loading points as 570 mm after 28 days of curing using wet gunny bags at ambient temperature. LVDT is fixed to measure mid-span deflection.

Specimen details:

Main reinforcement = 4 number of 12mm dia bars Stirrups = 8 mm dia bars @ 150mm c/c

Specimen dimension: 230mmx230mmx1500mm

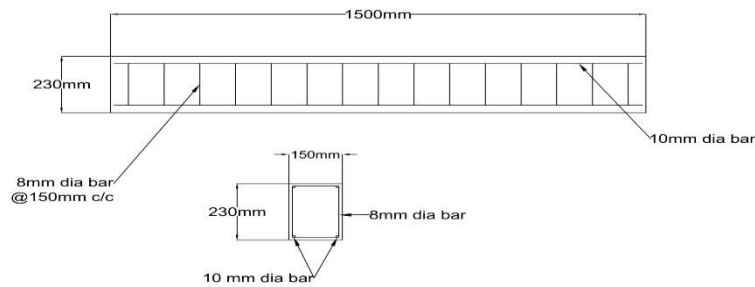


Fig. 4.7 Reinforcement Details



Fig. 4.8 RC Beam Test Setup

4.12 NUMERICAL INVESTIGATION

4.12.1 GENERAL

ANSYS 17.0 Workbench Environment is an instinctive pre-characterized component examination device utilized related to CAD frameworks and/or configuration models. ANSYS 17.0 Workbench is a product climate for performing primary, warm and electromagnetic examination. The class centers around math arrangement and advancement, fusing existing calculation, setting a characterized component model, judging and evaluating results. The class depicts how to utilize code and fundamental limited component reproduction translation of ideas and results.

ANSYS 17.0 is a broadly useful programming used to reproduce the exchange of all controls of physical science, structure, vibration, liquid elements, heat move and electromagnetism to engineers. ANSYS17.0 can import CAD information and help make a math with its "pre-handling" capacities. Likewise, on a similar pre-processor, the limited component model (a.k.a. circle) needed for the estimation is created. In the wake of characterizing the mounts and playing out the dissects, the outcomes can be seen as mathematical and graphical. Progressed designing examines ANSYS can be performed rapidly, securely and for all intents and purposes through its different correspondence systems, time sensitive stacking highlights and non-direct material models.

ANSYS 17.0 Workbench is a stage that incorporates reflection advancements and boundary CAD frameworks with special mechanization and execution. The force of the ANSYS17.0 workbench comes from ANSYS arrangement arrangements with numerous long stretches of involvement. Moreover, ANSYS Workbench's goal is to approve and improve the item in a virtual climate.

4.12.2 ANSYS MODEL DESCRIPTION

In this study, a 3D finite element model was developed using ANSYS V17 to simulate the RC beam similar to a two-point load test. Here it is first analyzed by taking a normal conventional beam, and secondly by a fully covered beam by three sides. Third, he took a beam of the same size and analyzed it by folding all three sides of the beam at 100 mm intervals on a 100 mm wide sheet. Finally, analyzed at 200 mm intervals and examined all three results. Here the model with main reinforcement 12 mm, 8 mm strips and beam cross section 230x230x1500 mm was created.

4.12.3 ANSYS MODELING PROCEDURE

The analysis focuses on

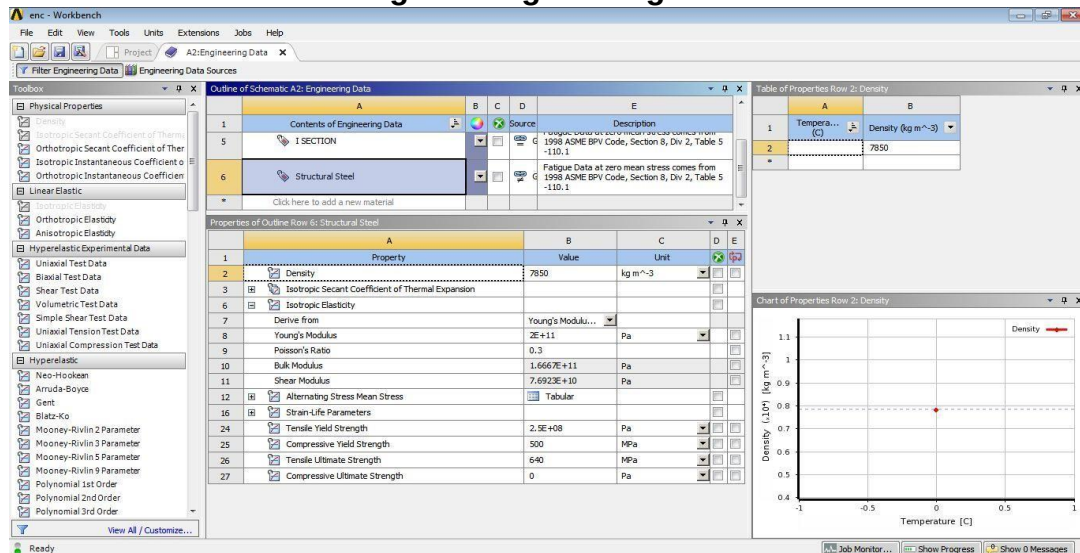
1. Engineering data
2. Geometry creation and optimization,
3. Attaching existing geometry,
4. Setting up the finite element model,

5. Solving and
6. Results.

4.12.3.1 ENGINEERING DATA

Material Properties like grade of steel, concrete etc are given in this in which I have chosen according to my specifications shown in fig.4.9

Fig. 4.9 Engineering Data



4.12.3.2 GEOMETRY CREATION

In this study, the main reinforcement of the model with 12 mm, 8 mm strips and beam cross section 230x230x1500 mm, which is shown in Fig. 4.10

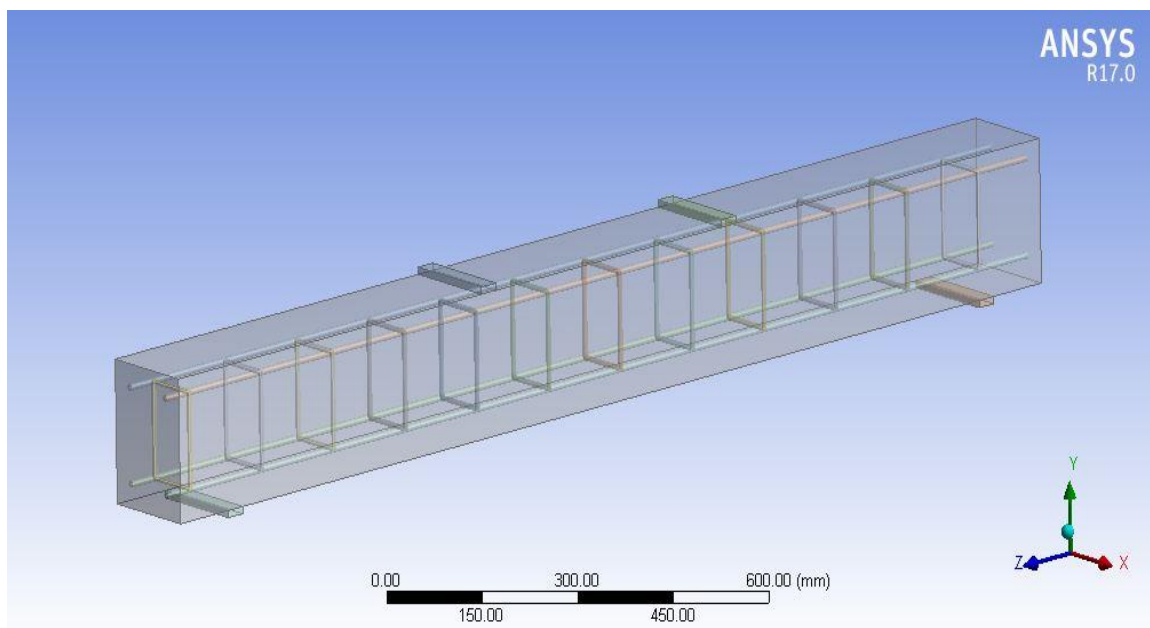


Fig. 4.10 Reinforcement Provision

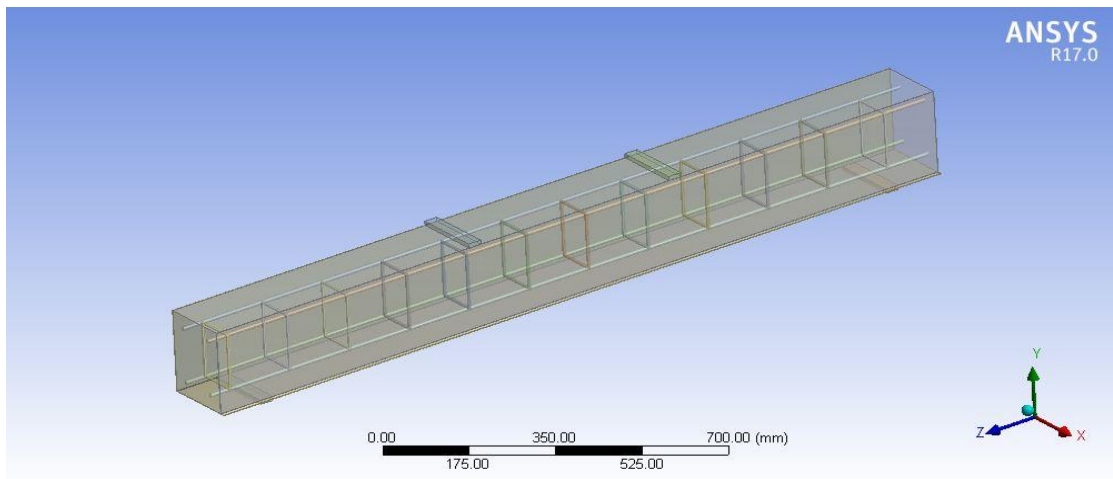


Fig. 4.11 CFRP Wrapped Without Interval

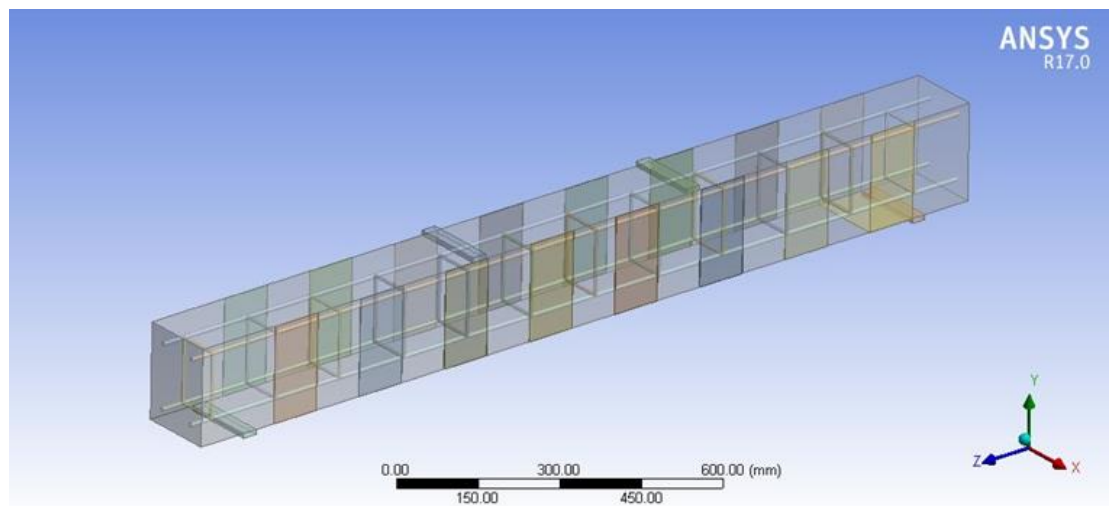


Fig. 4.12 CFRP Wrapped 100mm Interval

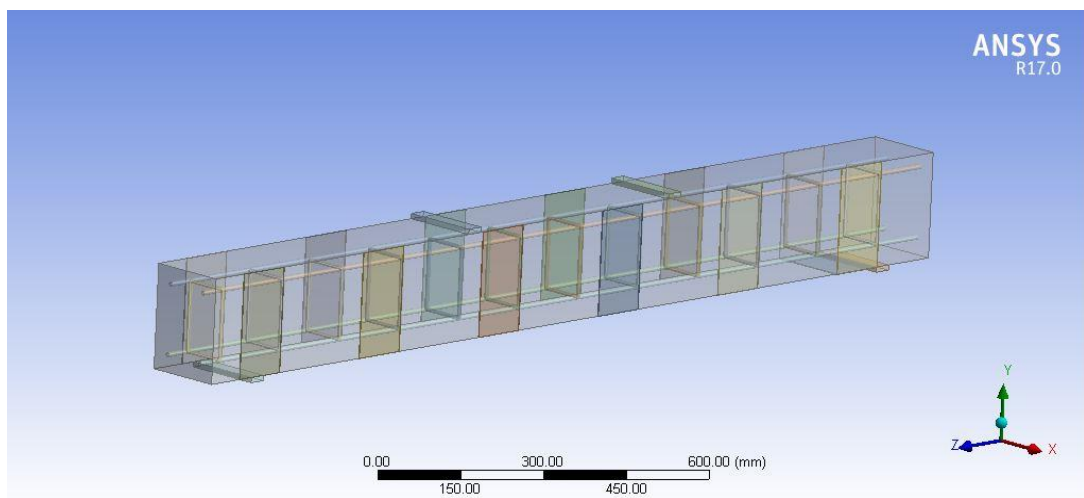


Fig. 4.13 CFRP Wrapped 200mm Interval

4.12.3.3 ASSIGNING THE SECTION PROPERTIES

- Define the properties of a particular part through the sections. After you have created an area, you can assign the area to the current display area using one of the following two methods.
- Select the area from the part and assign the section properties to the selected region.
- Set up the toolkit to create a homogeneous package with the region and assign the area to set.

4.12.3.4 SETTING UP THE FINITE ELEMENT MODEL

After completing the geometry design, I have gone to the modelling phase and assign all the material properties. Then I have generated mesh which helps us in solving the model in finite element method and results can be obtained accurately.

4.12.3.5 MATERIAL PROPERTIES

The material properties are added into workbench data table which are imported from the library which is present in the software.

Table 4.6 MATERIAL PROPERTIES

Material	Density kg/m³	Modulus of Elasticity Mpa	Poisson Ratio
Concrete	2400	32	0.2
Steel	7850	2×10^5	0.3
CFRP (UDC) 1mm (Tk)	49823	234500	0.28

4.12.3.6 MESH GENERATION

The Mesh generation is applied to convert larger size particles into the number of nodes. The process of generating the nodes is called Discretization. This process helps to apply the loads in each node, so the load will distribute throughout the structures shown in fig.4.14

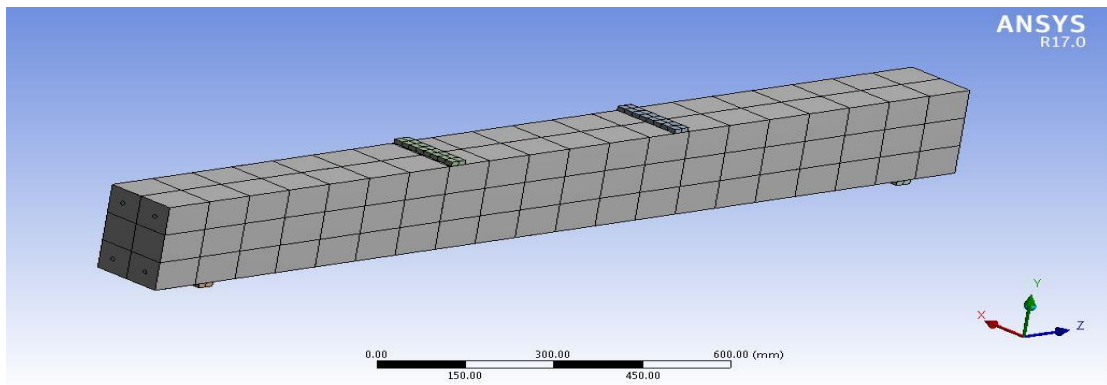


Fig. 4.14 Mesh Generation of Control beam

4.12.3.7 LOADING PATTERN

The RC beam were applied two point load to investigate the failure modes and improvement in strength as shown in fig.4.15

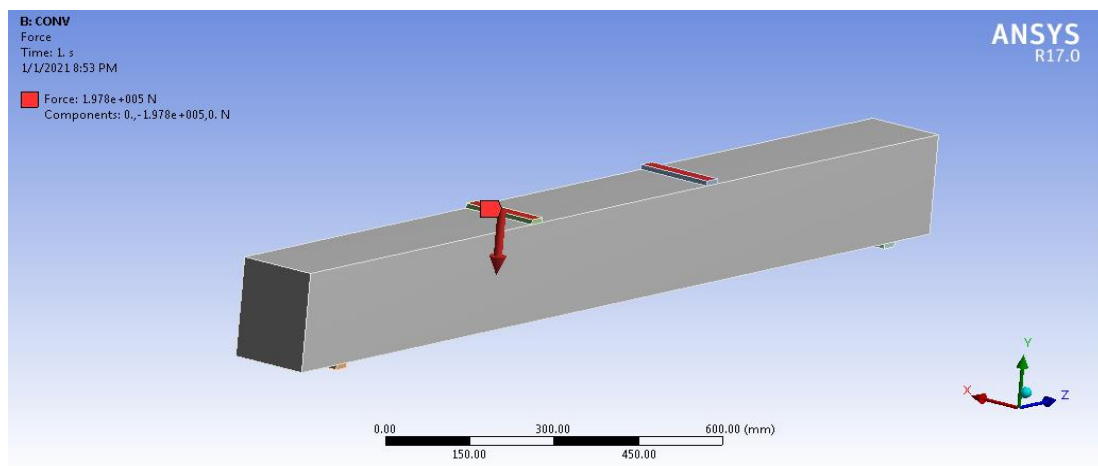


Fig. 4.15 Loading pattern

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 INTRODUCTION

The Experimental examination and mathematical reenactment investigation are conveyed by considering different boundaries on the RC pillar wrapped with FRP has been done to track down its underlying presentation. The outcomes from the parametric examination are talked about in this

5.2 EXPERIMENTAL RESULTS

5.2.1 *Compressive strength*

The results of the mechanical properties obtained based on the specimens tested 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 5.1.

Table: 5.1 Compressive strength of M 25 grade

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

From the table it is observed that rate of gain in Compressive strength is more at 28 days compared to 14 days.

5.2.2 *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 5.2.

Table: 5.2 splitting tensile strength of M 25 grade

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

From the table it is observed that rate of gain in splitting tensile strength is more at 28 days compared to 14 days.

5.2.3 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 5.3.

Table: 5.3 Flexural strength of M 25 grade

MixType	7Days N/mm ²	14Days N/mm ²	28Days N/mm ²
M25	2.13	2.98	3.42

From the figure it is observed that rate of gain in Flexural strength is more at 28 days compared to 14 days.

5.2.4 RC BEAM

The beams was subjected to two-point loading after 28 days of curing. Three LVDTs were placed below the two-point loading supports and mid-point. For every 4 kN, three deflection values were noted. The first crack load for the conventional beam was 65.3 kN and for fully wrapped (without interval) beam 140kN and for 200mm interval CFRP wrapped beam was 110kN and finally 100mm interval wrapped CFRP beam was 95kN which was greater than the first crack load for the Conventional beam was observed to be 65.3kN.



Fig 5.1 Experimental setup on conventional beam

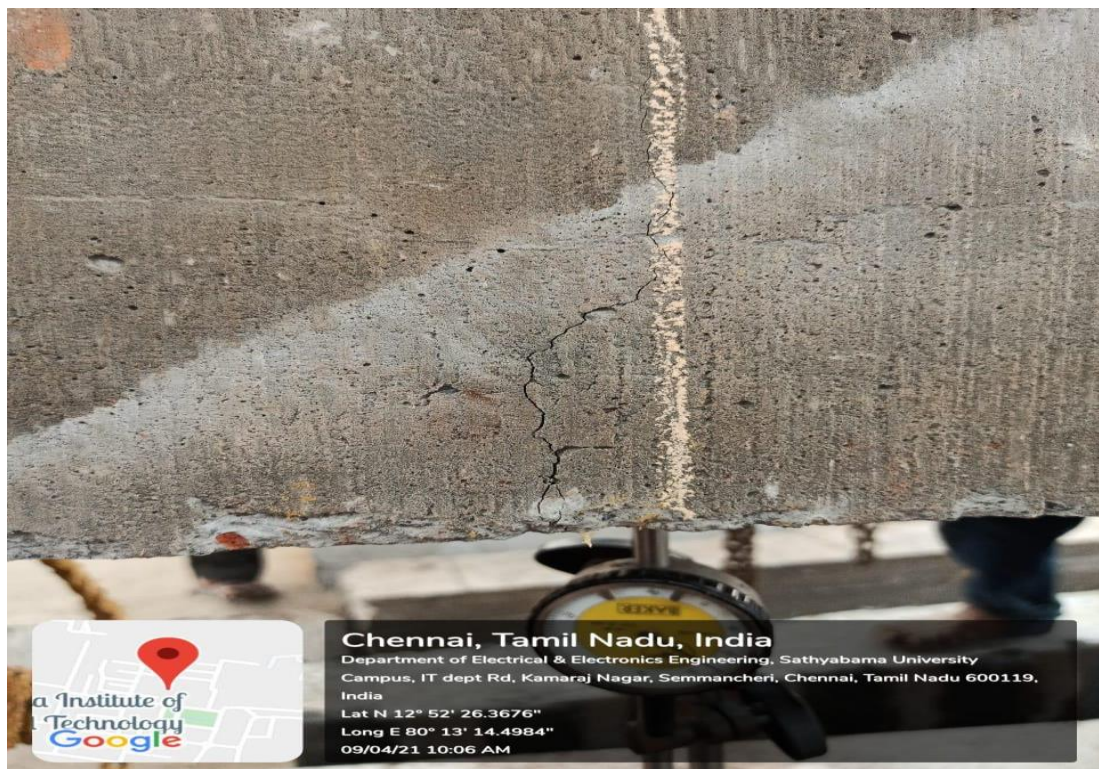


Fig 5.2 First crack on conventional beam



Fig 5.3 Experimental setup on CFRP fully wrapped beam



Fig 5.4 cracks on the sides of CFRP fully wrapped beam

This was due to the fully wrapped (without interval) beam bridges the hair cracks and it delays the first crack load, for the same fully wrapped (without interval) beam ultimate load was more than the 100mm and 200mm interval beam greater than the conventional beam.

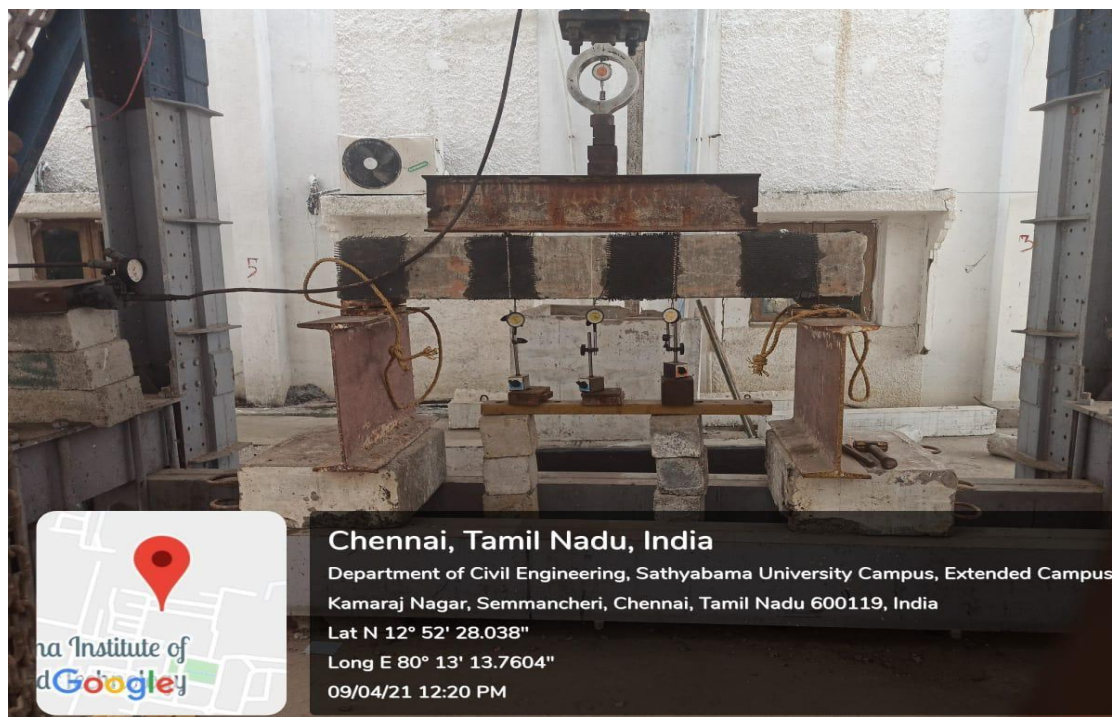


Fig 5.5 Experimental setup on CFRP wrapped beam with 200mm interval



Fig 5.6 First crack on CFRP wrapped beam with 200 mm interval

This clearly shows that the adding 200mm interval beam to the concrete does not much contribute in the strength development. As the loading increased, hair cracks were appeared at the bottom of the beam and transverse towards the top of the beam. The interval spacing is reduced the load carrying capacity increased. The comparison of first crack load and ultimate load for the beams was shown in figure 5.9.



Fig 5.7 Experimental setup on CFRP wrapped beam with 100 mm interval



Fig 5.8 First crack on CFRP wrapped beam with 100 mm interval

Comparing to other beams cfrp wrapped beams with 100 mm interval shows less load carrying capacity than other beam which is greater than the conventional beam. A less amount of capacity increased in 100mm interval beam.

A bar chart is shown in order to view the clear result of first crack developed on other beams and ultimate load on the beams achieved.

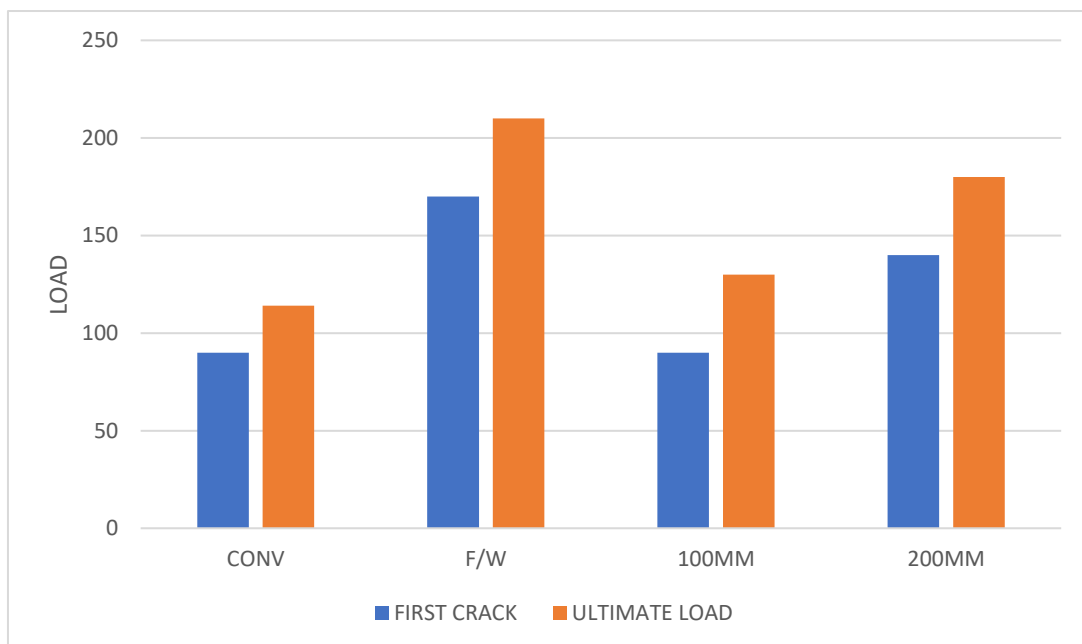


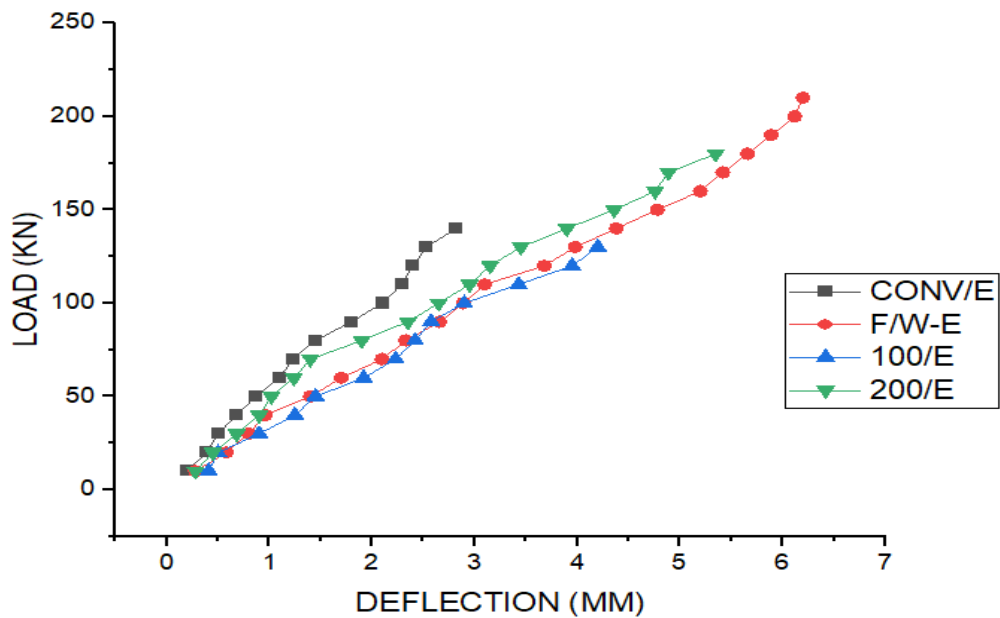
Figure 5.9 Comparisons of First Crack Load and Ultimate Load

Table 5.4 Experimental result

SI.No	Specimen Designation	Ultimate Load (KN)	Deflection (mm)
1	Conventional Beam	114	2.4
2	Fully wrapped (W/o Intervals)	210	6.2
3	WB-1-100mm Interval	130	4.2
4	WB-2-200mm Interval	180	5.3

5.2.5 LOAD-DEFLECTION BEHAVIOUR:

The load–deflection curve for all the beams were plotted. The comparisons of load-deflection curve for the conventional, fully wrapped (without interval) beam, 100mm interval and 200mm interval beam was shown in figure 5.10. The deflection values of conventional beam were larger compared to other beams.



**Fig. 5.10 Load Vs Deflection Curve for all Beams
(Experimental Result)**

5.3 NUMERICAL RESULTS

The numerical analysis is conducted for the parametric study. The stress contour of conventional RC beam, CFRP wrapped Without interval ,100mm and 200 CFRP wrapped interval RC beam are shown in Figs. 5.11 ,5.12 ,5.13 and 5.14. It is observed that the beams Table 5.5 shows the load–deflection values obtained using Ansys results.

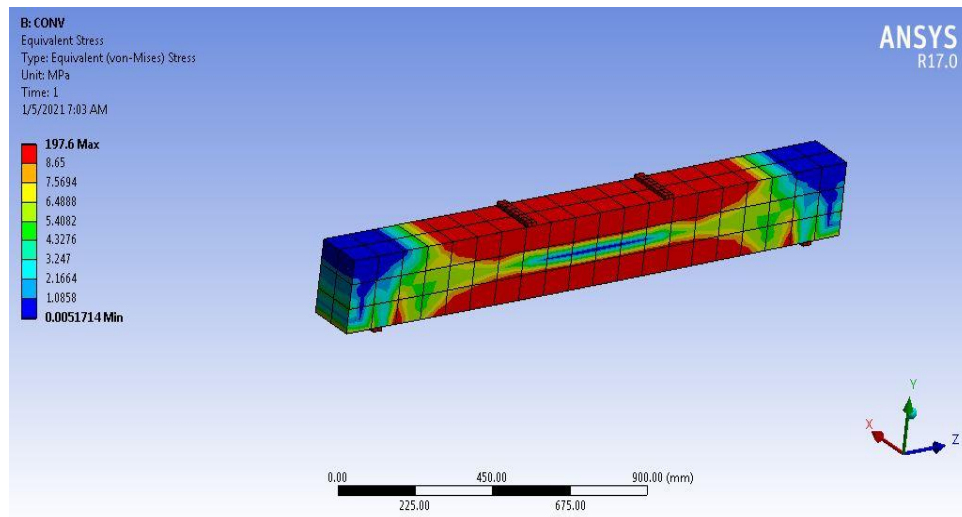


Fig. 5.11 Conventional Beam – Stress Contour

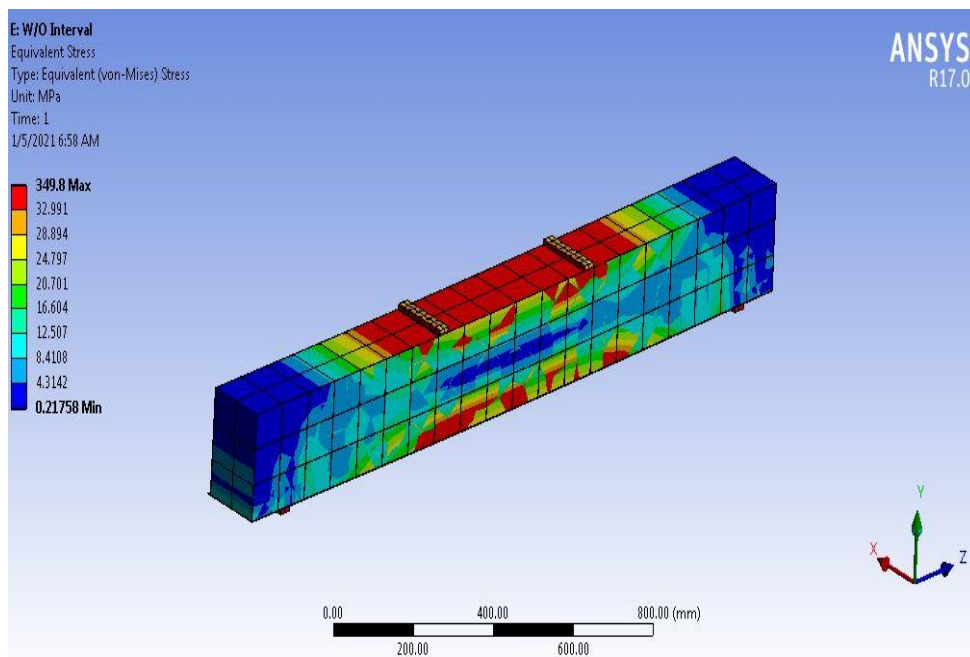


Fig. 5.12 CFRP Wrapped Without Interval – Stress Contour

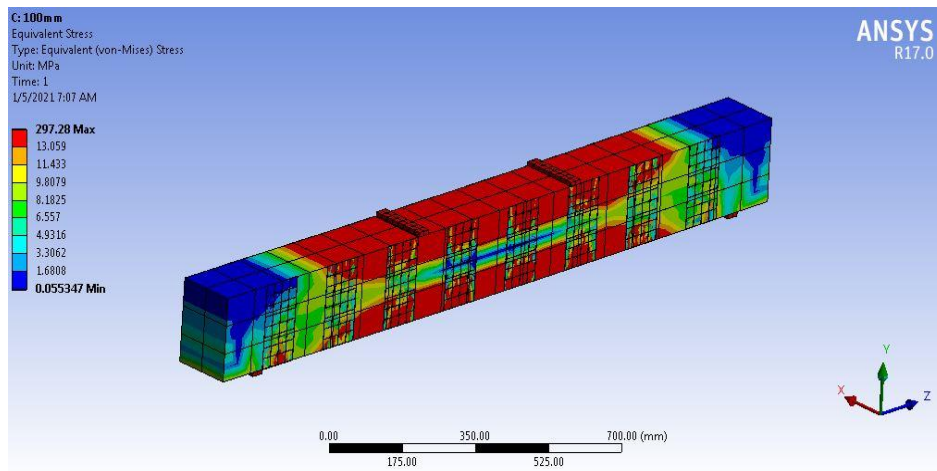


Fig. 5.13 CFRP Wrapped 100mm Interval – Stress Contour

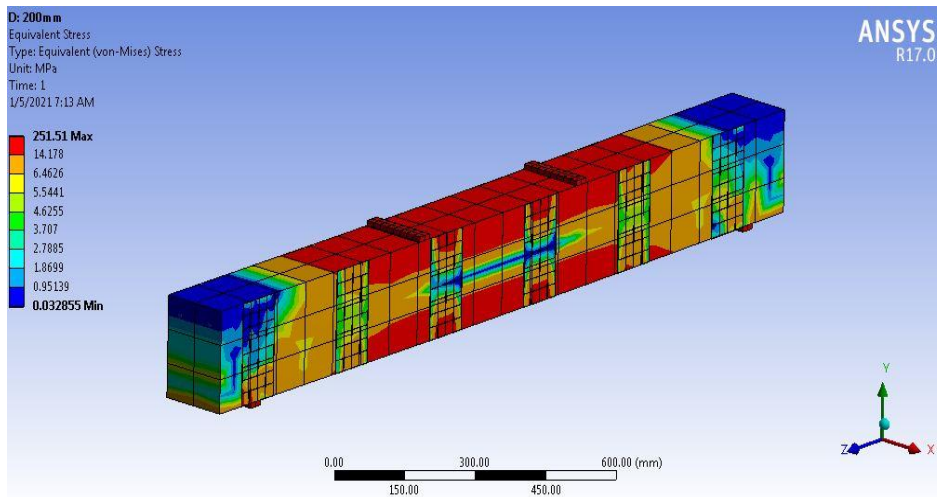


Fig. 5.14 CFRP Wrapped 200mm Interval – Stress Contour

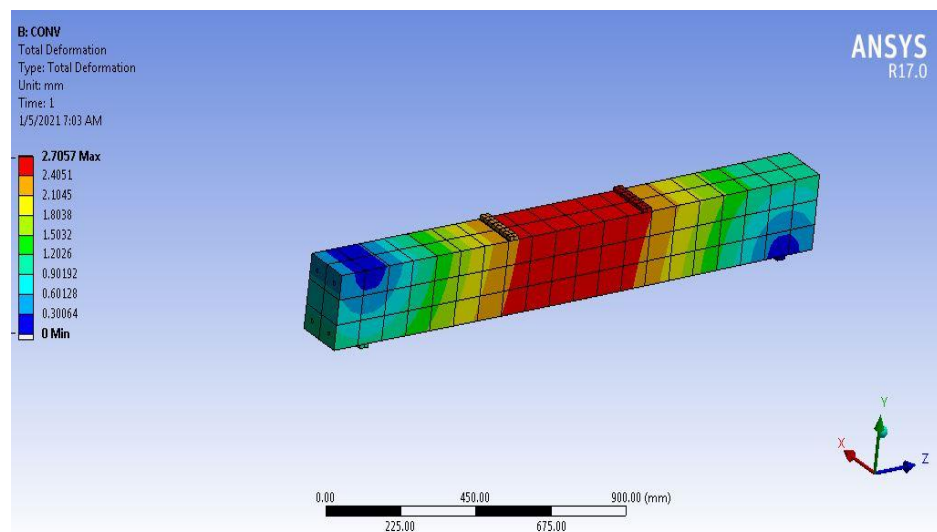


Fig. 5.15 Conventional Beam – Deflection Profile

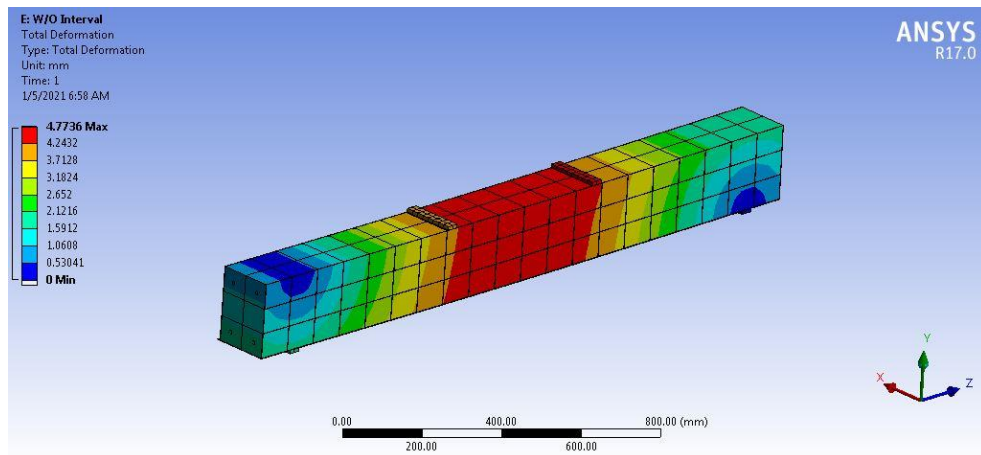


Fig. 5.16 CFRP Wrapped Without Interval – Deflection Profile

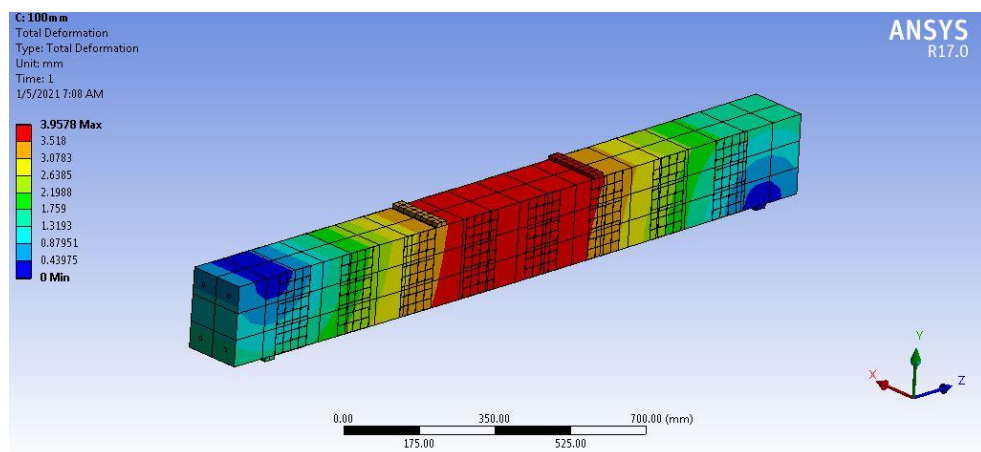


Fig. 5.17 CFRP Wrapped 100mm Interval – Deflection Profile

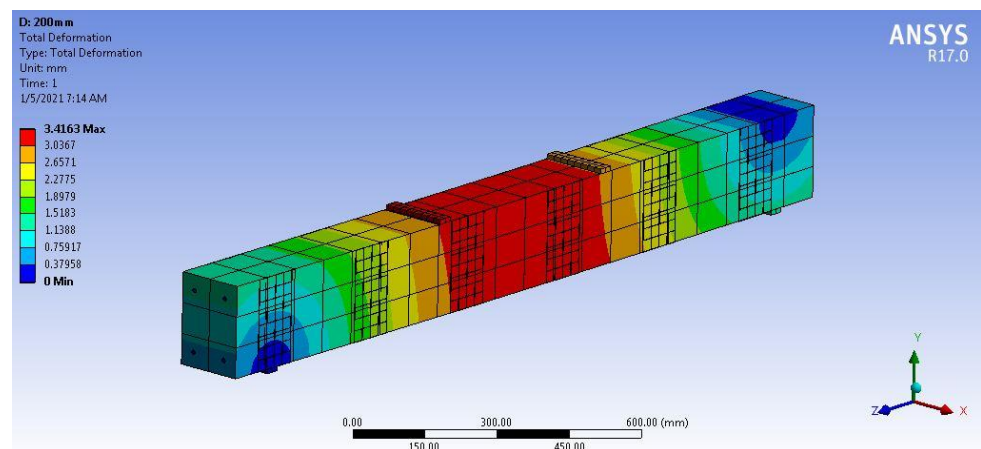
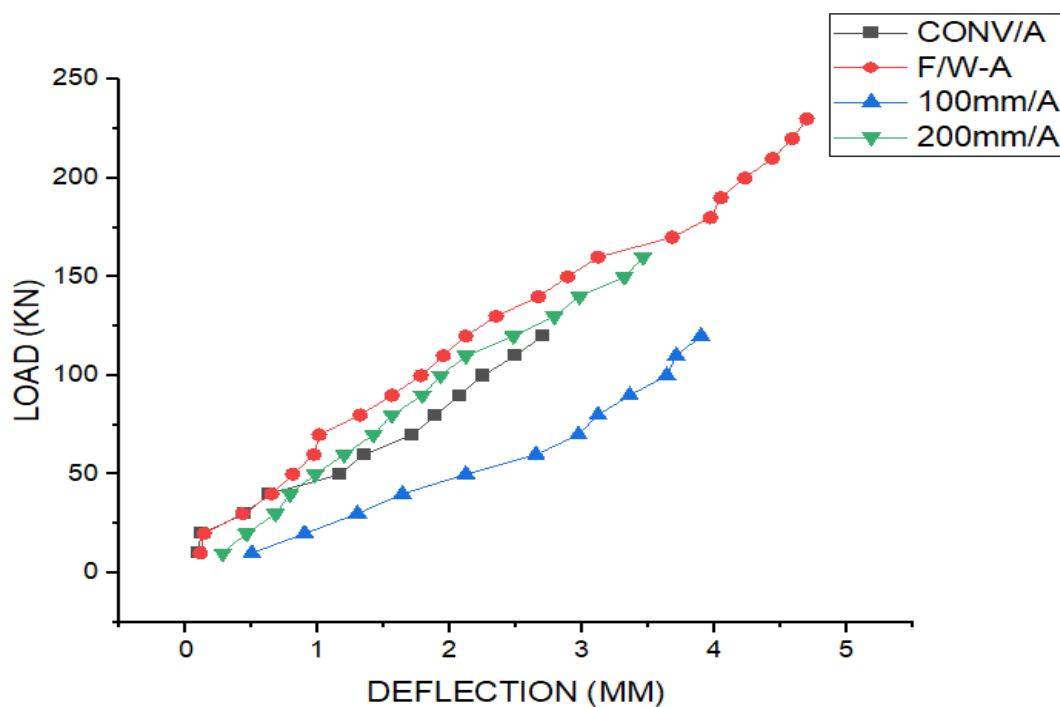


Fig. 5.18 CFRP Wrapped 200mm Interval – Deflection Profile

Table 5.5 Ansys Results

Sl. No	Specimen Designation	Ultimate Load (KN)	Deflection (mm)
1	Conventional Beam	120	2.7
2	Fully wrapped (W/o Intervals)	230	4.7
3	WB-1-100mm Interval	120	3.9
4	WB-2-200mm Interval	160	3.5



**Fig 5.19 Load Vs Deflection Curve for all Beams
(Numerical Result)**

5.4 COMPARISON OF EXPERIMENTAL RESULTS WITH ANALYTICAL RESULTS

Figure 5.20,5.21,5.22,5.23 shows the load –deflection curves comparison obtained using ANSYS and experimentally for various interval wrapping of CFRP. Results obtained from Ansys Finite Element Analysis were compared with the experimental results. It is observed that the Ansys Finite Element Analysis results were less coincide with the experimental result.

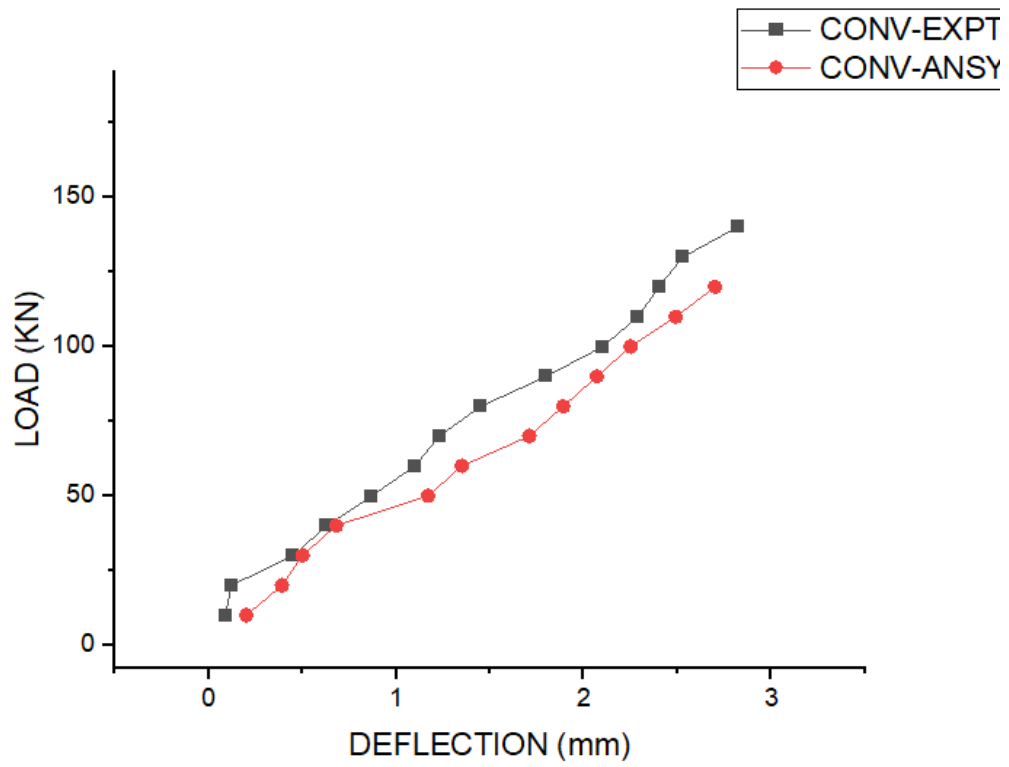


Fig 5.20 (conventional beam)

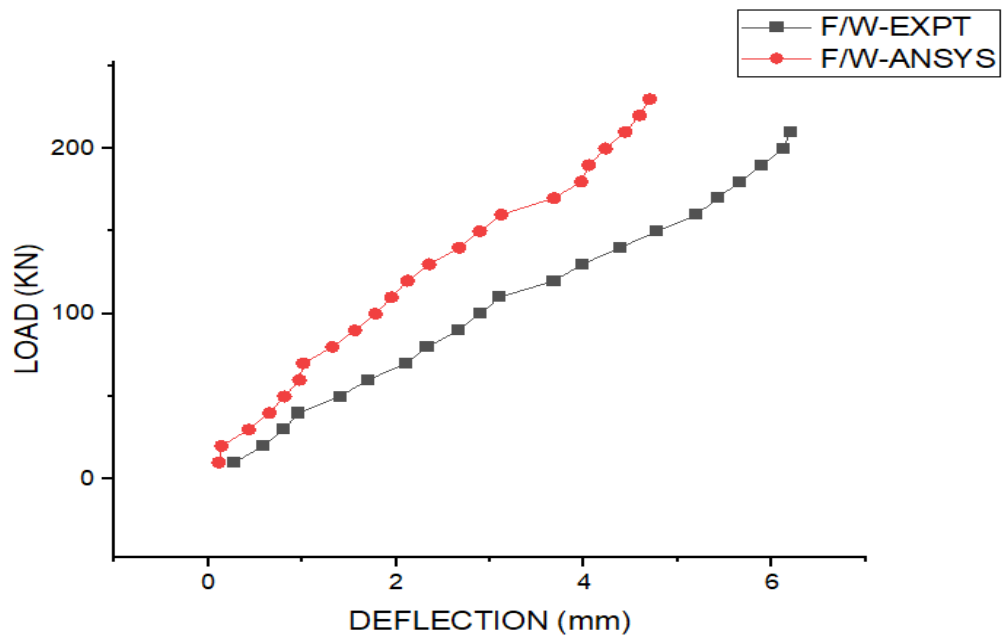


Fig 5.21 (CFRP fully wrapped beam)

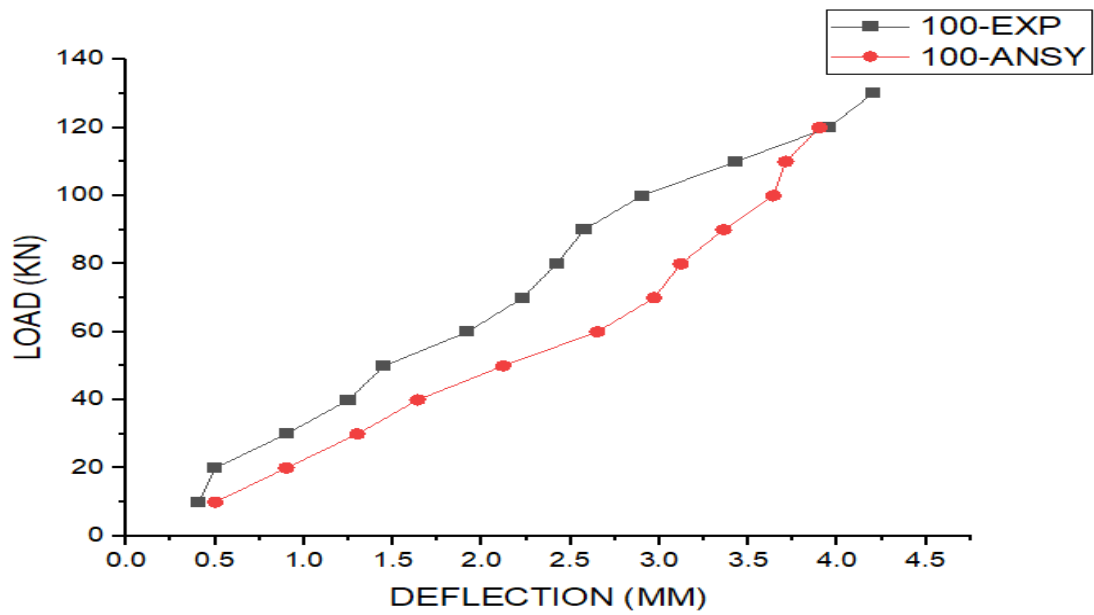


Fig 5.22 (CFRP wrapped beam with 100 mm interval)

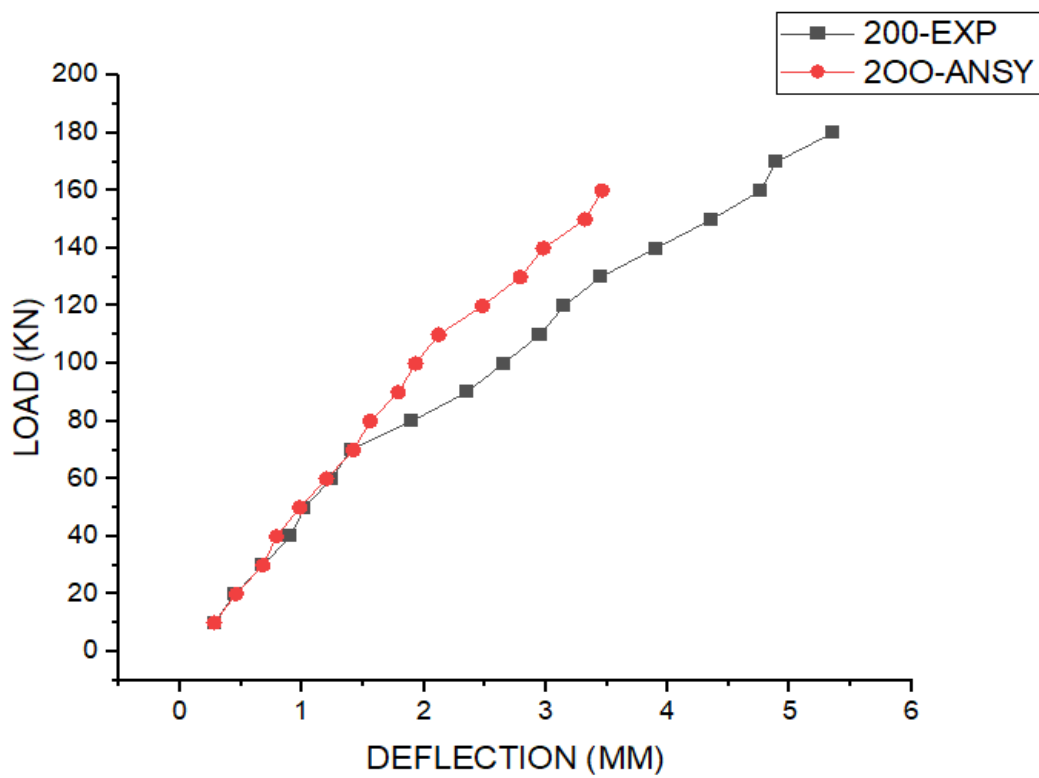


Fig 5.23 (CFRP wrapped beam with 200 mm interval)

CHAPTER 6

CONCLUSION

The reinforced concrete beam strengthened with FRP has much greater advantageous than the normal reinforced concrete beam. In this project, various literatures were collected to get an idea about the FRP materials. Numerical and experimental analysis of various interval of FRP strengthened beams was done and its results are obtained.

The beams were analyzed using 2-point load test and flexural cracks has been observed. From the study it shows that use of CFRP showed an improvement in both the ways and also increase the flexural capacity of the beam and it helps to increase stiffness under service loads. It also helps to reduce the deflection in both ways.

The future experimental work is needed to understand the behaviour RC beam with FRP through the design construction, instrumentation and testing of beams and also future work is needed to develop the recommended revisions to extend the current design provisions to account for the nature of FRP reinforcements.

It shows that CFRP has good effectiveness for increasing the load carrying capacity, cracks and stiffness for the concrete beams.

From this project it has been observed that CFRP strengthening method is one of the cost-effective methods and it reduces the flexural failure of the beam.

The interval wrapping spacing is reduced the load carrying capacity increased.

The value thus obtained is shows that the increase of load carrying capacity by strengthening with CFRP.

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