NUMERICAL AND EXPERIMENTAL INVESTIGATION OF CONCRETE BEAM REINFORCED WITH STEEL AND FRP BAR UNDER FLEXURAL ACTION

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Submitted in the partial fulfilment of the requirements for the degree of

Bachelor of Civil Engineering

Faculty of Architecture and Civil Engineering

MEHRAN UNIVERSITY OF ENGINEERING & TECHNOLOGY,

JAMSHORO

(October,2022)

CERTIFICATE

This is to certify that "Final Year Project-I Report on, **"Numerical and Experimental Investigation of Concrete Beam Reinforced with Steel and FRP Bar Under Flexural Action"** is submitted in partial fulfilment of the requirement for the degree of Bachelor of Civil Engineering by the following students:

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DEDICATION

This research study is wholeheartedly dedicated to our beloved parents, who have been our source of inspiration and always gave us strength and motivation and supported us morally, spiritually and financially. This research study is also dedicate to all our teachers for their guidance, motivation and continuous support for accomplishing our goals and straightening out our path. Insha'Allah we will do our best to achieve desired goals our life and certainly will be a reason that our parents and teacher may be proud of.

ACKNOWLEDGEMENT

We would like to acknowledge everyone who played a role in my academic accomplishments. First of all, We would like to thank Almighty Allah who is the supreme power and who has always shown me the right path gave strength to accomplish my task of thesis we are thankful to my parents who always supported us and looked best out of us. We are whole- heartedly thankful to my supervisor Engr.Rabinder Kumar.

ABSTRACT

Steel free concrete beams are new and innovative concept in structural engineering in recent days. Reinforced concrete is a widely used composite material made up of concrete and steel. The tensile strength of concrete corresponds to 1/10th of the compressive strength. To improve this steel is added to take the tension and leave the concrete to take compression. The long-term serviceability of concrete structures may be reduced due to corrosion of rebars which affects the overall integrity and serviceability of a structures. Fiber Reinforced Polymers (FRP) seems to be an alternative to steel rebars to counter corrosion related issue. The use of FRP bars as reinforcement in concrete beams have promising benefits over steel reinforced concrete beams. Such as less corrosion, higher flexural strength. However, the failure patterns of FRP reinforced beams under flexure action are still not well investigated. So, this research investigates the FRP reinforced beams under flexure action it can be used for various structural applications.

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INTRODUCTION

1.1 BACKGROUND

In recent century, many structural engineers have used reinforced concrete (RC) in building construction. Reinforced concrete is a composite material from concrete and steel. Steel reinforcing is a steel bar or meshes of steel wires embedded in concrete and makes use of as a tension device in reinforced concrete by bearing the concrete in compression wherein RC is fire resistant whereas The Fibre Reinforced Polymers(FRP) composite materials have experienced a continuous growth of use in structural strengthening and in repairing in last decade. Because FRP is Light weight-easily handled and transported, high strength to weight ratio, Corrosion resistant-will now no longer corrode(Nonmagnetic) and Environmentally safe.

Furthermore, RC works like an inflexible member with minimal deflection. The RC in the tensile strength correspond to (1/10) of the compressive strength. The maximum trouble that is available in RC is flexural crack failure as may be visible in . The flexural cracks begin on the tension face and could extend, at most, upto the neutral axis. In the general, cracking in reinforced concrete members is of a complicated nature. On the one side it entails diverse mechanisms and parameters associated with the interaction among concrete and reinforcement, geometry, sort of loading and support conditions.

The finite element method has been used to offer numerical solution to the behaviour of RC failure. One of the commercial software is ABAQUS software which handles the RC failures and which also shows the plasticity damage model for RC. This technique is much less steeply-priced as compare to experiment. Finite element method is implemented to analyses reinforced concrete structures primarily based totally on the usage of non-linear behaviour of the materials.

Cracks had been extreme issues withinside the structural characteristics of a building. They can appear anywhere; however arise specifically in walls, beams, columns, and slabs.

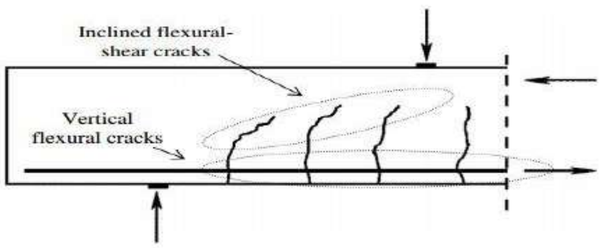


Figure 1.1: Flexural Crack Failure

FRP reinforcements and steel reinforcements have distinct and dissimilar mechanical properties, for example, FRP reinforcements exhibit linear-elastic and brittle stress-strain behaviour and have high tensile strength but exceptionally low strength in compression and shear. As a result, the performances of FRP bars in reinforced concrete beams and steel bars in reinforced concrete beams subjected to flexural actions are likely distinct from one another, which merits further investigation. Steel corrosion should reduce the strength and stiffness of steel reinforcements.

1.2 PROBLEM STATEMENT

The steel reinforcement is widely used in construction of many projects but due to its corrosion effects the structure rusts which is irreversible deterioration and causes reduction of reinforcement area which influences the long-term performances on structures. The other issues that occur in steel reinforcement are much labor cost due to its heavy weight, less economical.

Whereas FRP Bars will never corrode or rust and the most important feature of the polymer is its corrosion resistance, as well as its elongated strain to failure, which provides enough time to alert before failure occurs when compared to steel reinforcement. The other major point is that the FRP maintain its high strength while being a very lightweight material as compare to steel reinforcement. and need a very high maintenance due to which there should be more use of Fibre Reinforced Polymers (FRP). Thus we decided to analyze material behaviour effect of both materials by experimental and numerical method under flexural action.

1.3 AIMS AND OBJECTIVES

The purpose of this study is to look into the flexural behaviour of concrete beams reinforced with steel and FRP bars.

I. To investigate the flexural behavior of concrete beams reinforced with steel and FRP bars experimentally.

II. To investigate the flexural behavior of concrete beams reinforced with steel and FRP bars numerically using ABAQUS.

III. To contrast experimental and numerical results of Concrete beams reinforced with steel and FRP bars are analysed.

1.4 SCOPE OF RESEARCH

The purpose of this research is to run numerical simulations using the commercial software ABAQUS, which is used commonly to simulate the RC structures under loads. It demonstrates that numerical simulations can produce reliable solutions, and the obtained results are then compared to laboratory experiments. To visualise the non-linear behaviour of the materials, the ABAQUS software depicts the crack behaviour of concrete beams with steel bars and FRP bars under flexural action.

Chapter-2

LITERATURE REVIEW

2.1 REVIEW

In this work an attempt has been made to aim a numerical and experimental study for concrete in which reinforcement steel and FRP bars have been embedded to recognize the crack propagation in RC beam to model the materials behaviour ,so one of commercial software which is abaqus software which clearify the RC failures and shows its damage model.In this chapter, we will study the review of studies conducted on this work and will observe the performance and behaviour of plasticity damage models.

2.2 HISTORICAL BACKGROUND

Abaqus was originally spelled ABAQUS instead of ABAQUS when it was initially launched. Hibbitt, Karlsson & Sorensen was created in January 1978 by Dr. David Hibbitt, Dr. Bengt Karlsson, and Dr. Paul Sorensen to develop and distribute ABAQUS software. Karlsson met Hibbitt and Sorensen while working as a support analyst at a Stockholm data centre, while Hibbitt and Sorensen met while working on their PhDs at Brown University. ABAQUS was designed to analyse nonlinear structures in both static and dynamic modes, as well as nonlinear steady and transient heat transport and conduction problems. Many other software programmes have been developed with the objective of addressing non-linear physical behaviour and showing finite element analysis results, such as:

- Agros2D
- CalculiX
- DIANA FEA
- FEniCS Project
- FreeCAD
- Advance design Software
- Autodesk Simulation
- ANSYS
- VisualFEA

Abaqus is more professional, greater in accuracy than the others and it is a friendly user software. It's a programme for modelling, analysing, and visualising the results of finite element analysis on mechanical components and assemblies.

2.3 CRACK PATTERNS IN BEAMS

Flexure Cracks in Reinforced Concrete Beams

Flexure cracks are occurred When beams are subjected to high flexural stress and low shear stress and when the beam cross section is insufficient when it has more load loads than the defined loads.

Shear Cracks in Reinforced Concrete Beams

Shear cracks are frequently formed as a result of structural pressure or movement. Due to the combined impacts of flexural and shearing action, these cracks are diagonal tension cracks.

Torsional Cracks in Reinforced Concrete Beams

These are the collection of inclined cracks runningroughly parallel during the period of the member.

Corrosion Cracks in Reinforced Concrete Beams

Corrosion cracks in concrete beams runs besides the reinforcement.

Shrinkage Cracks in Reinforced Concrete Beams

When new concrete is exposed to rapid moisture loss, shrinkage fractures develop.Shrinkage cracks in reinforced concrete beams also occur due to improper curing or lack of control over the water-cement ratio.

Sliding Cracks in Reinforced Concrete Beams

These types of cracking in concrete occur when the concrete is disturbed in its fresh condition and mainly occur at the edge of the beam supports.

Tension Cracks in Reinforced Concrete Beams

These varieties of cracks when the tensile reinforcement is insufficient. Mostly those cracks seem because of shrinkage or temperature variations.

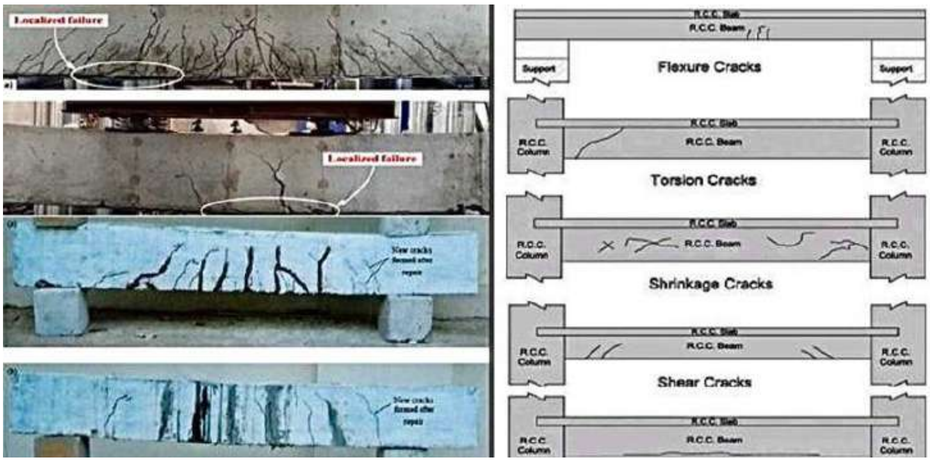


Figure 2.1: Crack Pattern In Beams

2.4 PREVIOUS RESEARCHES

- **Hasni et al (2021) Attempt a numerical model for the concrete with embedded reinforcement steel to predict the crack propagation in RC beam.**

- **Chen et al (2018). The numerical and the experimental study on the rc beams embedded with the frp bar under impact loads.**

- **Et al Luc(2019),studied the experimental analysis of the ecc-concrete composite beams with the frp bars under the flexural action.**

- **Numerical Investigation of the Behavior of Reinforced Concrete Beam Reinforced with FRP Bars, et al Zhou(2018).**

This experiment investigated the conduct of strengthened concrete beam, strengthened with FRP bars, based on finite element software (ABAQUS).

- **Evaluation of reinforced concrete beam behaviour using finite element analysis by ABAQUS,et al Shariati,(2012).**

  This study determines the non linear behaviour of rc beams when subjected to the flexural loadings.

- **Finite Element design of the RC Beam-Column Connections with Joint Shear Failure Mode. Et al Dehghan(2017).**

  The numerical results are compatible with the experimental data in terms of joint shear capacity, deformations, and cracking pattern at critical spots in joint shear behaviour.

- **Behavior of Reinforcement Concrete Beams Using Steel Strips as a Shear Reinforcements. Et al Ammash(2017)**

  In this paper, experimental Reinforced Concret beams which uses the steel strips contrast to the bar strips have been determined.

  Some other related researches are;

- **Et al Zhang,Pang (2017), Worked On the Finite Element computation Of Anti-Bending Of Early Age RC Beam Based On Bond-Slip Constitutive.**

- **Et al Saleem,Khurram (2017), computed the Finite Element Simulation Of Reinforced concrete Beams Under Flexure action With Fiber Reinforced Polymer (Frp) Sheets.**

- **Et al Seok (2019).Finite Element analysis Of Bond-Zone Behavior In RC beam.**

2.5 SUMMARY OF THE CHAPTER

This chapter discusses finite element modeling of RC beams under flexural action. It also includes a brief introduction and related terms of beam cracks and their causes, furthermore the detailed review of the literature of different researchers have been studied and For a reinforced concrete beam subjected to flexural loading, compares the computational and the experimental results and thoroughly observed their results and conclusions.

Chapter-3

METHODOLGY

3.1 OVERVIEW

This chapter provides an overview of the types of research pursued within the framework of thestudy.this study is composed in the form of the experimental and numerical investigation of the rc beam with steel and frp bars. The software which is used in this modeling is known as abaqus software. These two methods are used to analysis the rc beam and the with steel and FRP bars under the flexural action.
The design and analysis of beam is conducted in both ways i.e Numerically and Experimentally Analsysis. The process of each study is defined individually.

3.2 NUMERICAL ANALYSIS

ABAQUS is a set of finite element analysis programs originally developed by Hibbitt, Karlsson and Sorensen. The software used is ABAQUS which is the simulation tool used to analysis and complex problems of engineerings.

The numerical analysis in general is a complete ABAQUS simulation which is consists of the three different distinct stages,which have their own function from the modeling to the visualization through which the results are obtained:

1) Preprocessing
2) Simulation
3) Post-processing

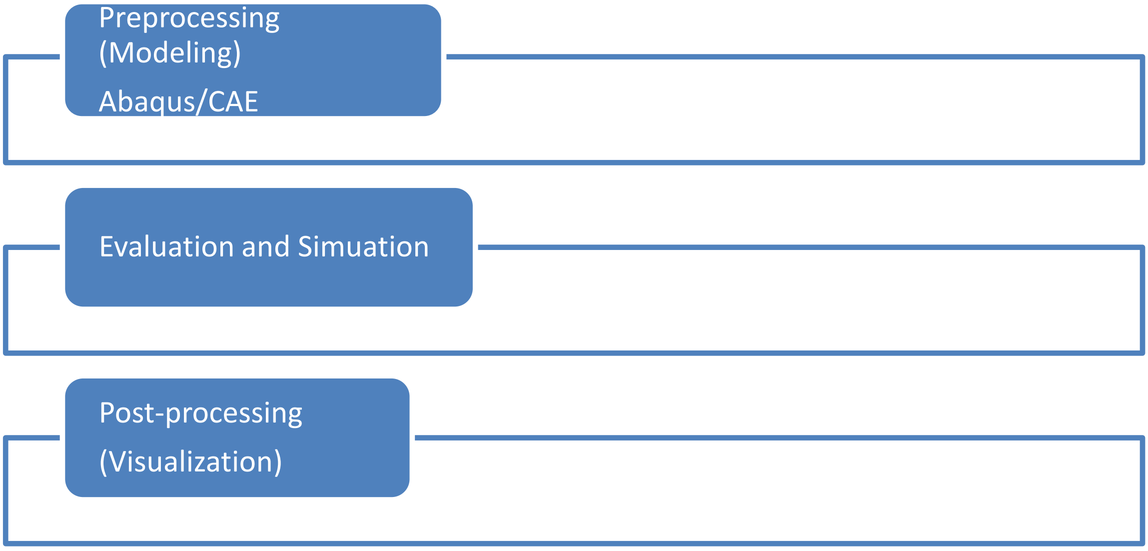


Figure 3.1: Stages of ABAQUS Simulation

Structural Modeling

The analytical modeling in ABAQUS consists ofdiverse steps and those steps are referred to as modules, whereinevery module defines anfactor of the modeling process; for example, defining the geometry, defining material properties, and generating a mesh. The modeling contains 10 modules which are shown in the figure below and these describes the whole process in each module.Each modules has their own function which are mentioned in the Abaqus modules .

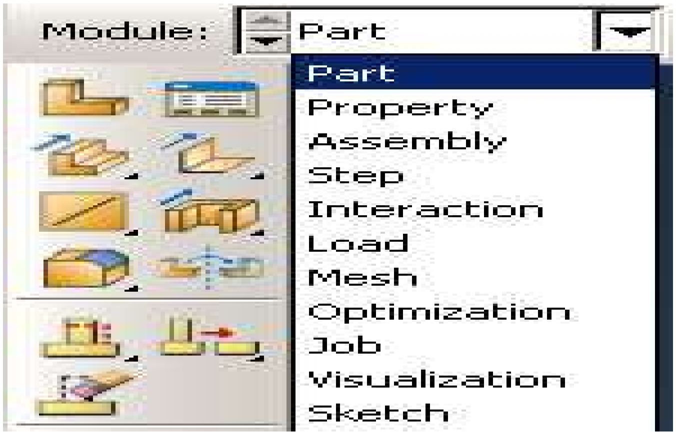


Figure 3.2.1.1: Modules Of Abaqus/CAE

It is necessary to insert all these modules to create a complete analysis of model, as mentioned and described below:

1. Part

Create individualelements or partsthrough sketching or importing their geometry.

2. Property

Generate the section properties and define the properties of material then describe to the part areas. The following steps should be considered:

- ✓ Specify the materials.
- ✓ Classify the beam section profiles.
- ✓ Sections need to be characterised.
- ✓ It is necessary to assign sections and the orientations.

3. Assembly

Create and assemble the part instances. The assembly includes the following parts:

- ✓ Beam
- ✓ Reinforcement bars
- ✓ Stirrups
- ✓ Supports

4. Step

In this step it is necessary create and define the analysis steps. It contains the following steps.

- ✓ To produce the analysis steps of the model
- ✓ Identify the output requests
- ✓ Describe adaptive meshing

5. Interaction

Specify the interactions, including contact, among the areas of a model, you should suggest wherein steps of the evaluationthey'reactive. For example, to insert the the loading at the required points of model.

You can define the following objects:

- ✓ The Constraints which are imposed by ties.
- ✓ The Constraints on embedded regions
- ✓ The Constraints on coupling
- ✓ The Constraints which are imposed by rigid bodies.

6. Load

In this section, the differents loadings are defined to the model.

7. Mesh

Meshing is the important section in which a beam is messed.it helps to identify the excat region of the deformation of the beam model.

8. Optimization

It only calculates the final design of the model.

9. Job

In this section a job is created and submitted it for analysis and monitor its progress.

10. Visualization

To view the consequences of the analysis. The Visualization module presents graphical display of model of finite element and its results. You can view model and consequences information from an output database via way of means of generating different defined plots.

3.3 GENERAL ABAQUS ASSUMPTIONS

The user enters the beam elements' cross-sectional geometry, and the ABAQUS compute the cross-sectional properties, including the region and moments of inertia. For elastic – plastic analyses, ABAQUS shows the yield moment, plastic moment, and compression and tensile forces at yield.. Element is able to show the plastic deformation, cracking in three orthogonal directions, and crushing.

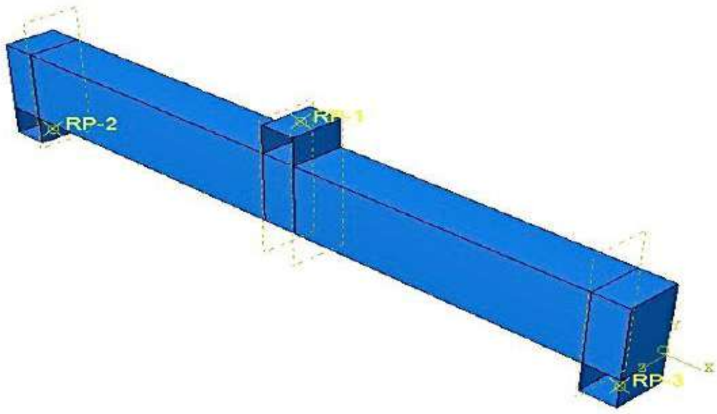


Figure 3.3.1: Solid model

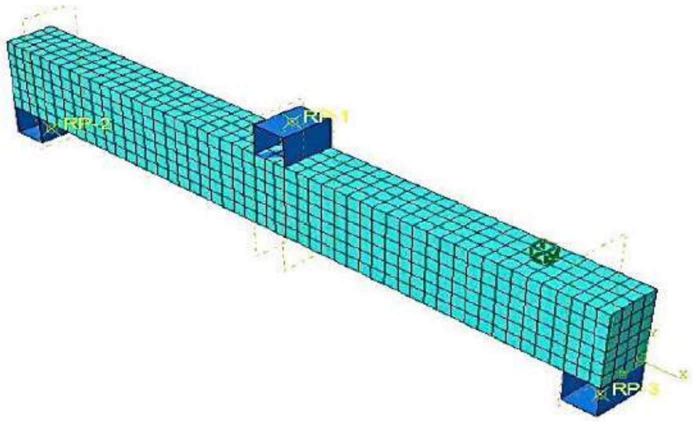


Figure 3.3.2: Meshing of concrete beam

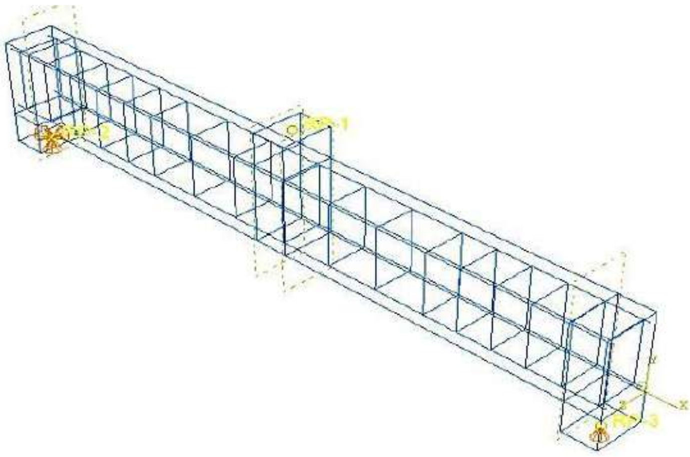


Figure 3.3.3: Meshing of steel bars

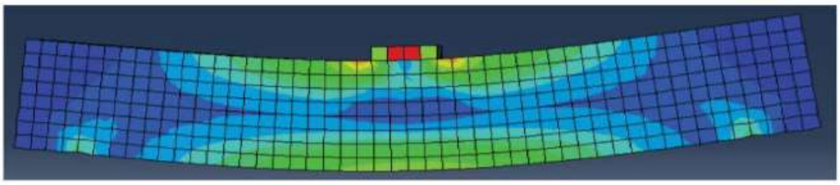


Figure 3.3.4: Deformation of beam

3.4 EXPERIMENTAL ANALYSIS

The experimental investigation and analvsis of flexural behaviour of concrete beams with steel and frp bars is also conducted. As experimental work shows, varying load value,the deflection of beams and tends to expose the linear increment.

Modulus of rupture

In a flexural test on a reinforced concrete beam, the modulus of rupture is the maximum tensile stress reached at the bottom fibre of a standard size beam under the loading .

Purpose of Flexure Test

The three point and four point flexure bending tests on universal testing machines are the most common types of flexure tests. The main purpose of the flexure test is to determine the flexural strength and modulus. These values can be used to evaluate the sample material's ability to withstand flexure or bending forces. When a specimen is subjected to flexural loading, all three essential stresses: tensile, compressive, and shear, are present, and the flexural properties of the specimen are the result of the combined effect of all three stresses.

Procedure:

1) The beams were made with rectangular cross section of 200 mm (width) by 250 mm (height) with total length of 2000 mm.
2) take mix proportion as 1:2:4 with water cement ratio of O.5.
3) Design the reinforcement with suitable mould size as well as frp bars.
4) Then fix the reinforcement and FRP bars individually in the mould.
5) Calculate the required quantity for the standard mould.
6) Weigh the required amount of cement,fine and coarse aggregate and water.
7) Start the mixer machine put the aggregates (coarse and fine aggregate) and half of the
8) water in mixer.
9) After homogenous mixture of aggregates. Put the cement and remaining water.
10) Mix it until homogenous mixture is obtained.
11) Put the concrete of the machine and place it in the formwork of the beam.
12) During placing it should be compacted through rod. (mould should be oiled)
13) Test of flexural strength of casted beam at 7 days and 28 days.

3.5 SUMMARY OF THE CHAPTER

This chapter introduced the modelling and experimental techniques used to investigate the flexural response of concrete beams with steel and FRP bars. Both studies' steps were also elaborated separately, and analyses were performed using the finite element computer programme ABAQUS and experimentally in universal testing machines that demonstrated the load deflection behavior of beams.

Chapter 04
EXPERIMENTAL INVESTIGATION OF CONCRETE BEAM REINFORCED WITH STEEL AND FRP BARS UNDER FLEXURAL ACTION

4.1 INTRODUCTION

The experimental work is done on concrete beam which is reinforced with the steel and Fibre Reinforced Polymers(FRP).This investigation shows experimented study of the flexural action on concrete beam and were tested in laboratory after curing of 28-days and results were obtained from the testing. The rusting of reinforcing steel is an issue in reinforced concrete structures. Steel reinforcement corrodes quickly in harsh situations such as maritime environments. Chloride ions, which can be present in de-icing salts in northern regions and sea water along coastal areas, promote corrosion. Other materials, such as Fiber Reinforced Polymers (FRP), have evolved as an alternative to steel reinforcement when the RC member's exposure scenario necessitates durability under harsh conditions. FRP materials are anisotropic, with great tensile strength and no yielding solely in the direction of the reinforcing fibres.

4.2 EXPERIMENTAL ANALYSIS

The experimental investigation and analysis of flexural behavior of concrete beams with steel and FRP bars is also conducted. The beams were four point loaded using UTM after undergoing 28 days of cure. At the bottom of the beam, dial gauges were set. Furthermore, because hydraulic force is applied linearly, we monitor the beam deflection at each interval of 5 KN load and keep track of the first fracture where the load and related deflection occur. We also record the ultimate load and deflection for each beam section. Total six beams were experimented in which three of were steel beams and remaining three were Fibre Reinforced Polymer(FRP) beams.

As experimental work shows, varying load value, the deflection of beams and tends to expose the linear increment. Utilizing a universal testing machine, a beam supported by two supports and subjected to a load at the center is utilized to examine the relationship between load and deflection of the beam. Until the first crack developed, the beams were visually inspected, and the associated load was noted. The cracks seems appearing in shear and flexure patterns because the yielding of the steel bars caused the control beam with steel reinforcement to fail in flexure.

4.3 PURPOSE OF FLEXURAL TEST:

Thefour-point flexure bending tests on universal testing machines are the most common types of flexure tests. The main purpose of the flexure test is to determine the flexural strength and modulus. These values can be used to evaluate the sample material's ability to withstand flexure or bending forces. When a specimen is subjected to flexural loading, all three essential stresses: tensile, compressive, and shear, are present, and the flexural properties of the specimen are the result of the combined effect of all three stresses.

4.4 DESIGN OF REINFORCED BEAM

In the design and analysis of reinforced concrete members, you are faced with a problem that most of you are not familiar with: "The mechanics of members consisting of two materials." To make matters worse, one of the materials (concrete) behaves differently in tension than in compression and may be considered to be either elastic or inelastic, if it is not completely neglected. Compared to other materials, reinforced concrete has strong compressive strength, great resistance to the effects of water and fire, and its resistance improves with time owing to hydration. However, due to its low resistance to stress and tenth of its compressive strength, it must have steel reinforcement in tensile places. Three fundamental needs must be met in the design of a structure: stability (to prevent tipping, sliding, or buckling under the action of loads), strength (to safely withstand the stresses caused by the loads in the various structural parts), and serviceability (to allow for maintenance) (to ensure satisfactory performance under service load conditions). Two more factors that a smart designer must take into account are as follows: affordability and aesthetics. The working stress method (WSM), a conventional design approach used in building design and analysis for reinforced concrete, is being phased out progressively. This approach compares the measured allowed stresses to the stresses in the structural members as determined by the working loads (service loads). By doing this, the long-term effects of creep, shrinkage, and stress concentrations will be lessened.

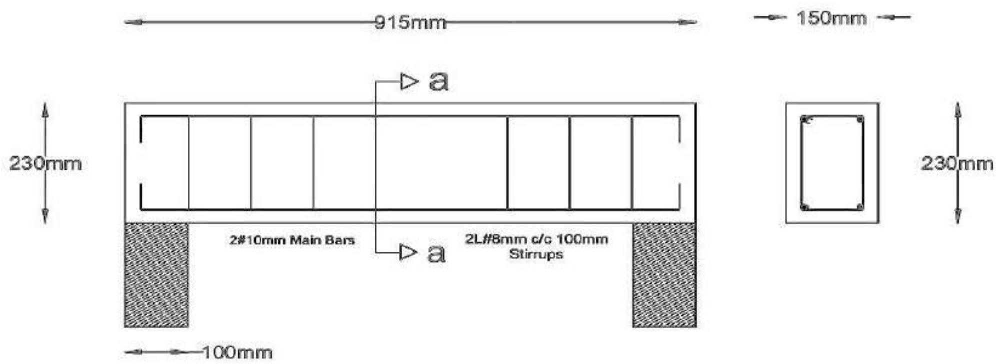


Figure 4.1: Detailing of the reinforcements of the beams

4.4.1 DESIGNS CODES AND SPECIFICATIONS:

Building codes, which are governed by law and contain regulations for things like plumbing, ventilation, and accessibility for the physically challenged, must be followed in the design and construction of buildings. A local organization, for instance a city, a county, or, in the case of certain major urban areas, a consolidated government, is responsible for administering a building code that has the legal status of a law. The design criteria and limits that must be met are listed in building regulations, not the design methods themselves. The need for minimal live loads for structures is particularly significant to the structural engineer. While the engineer is urged to look into the actual loading circumstances and makes an effort to determine realistic values.

4.4.2 MODULUS OF RUPTURE:

In a flexural test on a reinforced concrete beam, the modulus of rupture is the maximum tensile stress reached at the bottom fiber of a standard size beam under the loading.

There are three types of beam sections.

- Balanced beam section
- Under-Reinforced beam section
- Over-Reinforced beam section

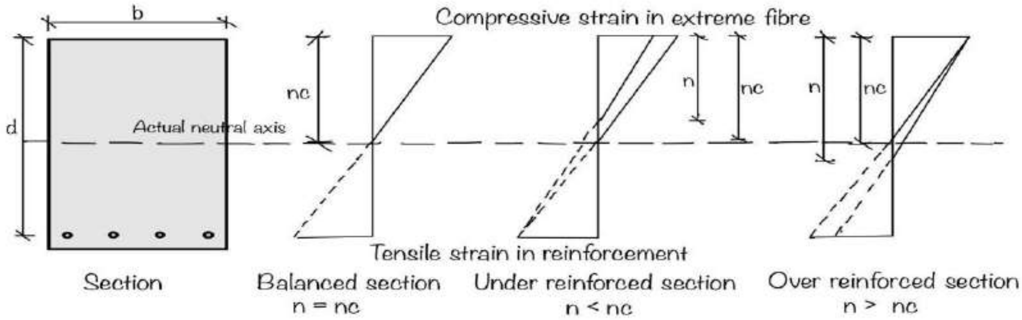


Figure 4.2: Types of beam sections

- Balanced section

A balanced section is one in which the stress in both concrete and steel reaches its allowable value at the same time. This section's steel percentage is known as balanced steel, and the neutral axis is known as critical neutral axis nc.

- ➢ Under reinforced section

The percentage of steel provided in an under reinforced section is less than that provided in a balanced section. As a result, the true neutral axis will shift upwards, as seen in Fig.8. The stress in the steel first achieves its allowable value in the under reinforced portion, while the concrete is under stressed.

The failure is ductile in inadequately reinforced sections because the steel fails first and a sufficient warning is given before collapse. Designers choose under-reinforced portions due to ductile failure and cost savings.

- ➢ Over reinforced section

The percentage of steel provided in an over reinforced section is more than in a balanced section. As a result, the true neutral axis shifts downward, i.e., n>nc. Fig.8. Concrete stress reaches its allowable value in this portion, although steel is not fully stressed. Concrete is brittle, and it collapses suddenly by crushing or failing suddenly. The over strengthened portion is uneconomical because steel is not fully utilised (steel is substantially more expensive than concrete).

A bending force causes a beam to bend, resulting in a minor curvature. The concrete suffers tensile stress at the curvature's outer face (tensile face), whereas compressive stress occurs at the curvature's interior face (compressive face).

Find Whether the Beam Is Under, Over Or Balanced Section.

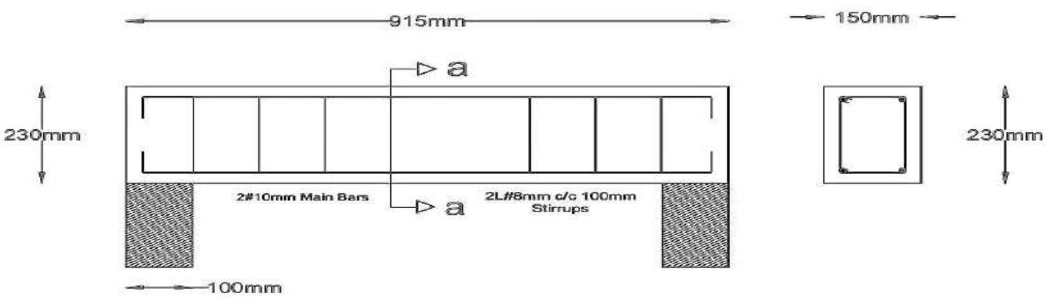


Figure 4.3: Beam section

From above fig.4.3given data is:

Total depth(D)= 230mm

Effective depth(d)= 205mm

Effective cover= 25mm

Width(b)= 150mm

f_y =Fe-415= 60 grades of steel

M20 concrete grade f*ck*= 21N/mm²

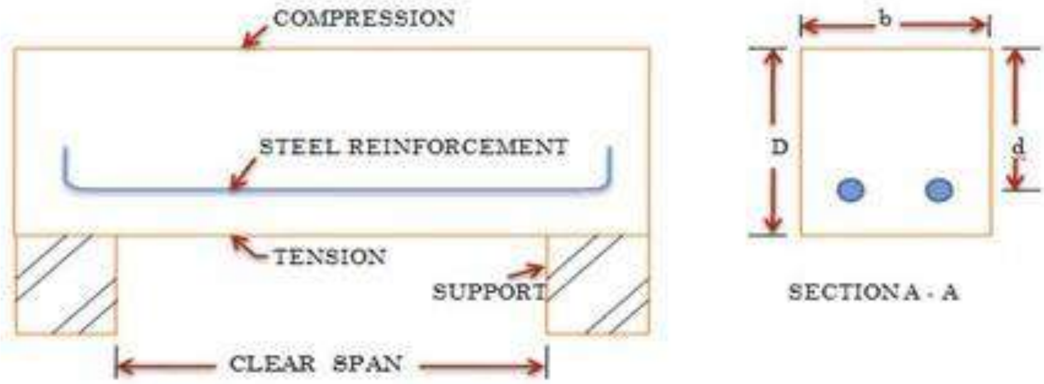


Figure 4.4: Beam section.

We know that the depth of neutral axis is;

$$\frac{x_u}{d} = \frac{0.87\ f_y\ A_{st}}{0.36\ \ f_{ck}\ \text{bd}} \text{------------------- (1)}$$

Now calculate A_{st}:

A_{st}= $2x\frac{\pi}{4}(10)^2$

A_{st}= 157.07mm²

Now solve equation (1)

$$\frac{x_u}{d} = \frac{0.87\ x\ (415)\ x\ (157.07)}{0.36\ \text{x}\ (21)\ \text{x}(\ 150)\ \text{x}\ (205)}$$

$\frac{x_u}{d}$=0.2561

Limiting depth of neutral axis is

$\frac{x_{umax}}{d}$=0.48

Since x_u<x_{umax} the section is under reinforced which can be seen in below fig:4.5.

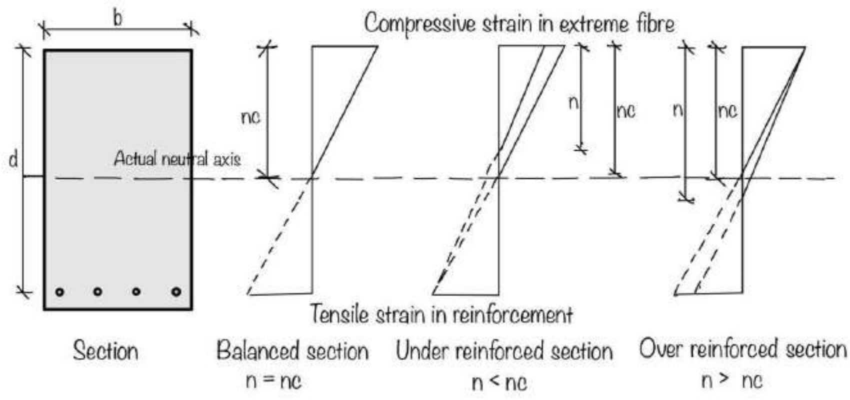


Figure 4.5: Different types of RCC beam sections.

4.4.3 DIFFERENCES BETWEEN SINGLYAND DOUBLY REINFORCED BEAMS.

- Singly reinforced beam

A singly reinforced beam is one in which the concrete element is strengthened only near the tensile face, with the reinforcement, known as tension steel, designed to resist tension.

- Doubly reinforced beam

A doubly reinforced beam is one that, in addition to tensile reinforcement, has reinforcement near the compressive face to help the concrete resist compression. The latter type of reinforcement is known as compression steel. If the compression zone of a concrete is insufficient to resist the compressive moment (positive moment), further reinforcing must be given if the architect limits the section's dimensions.

4.5 CONRETE MIX DESIGN

The five main components of a concrete mix are cement, water, coarse aggregates, fine aggregates (i.e. sand), and air. These components are combined in different ratios. To provide the mixture specific desired features, additional elements can be added, such as pozzolanic components and chemical admixtures. While ready-made The process of choosing the components of a concrete mixture and determining their proportions is known as concrete design. Always take the project's required strength, durability, and workability into account while creating a mix.

Among the well-known design techniques are:

1. The mix design method of trial and error
2. British DOE mix design approach

3. ACI mix design approach
4. IS Guidelines for Concrete Mix Proportioning
5. Rapid mix design method

4.5.1 BS CONCRETE MIXED DESIGN (DOE)

In this project is to determine the exact quantity of materials needed to produce 1m3 of concrete using the Design Method of the Department of Environment. (THE DOE METHOD).

- **PROCESS:**

This approach is made up of eight key processes that must be estimated. The BS concrete mix design has been calculated in the stages below.

1) Target of mean compressive strength
2) Water/Cement Proportion
3) The water content determined by the requisite slump value and size of aggregates
4) The cement content
5) The density of concrete
6) The content of aggregates
7) Amount of fine &coarse aggregates
8) Coarse aggregate

4.5.2 ASSUMPTIONS AND REQUIREMENTS FOR DESIGN:

The following are the design requirements and the assumptions that were used for the concrete mix design:

- Value of slump of 30mm-60mm.
- The Characteristics of compressive strength of 21N/mm² (2.5%failures permitted) for 28-days.
- The standard deviation of the tests is σ= 8N/mm².
- Ordinary Portland cement (42.5N).
- Fine aggregate= Uncrushed
- Coarse aggregate= Crushed

4.5.3: TARGET OF MEAN COMPRESSIVE STRENGTH

The target of mean compressive strength which is denoted as fm, target can be determined by Characteristic strength (fc)+(risk factor k x standard deviation(σ))

Failure acceptable in percentage	Value of risk factor
16.0	1.00
10.0	1.280
5.0	1.650
2.5	1.960
2.0	2.050
1.0	2.330

Table 4.1: Value Risk factor

$$Fm = fc + (k x \sigma)$$

$$Fm = 21+1.96x8=37 \text{ N/mm2}$$

4.5.4 CALCULTAION OF RATIO OF WATER-CEMENT:

The ratio of water-cement is calculated by using the data which is given in table 4.2

Type of cement	Type of coarse aggregate	Compressive Strength (N/mm2)			
		Age (days)			
		3	7	28	91
Ordinary Portland Cement (OPC) Or Sulphate-resisting Portland (SRPC)	Uncrushed	22	30	42	49
	Crushed	27	36	49	56
Rapid-hardening Portland (RHPC)	Uncrushed	29	37	48	54
	Crushed	34	43	55	61
1 N/mm2 = 1 MN/m2 = 1 MPa					

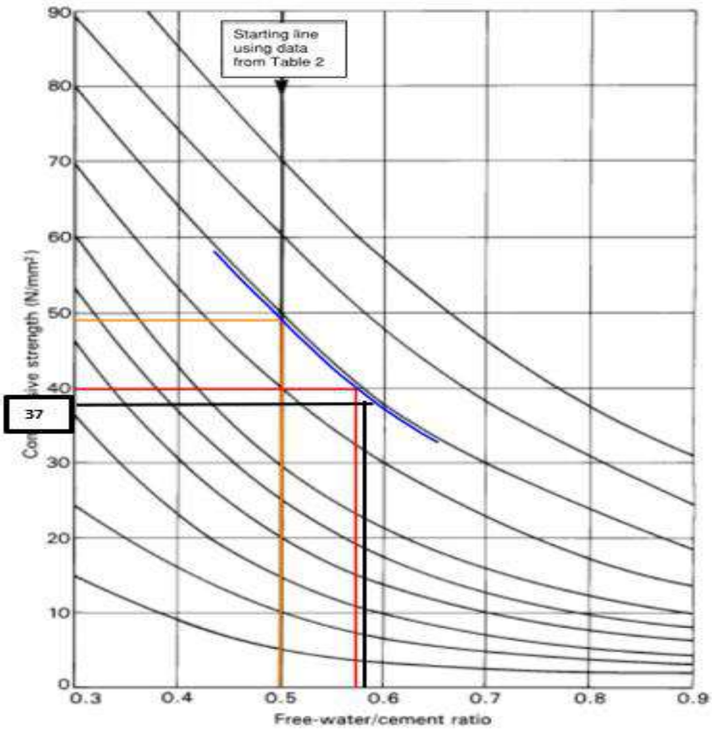
Table 4.2: The Approximated compressive strength of concrete made with 0.5 ratio of water-cement.

Because one of the design mix requirements stated that the mix will use regular Portland cement with crushed aggregate, the 28-day strength value of 49 N/mm^2 from the previous table can be used to determine the ratio of water-cement:

1. . The value of free water/cement axis is given of 0.5 because it is used in table 2.

2. The nearest curve is offset parallel to the point of intersection(of blue color) of the compressive strength value of 49 N/mm² and the value of free water / cement is 0.5 (of orange color).

3. A horizontal line is made from the target compressive strength of 37N/mm² to the parallel curve, and a vertical line is drawn from this point of junction to find the necessary free water / cement ratio of 0.56(black).



Graph 1: Ratio of water-cement

4.5.5 THE WATER CONTENT:

The following factors are used to calculate the required water content to ensure appropriate concrete workability:

- The value of slump (30millimeter – 60millimeter)
- The size of aggregates is 20milimeter

The values of these parameters are specified in the design specifications and can be found in Table.4.3.

Slump (mm)		**Very Low**	**Low**	**Medium**	**High**
		0 – 10	**10 – 30**	**30 – 60**	**60 – 180**
Vebe (seconds)		**>12**	**6 – 12**	**3 – 6**	**0 – 3**
1. Water Content					
Maximum size of aggregate (mm)	*Type of aggregate*	Water content (kg/m³)			
10	Uncrushed	150	280	205	225
	Crushed	180	205	230	250
20	Uncrushed	135	160	180	195
	Crushed	170	190	210	225
40	Uncrushed	115	140	160	175
	Crushed	155	175	190	205
1. Reduction in water content when fly ash is used					
Percentage of fly ash in cementitious material		Reduction in water content (kg/m³)			
10		5	5	5	10
20		10	10	10	15
30		15	15	20	20
40		20	20	25	25
50		25	25	30	30

Table 4.3: The free water content and workability values

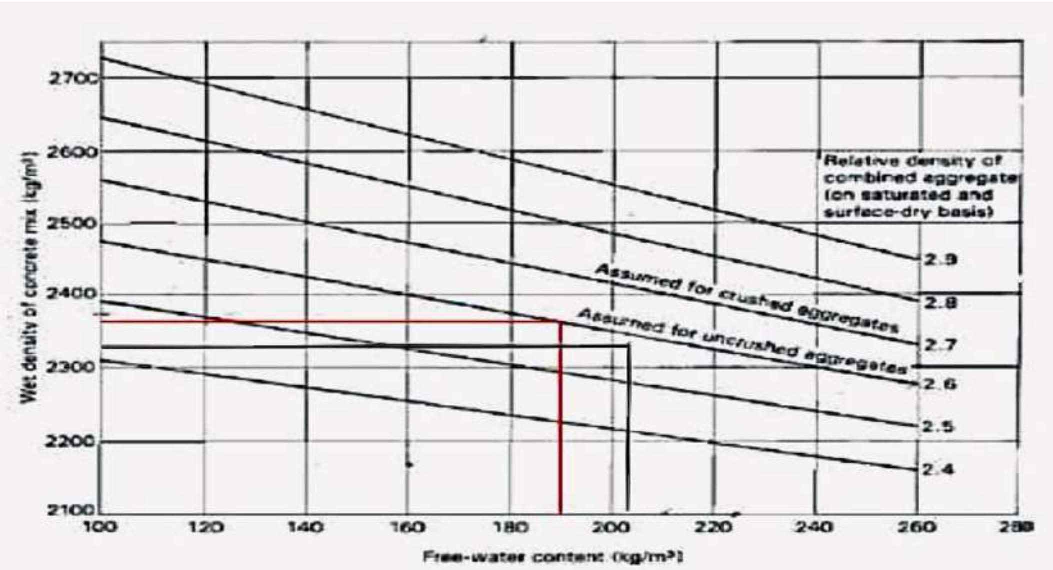
Using the parameters in Table.3 (above), we can calculate that the needed water content is 210 kg/m3 by joining the value at 20 mm size of aggregate and the value of slump for crushed aggregate at 30 mm - 60 mm.

4.5.6 CEMENT CONCRETE:

The following formula is used to calculate the amount of cement needed. Cement content per m³ = free water/cement ratio. Because the numbers for the water content and the free water / cement ratio are known, it is simple to calculate. 210/0.56 = 375 kg/m³ cement content**.**

4.5.7 THE CONCRET DENSITY:

- This approach calculates the density of fresh concrete using a graphical methodology based on the relative aggregate density and free-water content.
- The relative aggregate density which is given at 2.6 and the value of free-water content which is 210 kg/m³, the density can be determined to be 2325 kg/m³, as illustrated in graph.2.



Graph 2: Fresh Concrete Density (G.D.Taylor,2000*)*

4.5.8 THE CONTENT OF AGGREGATES:

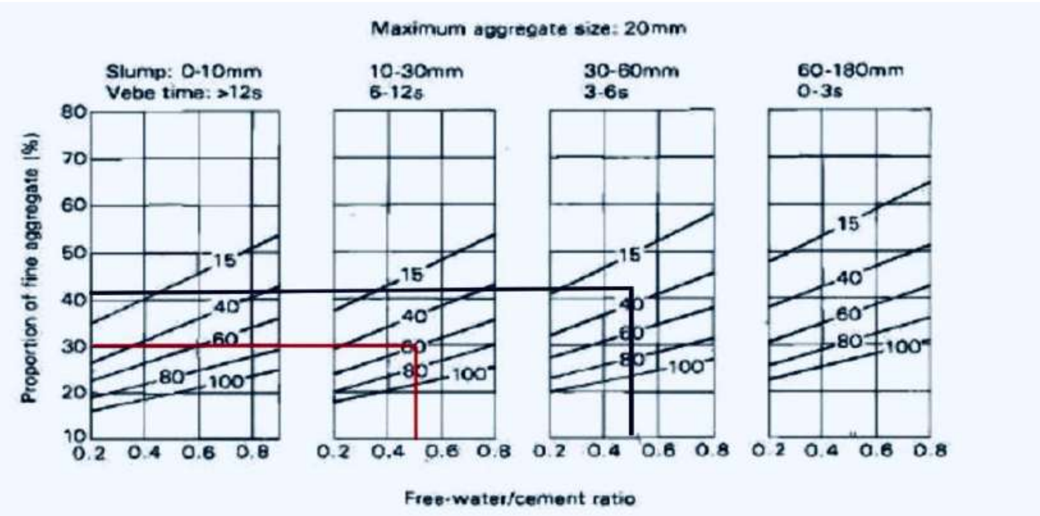
Using the fresh concrete density of **2325kg/m^3**, and the aggregate content can be calculated using the following formula: Aggregate content=fresh density – (cement content + water content). These values have already been calculated, therefore:
Aggregate content= **2325– (375+210Aggregatecontent) = 1740 kg/m³**

4.5.9 FINE AGGREGATE CONTENT:

The amount of fine aggregate in the concrete mix will be determined on:

- The grade of sand
- The size of aggregate (maximum)
- The concret workability
- The ratio of free water-cement

Figure 3 (below) depicts a graphical technique for estimating the proportion of the fine aggregate, which yields a result of 42% by beginning with a 0.5 ratio of free water-cement and drawing a line vertically upwards to the percentage of fine aggregate passing through a 600 m sieve (%). The proportion of fine aggregate is then determined by drawing a horizontal line.



Graph 3. Sand proportion with respect to sieve

The amount of fine aggregate can be estimated using the total aggregate content of 1740 kg/m3.

1743.42= 730.8 kg/m³.

4.5.10 COARSE AGGREGATE CONTENT:

After calculating the fine aggregate content, we can simply subtract this figure from the overall aggregate content to calculate the proportion of aggregate required.

1740 – 730.8= 1010 kg/m3

4.5.11 SUMMARY:

Based on the calculations above, the correct amount for each component for each m^3 of concrete is shown below in table.4.4:

Material	Quantity(kg/m^3)	Ratio
Cement	375	**1**
Water	210	**W/C =0.56**
Fine Aggregate	730.8	**1.95**
Coarse Aggregate	**1010**	**2.70**

Table.4.4: Calculated quantity for each material.

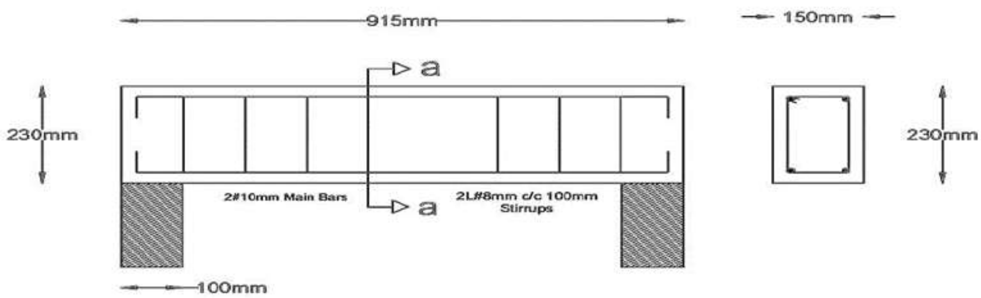
4.6 MATERIAL CALCULATIONS

4.6.1 CHARACTERISTICS OF 28-DAYS COMPRESSIVE STRENGTH OF $21N/MM^2$ OR 3000PSI.

- Ordinary Portland Cement (OPC)= 42.5 N
- Coarse aggregate size= 20mm
- Water cement ratio (w/c) = 0.56
- Proportion= 1:1.95:2.70
- Cement= 375 kg
- Fine aggregate= 730.8 kg
- Coarse aggregate= 1010 kg
- Water content= 210 kg

➢ **MATERIAL CALCULATION OF BEAM:**

The dimensions of beam are 3ft x 6in x 9in so let’s calculate the volume of beam.



V= 3ft x 0.5ft x 0.75ft

V= 1.125ft³

V= 0.03185m³

The factor of safety is 1.5 so the volume of beam will be;

V= 0.048m³

Now Calculate the Right Amount of Material For Each Beam From Calculated Volume;

Cement= **375 x 0.048**

Cement= **18 kg**

Fine Aggregate (F.A)=**730.8 x 0.048**

F.A= **35 kg**

Coarse Aggregate (C.A)=**1010 x 0.048**

C.A**= 48.5 kg**

Water cement ratio(W/C)=**0.56**

Water= 0.56 x C= **0.56 X 18=> 10 kg**

Additional 2% Water For Fine Aggregate And Coarse Aggregate For Absorption Or Saturation;

Total water= **10 + 0.02(10) + 0.02(10)**

Total water= **10.4 kg**

The Next Step Is Material Calculation for Six Beams;

Cement= **18 x 6=> 108 kg**

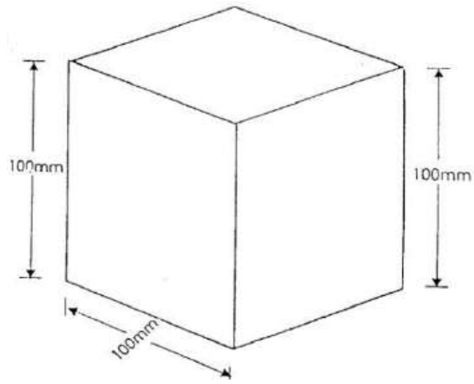
Fine aggregate**= 35 x 6=> 210 kg**

Coarse aggregate= **48.5 x 6=> 291 kg**

Water= **10.4 x 6=> 62.4 kg**

- **MATERIAL CALCULATION OF CUBE**

The dimensions of the cube are dimension= 100mm x 100mm x 100mm



Dimension= 0.1m x 0.1m x 0.1m

V= 0.1 x 0.1 x 0.1 => $0.001m^3$

Factor of safety is 1.5 = 0.001 x 1.5=> 0.0015

Now Calculate the Right Amount of Material for Each Cube From Calculated Volume;

Cement=375 x 0.0015 => 0.56kg

Fine Aggregate (F.A) =730.8 x 0.0015=> 1.1kg

Coarse Aggregate (C.A) = 1010 x 0.0015=> 1.515kg

Water = 0.56 x 0.56=> 0.3136kg

Additional 2% Water for Fine Aggregate and Coarse Aggregate for Absorption Or Saturation.

Total water= 0.439kg

The Next Step Is Material Calculation for Six Cubes.

Cement= 3.36kg

Fine aggregate= 6.6kg

Coarse aggregate= 9.09kg

Water= 2.634kg

4.7 CASTING AND CURING OF BEAMS AND CUBES

Casting and curing concrete cylinder and beam specimens from fresh concrete representative samples is critical in building construction. This is so that the outcomes of the tests performed on these samples may be used for a variety of important objectives. Consider the acceptance of the specified concrete strength, the evaluation of the mix's suitability for strength, and quality control. Finally, the concrete used to create the mould specimens must be sampled after all on-site adjustments to the mixture proportions have been made. These adjustments include checking the adequacy of the concrete structure's curing and protection, identifying the structure's capability to be put into service, and determining the form removal time requirements .

4.7.1 APPARATUS

- Cube Molds
- Beam Molds
- Tamping Rod
- Vibrators
- Mallet
- Tool for Placement and Finishing
- The apparatus for Slump

4.7.2 PROCEDURE:

- The beams had a cross section of 230 mm width by 150 mm height and a total length of 915 mm.
- Take mix proportion as 1:1.95:2.70 with water cement ratio of 0.56.
- Design the reinforcement with suitable mould size as well as FRP bars.
- Then fix the reinforcement of steel and FRP bars individually in the mould.
- Calculate the required quantity for the standard mould.
- Weigh the required amount of cement, fine and coarse aggregate, and water.
- Sieve the coarse and fine aggregates.
- Start the mixer machine and then put the aggregates and water.
- Mix it until homogenous mixture is obtained.
- Reinforcement of steel and FRP is placed in mould with 25mm cover.
- Now place it in the formwork of the beam. (mould should be oiled)
- It should be compacted through rod continuously 25 times each in three layers.
- Now after casting beam, place it for 28-days for curing
- Now conduct test of flexural strength of casted beam at 28-days.

4.7.3 EXPERIMENTAL WORK

Figure 4.6: Sieve of fine and coarse aggregates

Standard sieve designation (ASTM E 11)		Nominal sieve opening	
		mm	in.
Coarse sieves			
Standard	Alternate		
75.0 mm	3 in.	75.0	3
63.0 mm	2-1/2 in.	63.0	2.5
50.0 mm	2 in.	50.0	2
37.5 mm	1-1/2 in.	37.5	1.5
25.0 mm	1 in.	25.0	1
19.0 mm	3/4 in.	19.0	0.75
12.5 mm	1/2 in.	12.5	0.5
9.5 mm	3/8 in.	9.5	0.375
Fine sieves			
4.75 mm	No. 4	4.75	0.1870
2.36 mm	No. 8	2.36	0.0937
1.18 mm	No. 16	1.18	0.0469
600 µm*	No. 30	0.60	0.0234
300 µm	No. 50	0.30	0.0117
150 µm	No. 100	0.15	0.0059
Finest sieve normally used for aggregates			
75 µm	No. 200	0.075	0.0029

*1000 µm (micro-meters) = 1 mm.

Table4.5: Sieves used for sieve analysis of concrete aggregates.

Figure 4.6: Arrangement of Steel and FRP Reinforcement.

Figure:4.7: Mould of Steel and FRP Beam.

Figure 4.8: Mixing of Concrete in Mixer

Figure 4.9: Placement of Concrete.

Figure 4.10: Roding of concrete

Figure 4.11: Finishing of Concrete beam

- **CONCRETE WORKABLIY**

The concrete slump test or slump cone test is the most common test for workability of freshly mixed concrete.

- **SLUMP TEST OF CONCRETE**

The concrete slump test, also known as the slump cone test, is used to evaluate the workability or consistency of the concrete mix created in the laboratory or on the construction site as the project is being completed. Concrete slump tests are performed from batch to batch to guarantee that the quality of the concrete remains consistent throughout the construction process. The slump test is the simplest, least expensive, and quickest method for determining if concrete is workable..
The concrete slump value, which also exposes the water-cement ratio, is frequently used to measure the workability of concrete. However, other parameters including as component quality, mixing procedure, dose, and admixtures can all have an effect on the concrete slump value.

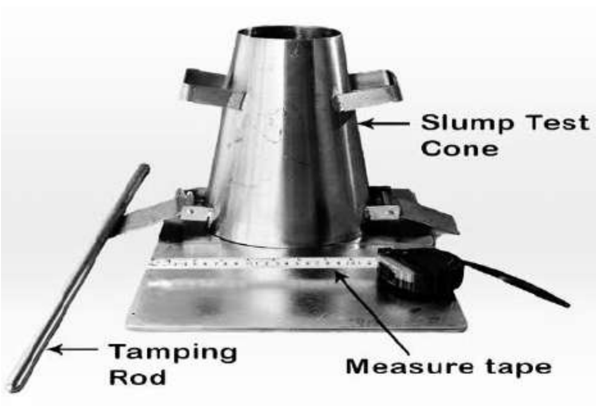
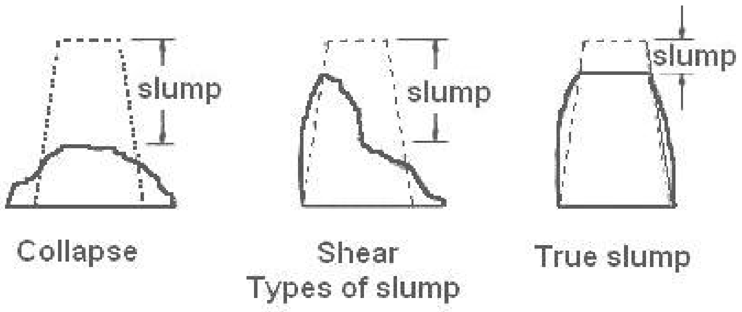


Figure.4.11a. Measuring equipment Slump of Concrete



- **SLUMP TEST VALUE OBSERVATION**

The specimen's subsidence during the test, as determined by the slump, must be expressed in millimetres.

Figure.4.11c: Slump test

The observed value of slump test was 90mm, the degree of workability of concrete is medium whose range is 50-100(mm).

Figure 4.12. Casted Beams

Figure 4.13: Casting of Cubes for Concrete Compressive Strength

Figure 4.14: Casted Cubes

Figure 4.14a: Testing of cubes

➢ 28-DAY COMPRESSIVE STRENGTH OF CONCRETE CUBE

S.NO	Cubes	Loads (N)	28- Days Compressive Strength (N/mm²)
1	Cube 1st	271820	27.18
2	Cube 2nd	268850	26.88
3	Cube 3rd	251950	25.19
4	Cube 4th	238500	23.85
5	Cube 5th	219760	21.97
6	Cube 6th	242500	24.25
		Average	24.8

Table 4.6 :28-day compressive strength of concrete

The design of 28-days compressive strength of concrete was 21N/mm and the experimental value of 28-days compressive is about 24.8 which is greater than designed compressive strength of concrete which is desirable for design.

4.8 FOUR POINT LOADING TEST

Flexural strength, also known as bend strength, is the capacity of a material to withstand deformation under load. The material's maximum internal stress at the time of rupture is represented by the flexural strength. Stress levels are used to measure it. The most popular method for assessing a specimen's flexural strength is the four-point bend test. The four-point bending flexural test's goal is to determine the material's bending modulus of elasticity, flexural stress, flexural strain, and flexural stress-strain response.

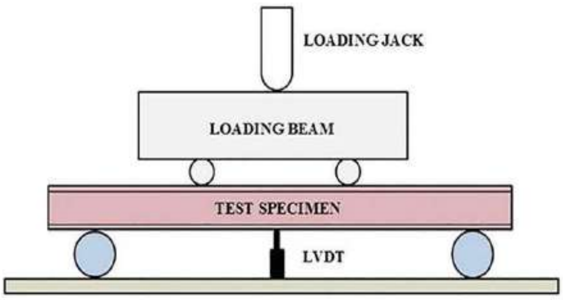


Figure 4.15: Four Point Specimen

Figure 4.16: Loading Arrangement of Specimen and dial guage

The six beams were tested in UTM machine in the laboratory in which three of them were steel beams and remaining three were FRP beams and shows different results which are shown below.

Figure.4. 16a: Meshing of beams

Figure.4. 16b: Four Point Beam testing in UTM

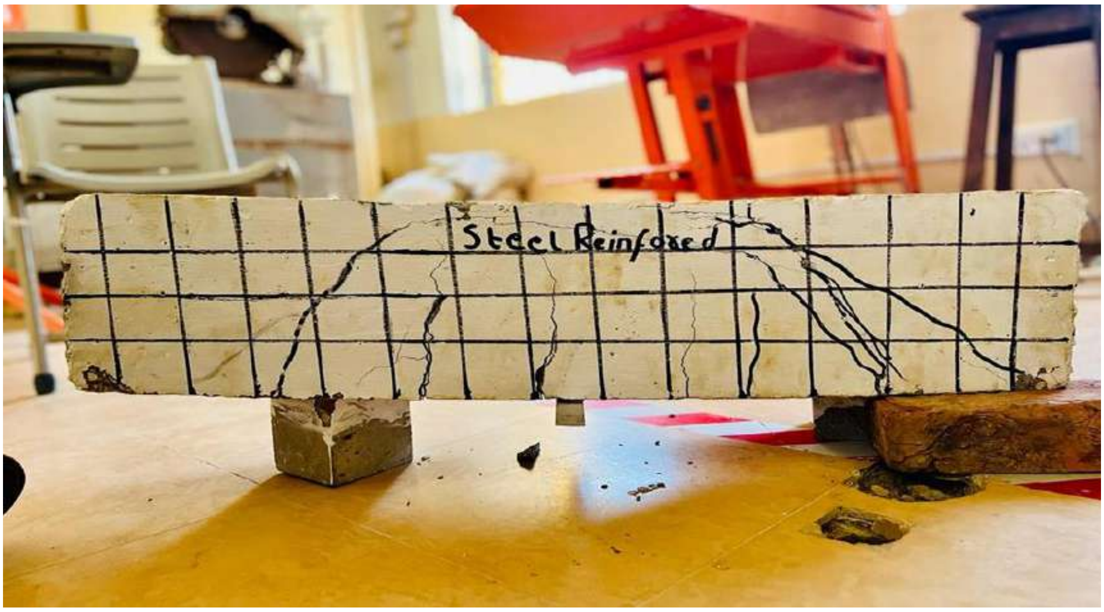


Figure.4. 17: Cracks Pattern in Steel Beam 1

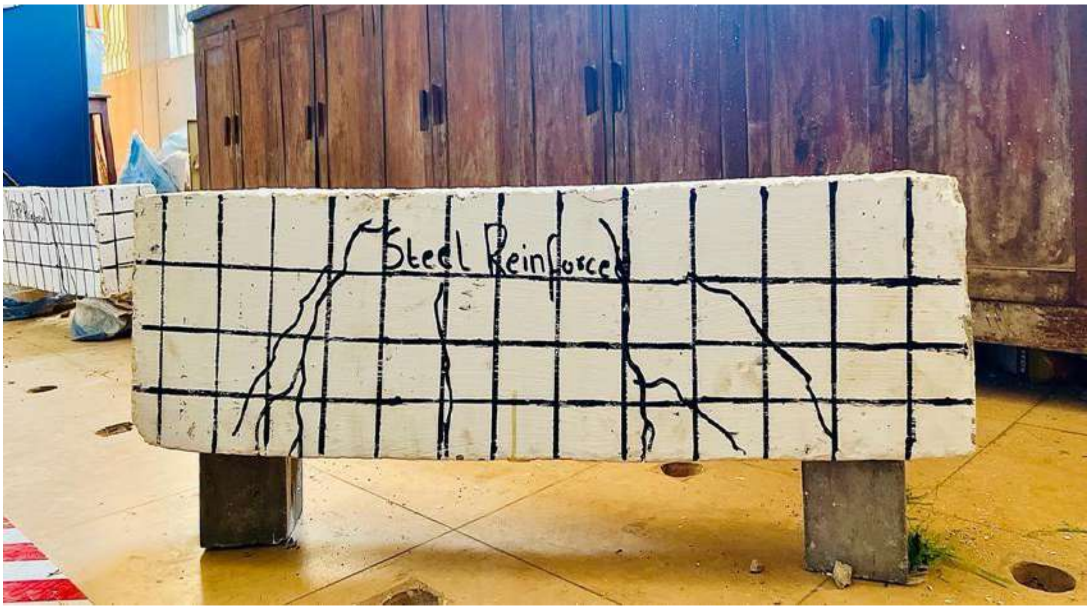


Figure4. 18: Cracks Pattern in Steel Beam 2

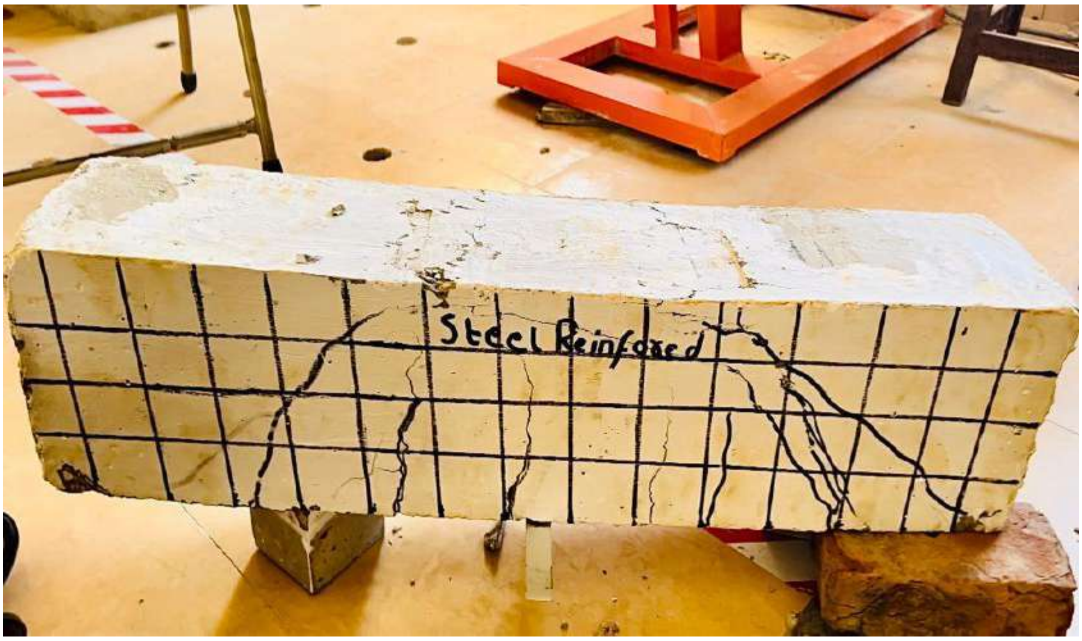


Figure4. 19: Cracks Pattern in Steel Beam 3

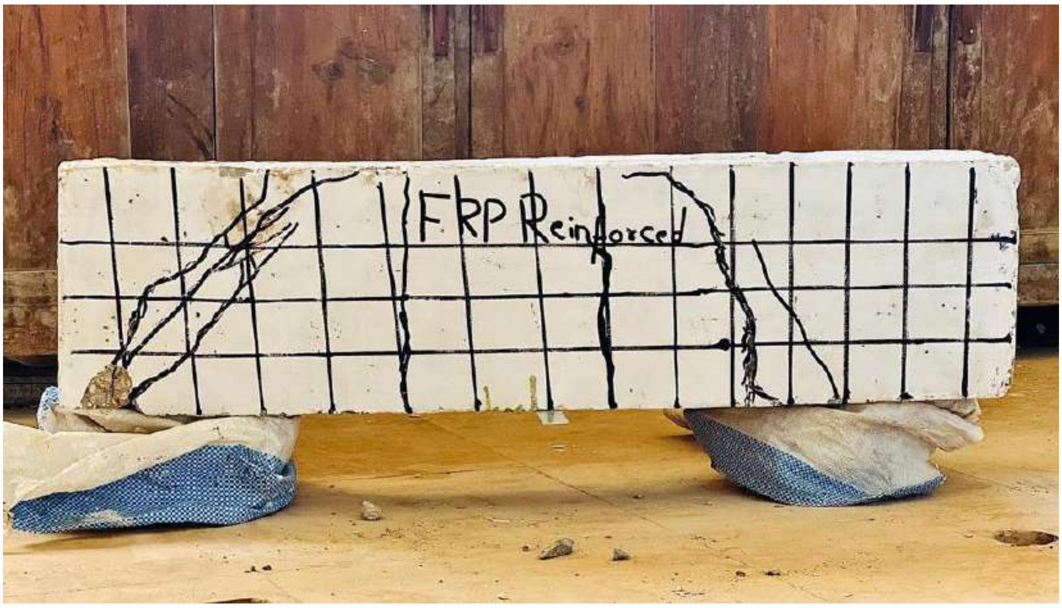


Figure 4. 20: Cracks Pattern in FRP Beam 1

Figure 4. 21: Cracks Pattern in FRP Beam 2

Figure 4. 22: Cracks Pattern in FRP Beam 3

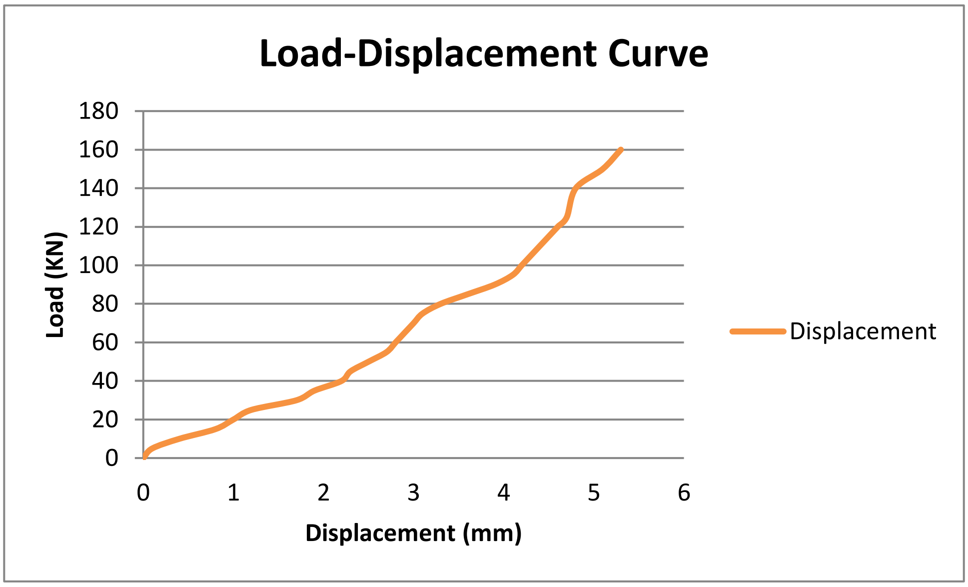
4.9 RESULTS AND GRAPHS

- **Load Displacement Results of Steel Reinforced Beam:**

    - **Beam 1**

S.No	Load (KN)	Displacement (mm)	Remarks
0	0	0	None
1	40	2.2	None
2	80	3.3	Cracks Appear
3	120	4.6	Shear &Flexural Cracks
4	160	5.1	Failure

Table 4.7: Load Displacement readings beam1

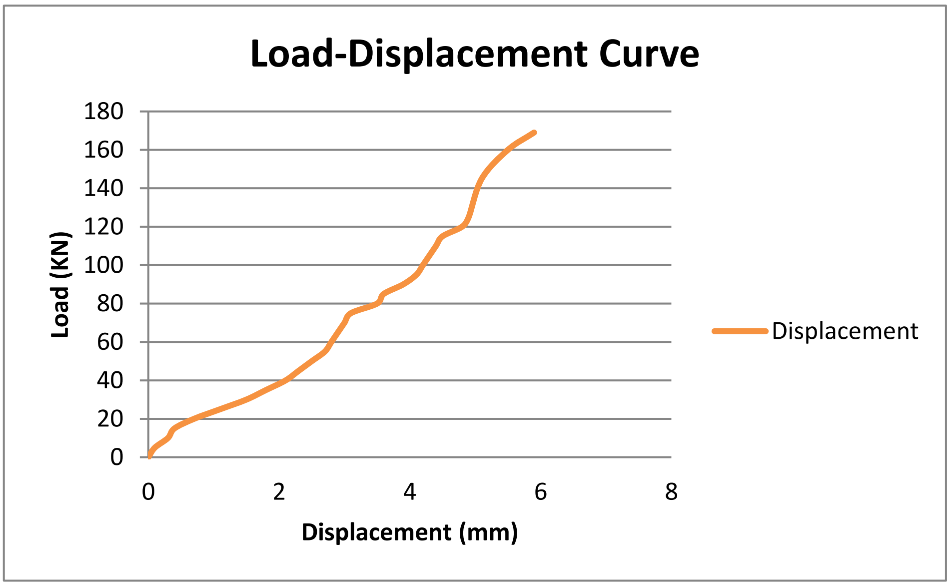


Graph 4: Load Displacement graph of beam1

- Beam 2

S.No	Load (KN)	Displacement (mm)	Remarks
0	0	0	None
1	40	2.1	None
2	80	3.5	Cracks Appear
3	120	4.8	Shear Crack Appear
4	160	5.4	Widening Shear &Flexural Cracks
5	170	5.7	Failure

Table 4.8: Load Displacement readings beam2

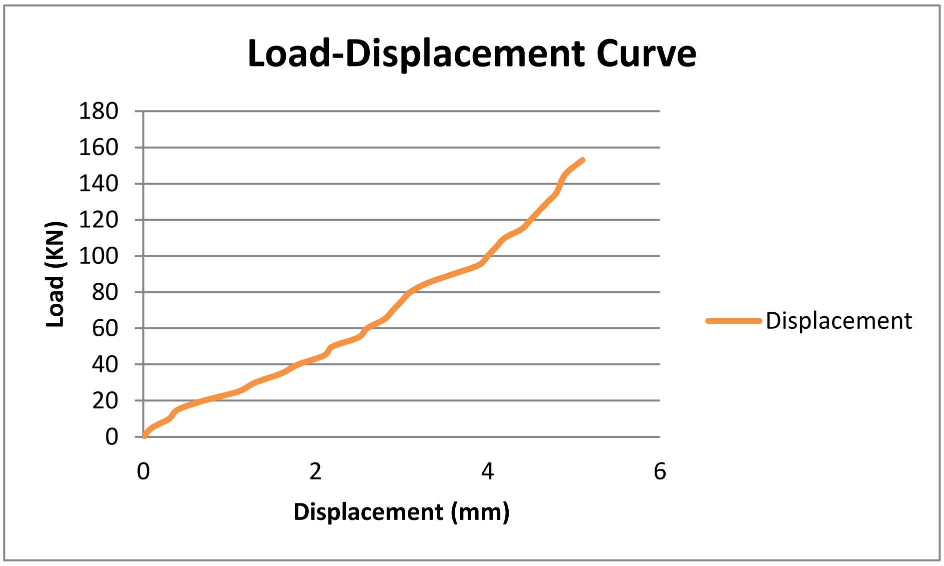


Graph 5: Load Displacement graph of beam2

- Beam 3

S.No	Load (KN)	Displacement (mm)	Remarks
0	0	0	None
1	40	1.8	None
2	80	3.1	Cracks Appear
3	120	4.5	Shear &Flexural Cracks
4	153	4.8	Failure

Table 4.9: Load Displacement of beam3



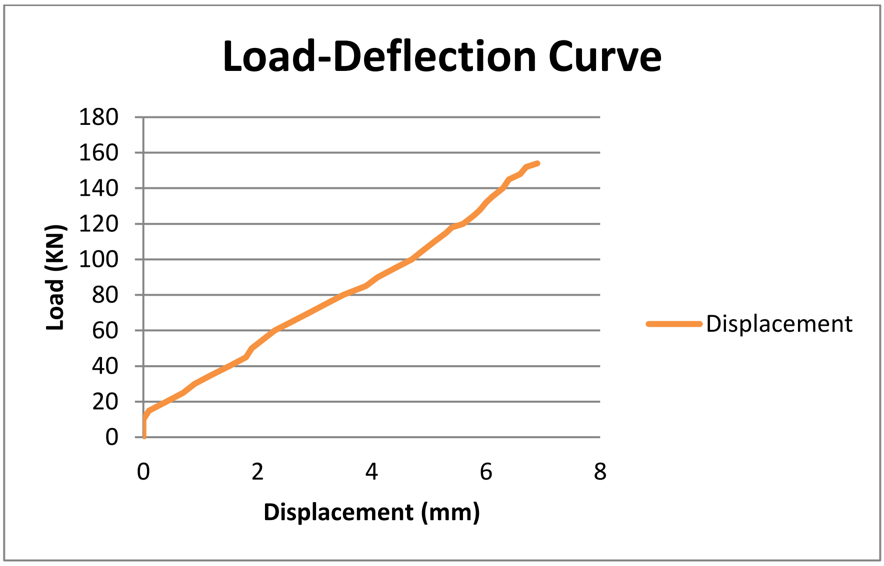
Graph 6: Load Displacement graph of beam3

➢ **Load displacement results of FRP reinforced beam**

- Beam 1

S.No	Load (KN)	Displacement (mm)	Remarks
0	0	0	None
1	40	1.5	None
2	80	3.5	Cracks Appear
3	120	5.6	Shear&Flexural Crack
4	154	6.7	Failure

Table 4.10: Load Displacement of beam1

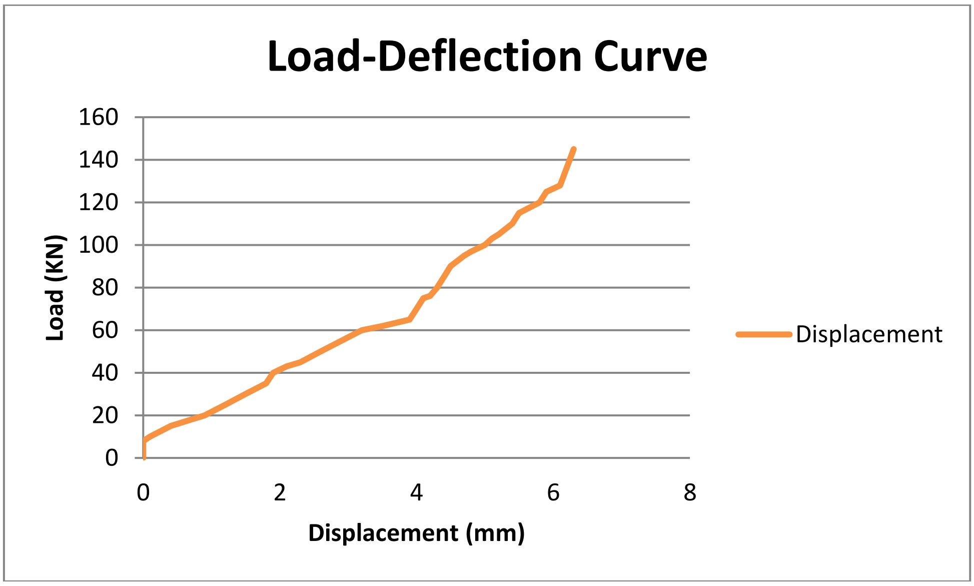


Graph 7: Load Displacement graph of beam1

- **BEAM 2**

S.No	Load	Displacement	Remarks
0	0	0	None
1	40	1.9	None
2	80	4.3	Cracks Appear
3	120	5.8	Shear &Flexural Crack
4	145	6.3	Failure

Table 4.11: Load Displacement of beam2

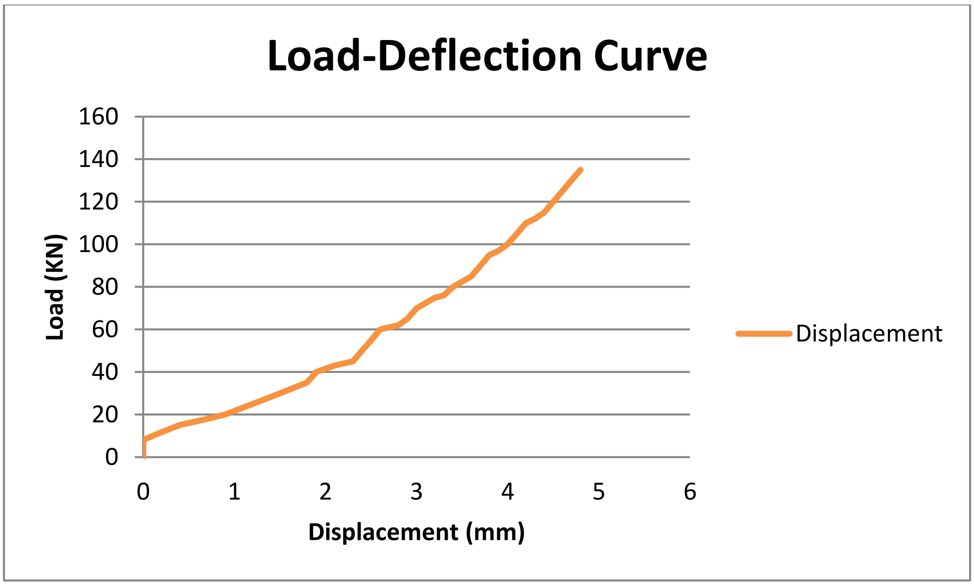


Graph 8: Load Displacement graph of beam2

- **Beam 3**

S.No	**Load**	**Displacement**	**Remarks**
0	0	0	None
1	40	1.9	None
2	80	3.4	Cracks Appear
3	120	4.5	Shear &Flexural Crack
4	135	4.8	Failure

Table 4.12: Load Displacement of beam3



Graph 9: Load Displacement graph of beam3

4.10 CONCLUSION

Experimental investigation	Ultimate load (at failure) Average (KN)	Displacement Average(mm)
Steel beam	161	5.2
FRP beam	144.6	5.9

In this work, an attempt has been made for experimental investigation of concrete reinforced with Steel and FRP beam under flexural action which consisted of the six concrete beams.

The failure mode of both beams was observed from the beam testing in UTM.

The load-displacement behavior of beams were noted in which there were little variations in displacement values of each beams at different ultimate load.

Chapter 05
NUMERICAL INVESTIGATION OF CONCRETE BEAM REINFORCED WITH STEEL AND FRP BARS UNDER FLEXURAL ACTION

5.1 INTRODUCTION

Reinforced concrete (RC) is one of the most important building materials and is widely used in many types of engineering structures. The economy, efficiency, strength, and stiffness of reinforced concrete make it an attractive material for a wide range of structural applications. Understanding the response of the structural components during loading is crucial to the development of an overall efficient and safe structure. Different methods have been utilized to study the response of structural components. The results are compared with the theoretical calculations that estimate deflections at the serviceability load of the beams. Finite element analysis can also be used to model the behavior numerically to confirm these calculations, as well as to provide a valuable supplement to laboratory investigations, particularly in parametric studies. With the continuous development of finite element theory and computer technology, the development of finite element analysis software is maturing. ABAQUS, as one of the largest universal finite element analysis software, is increasingly commonly used in research works and engineering. Because not only does it have high speed, high accuracy, and low-cost analysis of the numerical calculation of finite element analysis software, but also has a more user-friendly operator interface and visualization results, especially when it is used in the nonlinear analysis of reinforced concrete structure.The numerical findings of the ABAQUS FEA are compared with the experimental data, which demonstrate good agreement. Laboratory tests were carried out for plain, under, balanced, over reinforced sections. The failure mechanism of a reinforced concrete RC beam was modeled quite well using FEA and the failure load predicted was very close to the failure load measured during experimental testing. RC beam analysis withthe concrete damage plasticity model in ABAQUS model when compared with the experimental result revealed that FEM analysis result was found similar to numerical.

In this investigation, the behaviour of the experimental beams was simulated using the ABAQUS finite element programme. For this simulation, ABAQUS/Standard was chosen because of its user-friendly interface and support for parametric modelling. ABAQUS/CAE was used to generate the concrete beam's geometry, and a command-line interface was used to apply the element type. A beam model of the reinforcement in a concrete beam was made using ABAQUS/CAE, with the cross section provided.

5.2 MODELINGANDANALYZING OF CONCRETE BEAM USING ABAQUS:

The commercial software package ABAQUS (Dassault Systemes, Waltham, MA, USA) is frequently used to study many different kinds of complex systems. This software makes it possible to analyses complexsystems using finite elements to ascertain theirreplies under various loading circumstances. By simply generating the geometry under examination and associating it with the correct physical and material parameters, loading, and also providing the boundary conditions to the material to be modeled in ABAQUS/CAE which solves the model so quickly and saves the time.

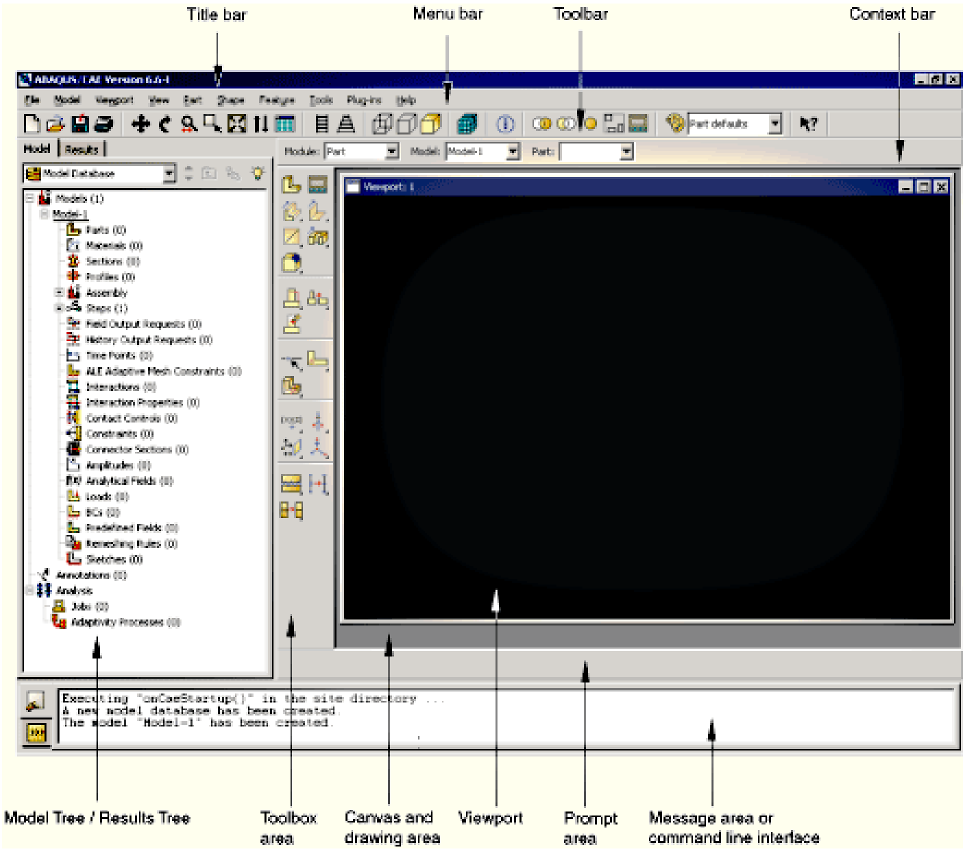


Figure 5.1: Display of Abaqus Software/ CAE

The sketch of the suggested reinforced concrete beam with dimensions of 915 150 230 is shown in the figure below in millimeters. Furthermore, the steel reinforcing parameters employed in this beam are as follows:

- Top Bar: 2-10mm -Bottom Bar: 2-10mm, Stirrups: 2L -8 mm @ 100 mm c/c

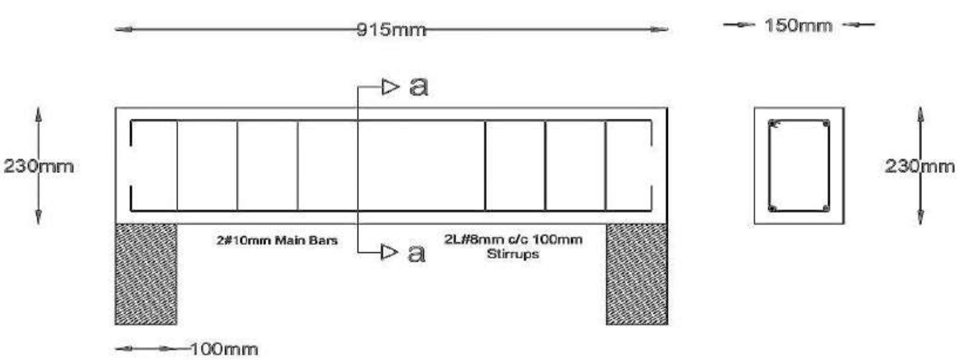


Fig. 5.2: Geometry and dimension of beam and its opening.

5.3 DESIGN CRITERIA

Concrete structure must satisfy the following conditions:

- The structure must be strong and safe
- The structure must be stiff and appear unblemished
- The structure must be economical.

When evaluating the safety and serviceability of a proposed design, advanced analytical techniques can be a crucial aid. The breadth and severity of a disaster in terms of human and economic damage in the case of a structural breakdown are closely tied to the rise in scale of modern structures.

As a result, thorough and in depth structural safety study is increasingly required. Due to its versatility in developing geometry and material modelling, ABAQUS has been selected for the analysis ofstructural members in this study with the goal of modelling and evaluating the concrete beam with steel.

5.4 MATERIAL PROPERTIES

ABAQUS has vas set of material library in the engineering data section. Either we can select a material from the library or we can manually enter the properties of material in ABAQUS/CAE. The CDP element requires linear isotropic and multi-linear isotropic material properties to properly model concrete. The substitution of material properties are very important for the model that need to be analyzed, the modulus of elasticity of the concrete (E*c*) and Poisson's ratio (μ) must be defined in the model.

5.4.1 ELEMENT TYPES

Element type used for this study is listed in the table below. CDP element type gives more stable results.

Table 5.1: Element types for working model

Material Type	Element
Concrete	CDP
Steel Reinforcement	BEAM

5.4.2 CONCRETE DAMAGED PLASTICITY

The reinforced concrete beam simulation that was employed in this investigation uses the Concrete Damage Plasticity (CDP), the most complete continuum model, to define concrete behaviour. The CDP model was created based on two concrete failure mechanisms and is applicable to concrete that is subjected to monotonic loading for many types of structures (such as beams, trusses, shells, and solids) that is crushing by compression and cracking by tensile force. When exposed to uniaxial pressure, concrete's stress-strain response displays a linear elastic relationship up until the failure stresses are developed, after which the concrete adopts a softening stress-strain behaviour.. The unloading response is weakened and the elastic stiffness of concrete is affected when the concrete is unloaded at any point from within the strain softening portion of the curve. The damage parameter in tension (dt), which can vary from zero to one and represents the specimen's undamaged condition to one, which denotes that the material has lost all of its strength, defines this decrease in stiffness. The parameters needed to define the yield surface in Abaqus before defining the concrete damaged value are made up of four constitutive parameters..For stresses below the critical value, which marks the beginning of inelastic behaviour, the Poisson's ratio regulates the volume changes of concrete. Concrete displays an increase in plastic volume under pressure once the critical stresses are obtained. By establishing a parameter called the angle of dilation, this behaviour is taken into consideration The dilation angle recorded in the plane at high confining pressure, or in the CDP model, is identified in this study using sensitivity analysis. The plastic potential surface eccentricity which is denoted as ϵ with a default value of 0.1. The fb0/fc0 ratio, with a default value of 1.16, compares the first uniaxial compressive yield stress to the initial biaxial compressive yield stress. Last but not least, "Kc" is the default value of 2/3 for the second stress invariant on the tensile meridian to the compressive meridian at initial yield (Abaqus User Manual, 2014). A biaxial laboratory test is required to determine the value of "fb0/fc0," and the parameter "Kc" should be determined using concrete's full triaxial tests.

The tests that are going to be confirmed in this study lack information on the identification process for the parameters "," "fb0/fc0," and "Kc," hence these procedures are not discussed in this paper. As a result, this study accepts default values.

Table-5.2: Plasticity damaged parameter

Plasticity	Value
Dilation angle	30
Eccentricity	0.1
fb0/fc0	1.16
k	0.6667
Viscosity parameter	0.0005
Density of concrete = $\mathbf{2.4} \times \mathbf{10}^{-\mathbf{6}}$N/mm Density of steel =$\mathbf{7}.8 \times \mathbf{10}^{-\mathbf{5}}$N/mm3	
modulus of elasticity of concrete =23.9GPa modulus of elasticity of steel =200GPa	
Poisson's ratio of concrete = 0.2 Poisson's ratio of steel = 0.3	
Concrete strength is M20	

The concrete damage plasticity (CDP) technique determines the constitutive behaviour of concrete by providing the scalar damage factors for both the compressive and tensile response. The variables dt and dc represent the damage variables in tension and compression, respectively. And the dt and dc values range from zero to one. The software user manual made the assumption that unaffected material would have a damage value of zero and completely destroyed material would have a damage value of one.The CDP approach primarily discusses two concrete failure mechanisms: compressive crushing and tensile cracking. Two hardening factors which are εt PL and εc PL.These factors are connected to failure mechanisms under tension and compression stress, regulate the yield surface.The damage parameters which are compressive and tensile are obtained by the equations which were prescribed by Birtel and Mark(2007);

- Compressive damage parameter (d_c):

$$d_c = 1 - \frac{\sigma_c E_c^{-1}}{\varepsilon_c^{pl}(1/b_c - 1) + \sigma_c E_c^{-1}}. \quad (1)$$

- Tensile damage parameter (d_t):

$$d_t = 1 - \frac{\sigma_t E_c^{-1}}{\varepsilon_t^{pl}(1/b_t - 1) + \sigma_t E_c^{-1}}. \quad (2)$$

Where;

- **dc**= Compressive damage parameter
- **dt**= Tensile damage parameter

- **σ_c**= Concretecompressivestresses
- **σ_t**=Concrete tensile stresses
- **E_c**=Modulus of elasticity of concrete
- **ε_{cpl},ε_{tpl}**= Plastic strains corresponding to compressive and tensile strengths of concrete
- **b_c, b_t**= Constant parameters, $0<b_{c,t}\leq 1$

5.5 THE ESTABLISHMENT OF MODEL

A beam has a cross-section that is 150 mm wide by 230 mm deep with a 25 mm clear cover, and it is 915 mm long. For this investigation, The data which was taken for design is;

- Concrete strength= 21 N/mm^2
- Concrete density= 2.4x10-5 N/mm^3
- Concrete Poisson's ratio= 0.2
- The confinement bars were made with a yield stress= 415 N/mm^2
- Longitudinal reinforcement with a yield stress= 415 N/mm^2.
- The steel has a density = 7.8x10-5 N/mm^3
- Young's modulus= 200000 N/mm^2
- Steel Poisson's ratio= 0.3

The reinforced used the Steel element in ABAQUS, whereas the concrete adopted the CDP element. To mimic the bonding between the reinforced and concrete, we implanted reinforced concrete elements.
In the engineering data part of ABAQUS, there is a substantial material library. Either a material can be chosen from the library or its properties can be manually entered into ABAQUS/CAE. Pre-experimental work took into account the material properties for all beam components with the same level of detail.
The reinforced concrete beam simulation that was employed in this investigation uses the Concrete Damage Plasticity (CDP), the most complete continuum model, to define concrete behaviour. The CDP model was created based on two concrete failure mechanisms and It is applicable to concrete exposed to monotonic loading in a variety of structures (such as beams, trusses, shells, and solids) that is crushing by compression and cracking by tensile force.

5.6 ABAQUS MODELLING

The 3D Finite Element models in abaqus software which is reinforced concrete beams that were created based on the main goals of this study and the various steps are concerned with modeling and these steps are determined as design requirement to be modeled in software and in last to analysis the model to generate the results which will show the exact behavior as of designed model and executes the crack patterns,stresses, displacement of beam and it will show the load verses deflection graph which will help to know the maximum displacement of beam. The steps involved in modeling are as addressed follow;

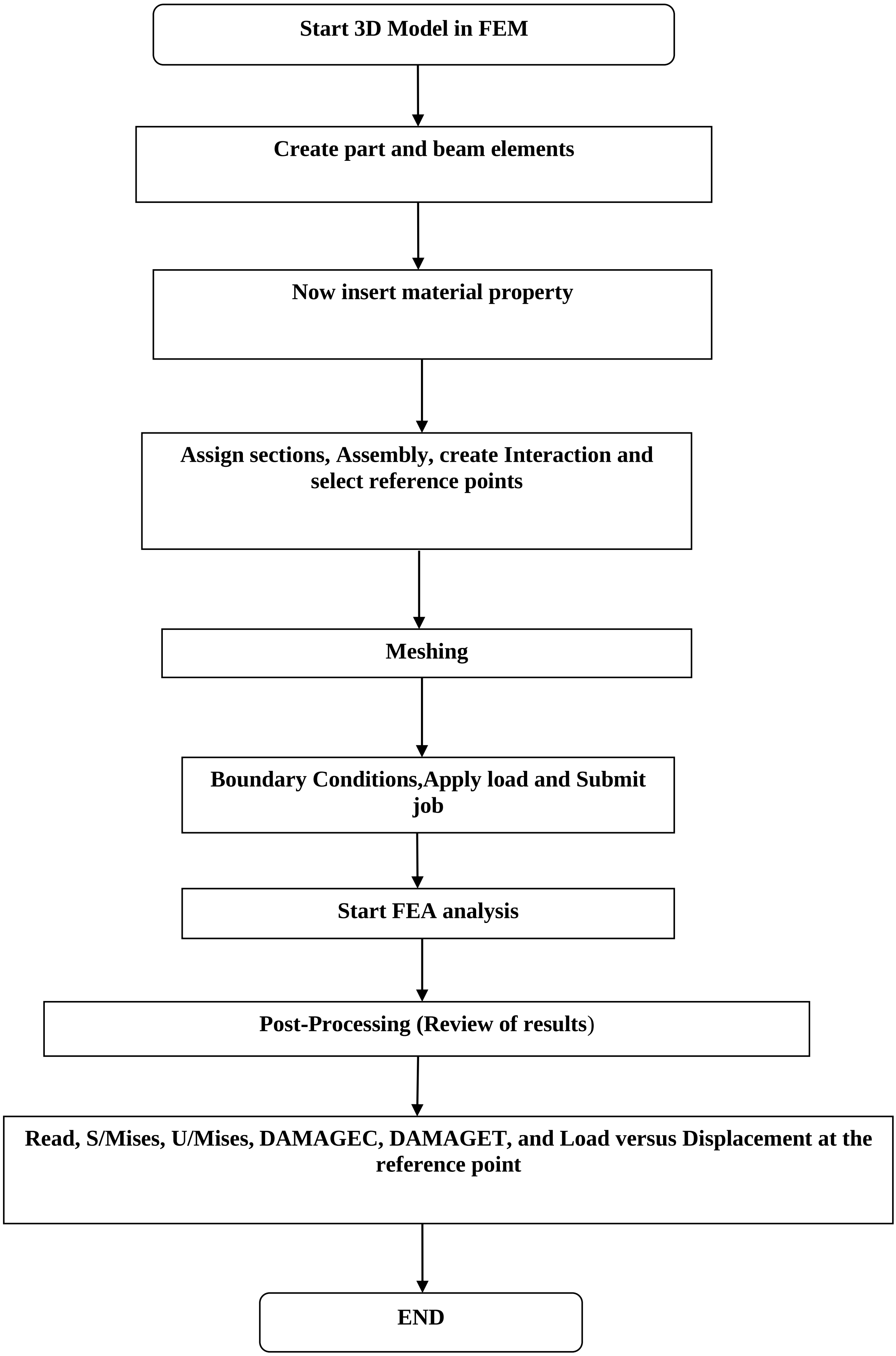
- The types of elements
- Material property
- Assigning the sections
- Defining the step
- Interaction if elements
- Defining the boundary conditions and load
- Meshing the model and then assigning the job
- Generating results

The Abaqus software shows the accurate results of a designed model, and it helps in linear and non-linear analysis of any model which will give accurate large deformations according to the loading conditions.

An realistic model of the structural elements and its constituent members working as a composite made up of concrete and steel is required for the numerical simulation of a structural concrete. A three dimensional solid element in "modelling space" employing deformable type for the beam was made since each segment is sketched out independently using ABAQUS and can then be extruded in any direction. The 8- node continuum solid element was used to create a concrete beam. Eight nodes with three degrees of freedom each make up the solid element and this solid element is capable of crushing, three orthogonal cracks, and the plastic deformation.

The considerations of concrete beam are (of size 915 x150 x230).made to make meshing and load conditions easier. The procedure for Abaqus modeling has been shown below in flowchart.

PREPROCESSING IN ABAQUS



5.6.1 STAGES OF ABAQUS MODELING

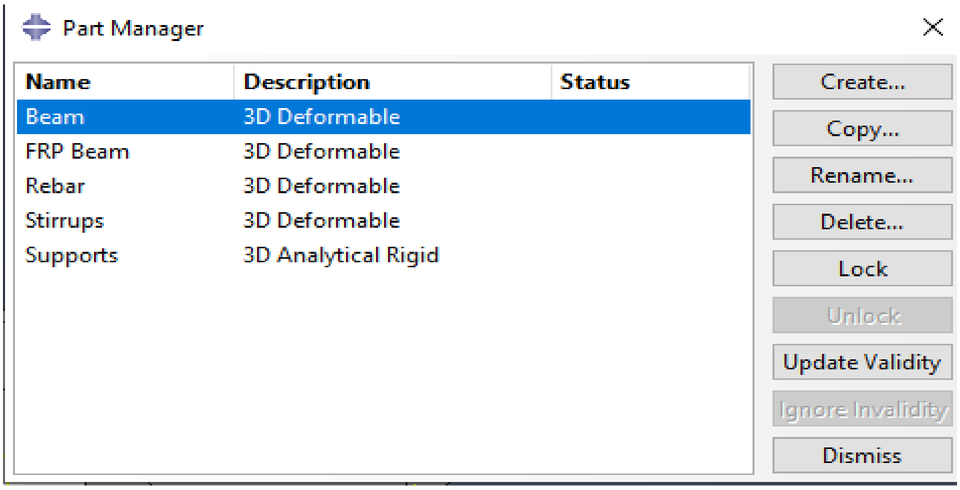


Figure 5.3: Create Parts

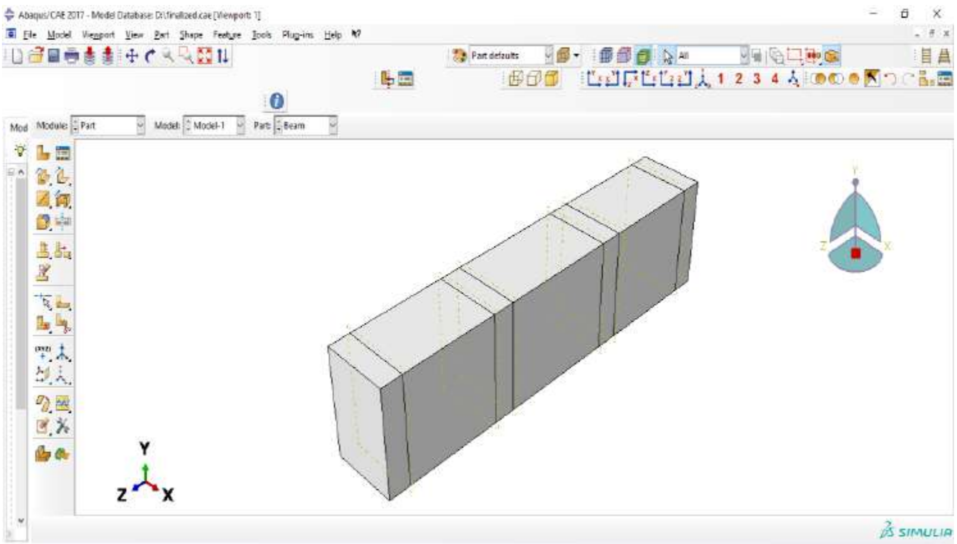


Figure 5.4: Modeling of Concrete Beam

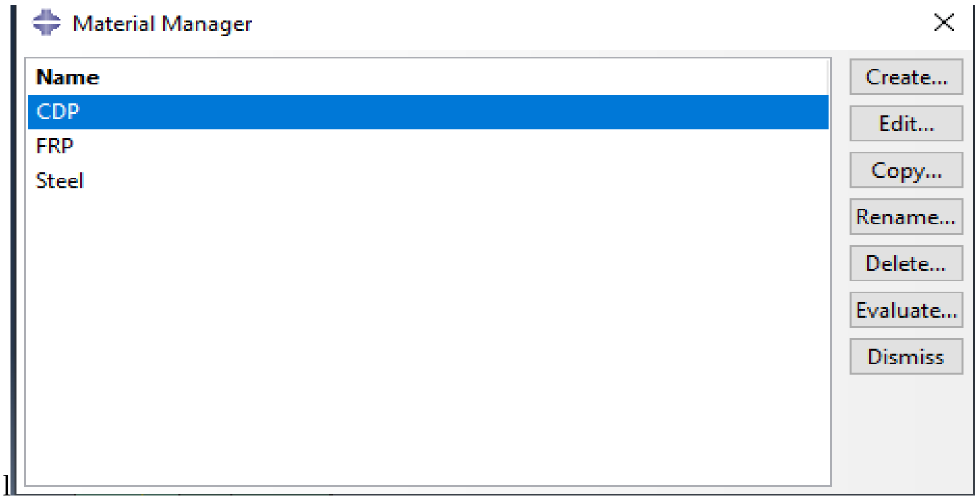


Figure 5.4: Define Material Properties

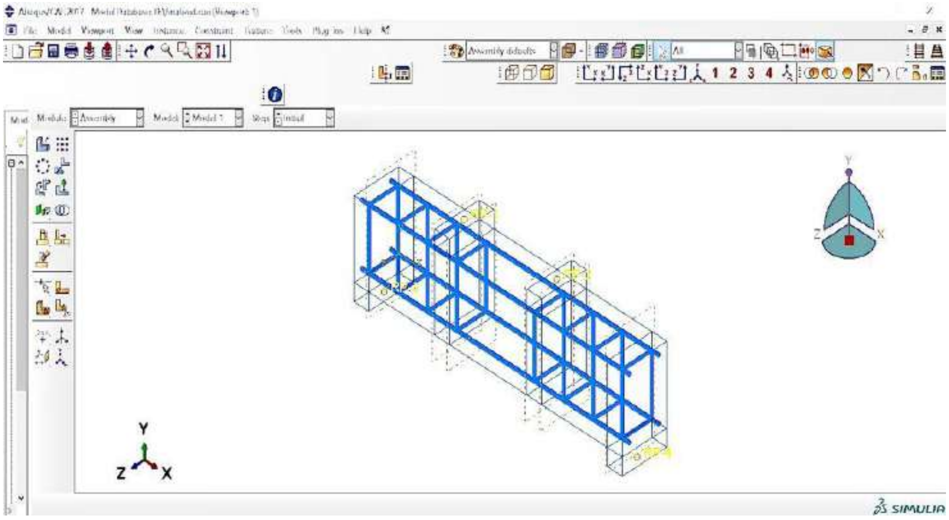


Figure 5.5: Assembling of part instances reinforcement

- **INTERACTIONS**

The contact technique is a simple way to explain the interaction between the concrete and steel beam. The contact formulations for the beam model are accessible in the Abaqus programme, which is used in this paper. A typical node-to-surface contact algorithm is provided by this software. Despite the fact that the meshes created on the surfaces of the two sections may differ, this kind of constraint enables you to combine them.

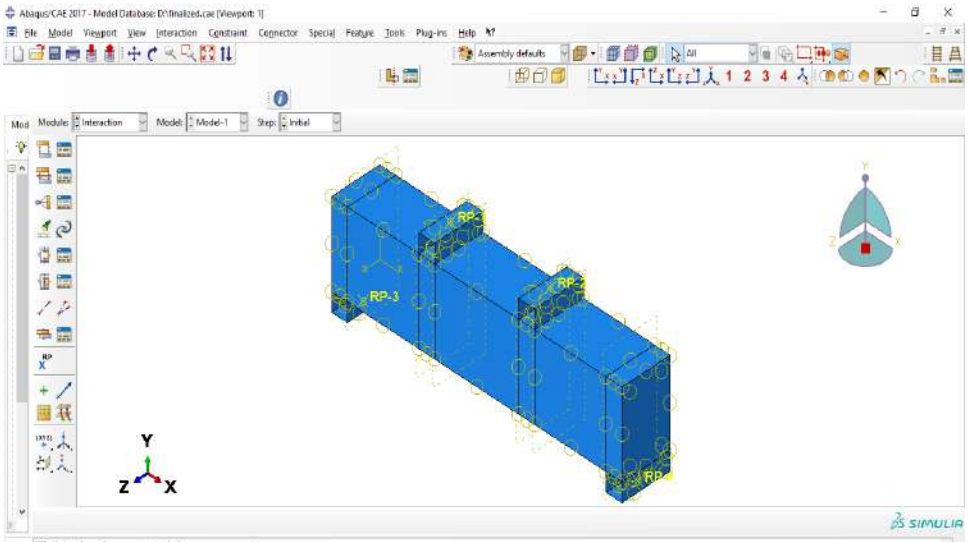


Figure 5.6: Interaction Between Concrete and Reinforcement

- **MESHING**

The qualities and regulating relationships are assumed over the discretized components and stated mathematically on the designated points known as nodes, meshing is critical in the FEA. As a result, adding more elements to a finite element model increases accuracy but also increases the time required to solve the equations. The mesh model is shown in the diagram below.

Actually, meshing is a component of a FEA model in that it is a determined arrangement of finite elements. A meshes can be defined on a part or an assembly in Abaqus/CAE.

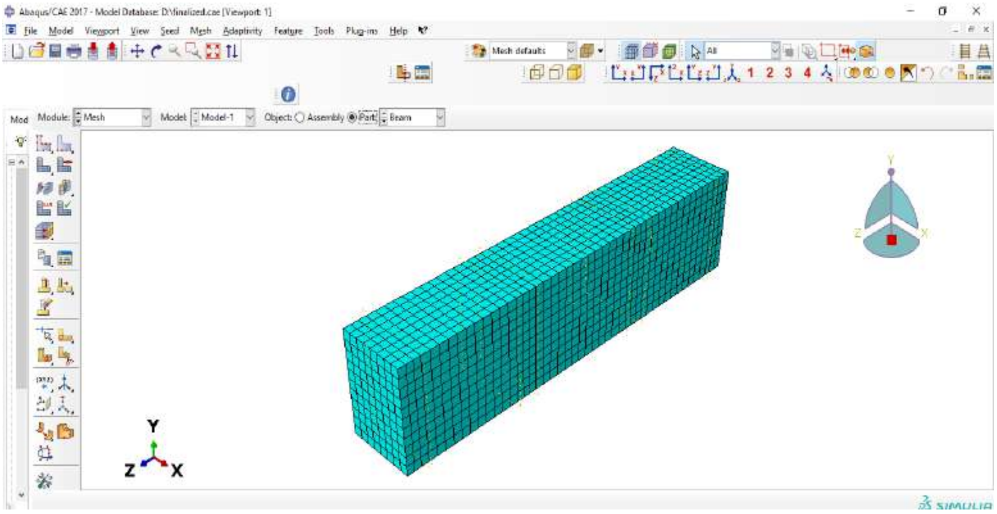
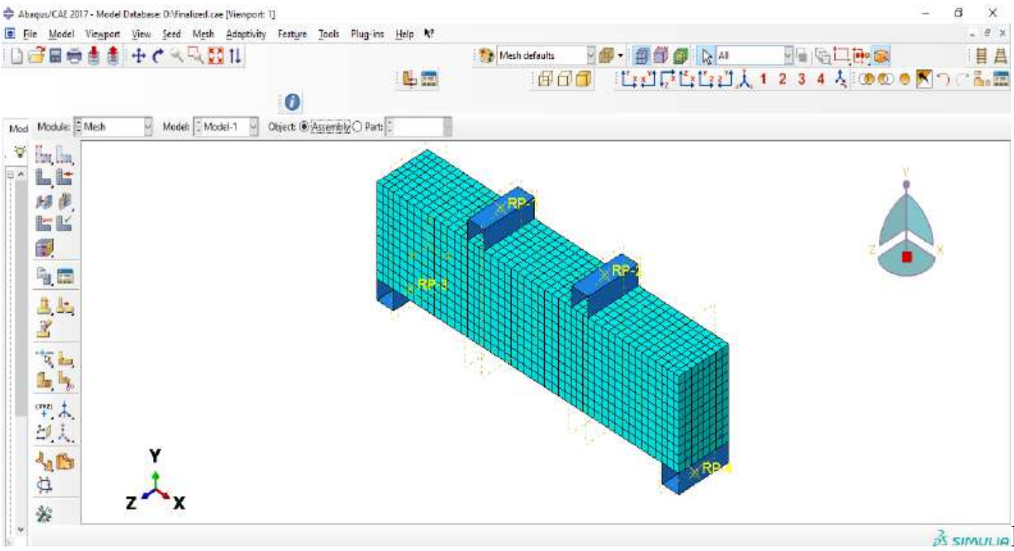


Figure 5.7: Modeling of Concrete Beam



ll

Figure 5.8: Meshing Beam and Supports

➢ LOADS AND BOUNDARY CONDITION

This step in finite element model FEM is necessary in which loads,land supports are defined to the model. There are different types of supports but these are defined to the design requirement of the beam.

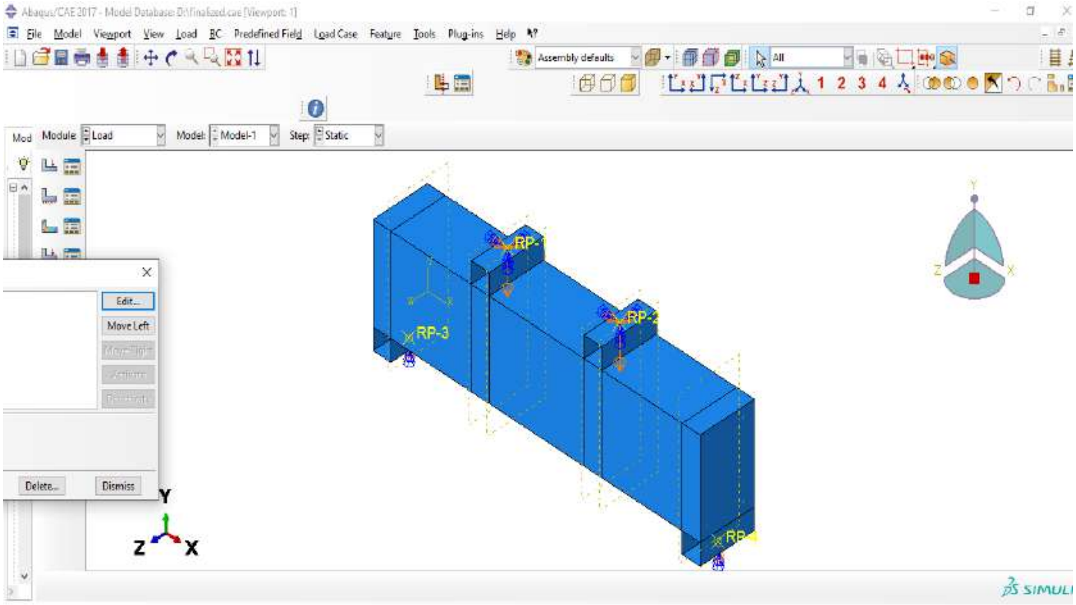


Figure 5.9: Defining Loads

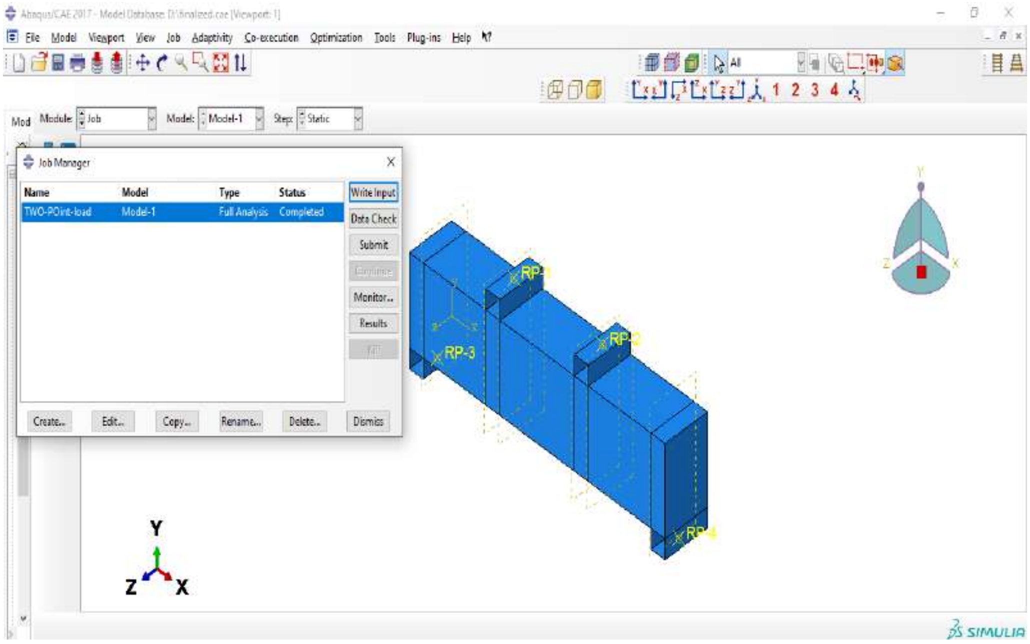


Figure 5.10: Create Job and Submit for Analysis

5.7 SIMULATION

After creating parts, inserting material properties and applingloads, the finite element model goes for analysis and Initial cracks appeared mainly in beam. With the increase of load, crack continues to grow and various cracks started to grow in the increased range at the same time when the yield point is reached, the occurs at the beam bottom. More flexural cracks developed in the midspan and near the support areas as the load rose, and the already present vertical cracks barely widened and deepened. Vertical cracks that were close to the supports began to shift their orientation and become inclined cracks when the stress was increased further. Depending on the reinforcing, different crack dispersion patterns were observed. The results of Abaqus model are shown below.

5.7.1 STEEL BEAMSIMULATIONS

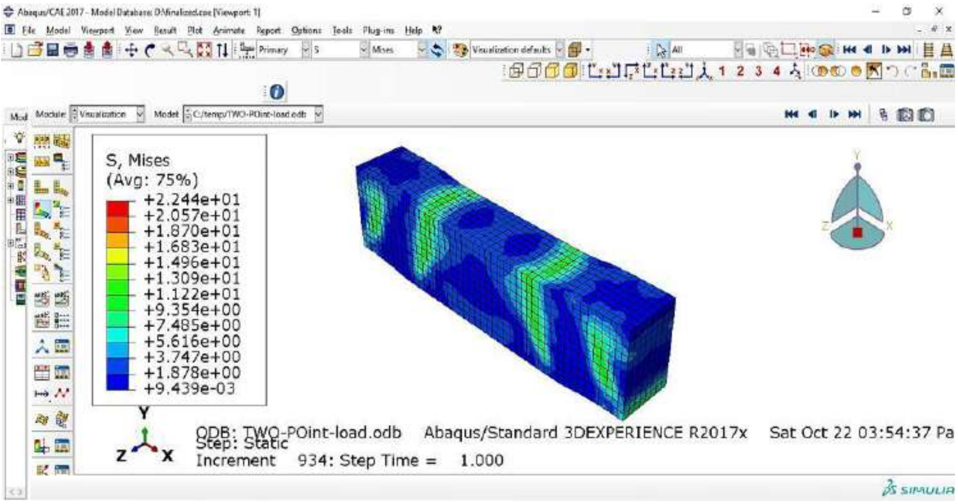


Figure 5.11: Stresses inducing in beam

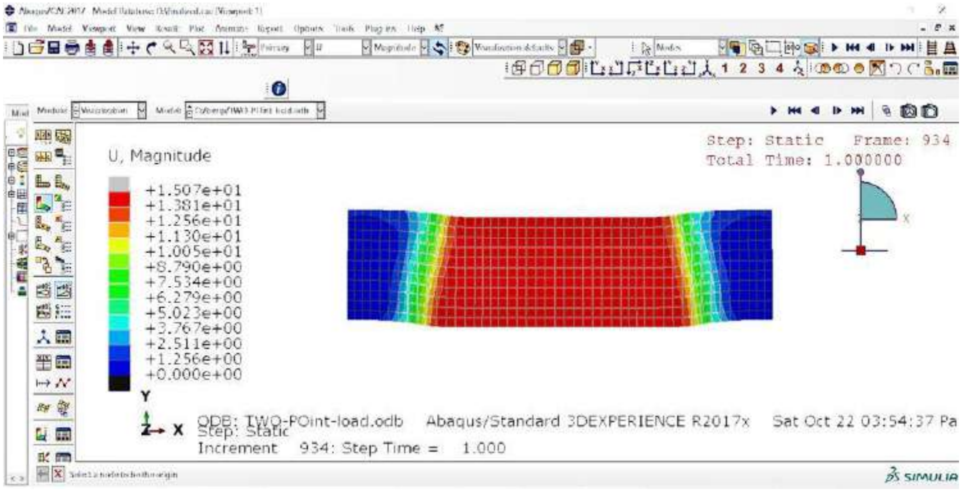


Figure 5.12: Magnitude

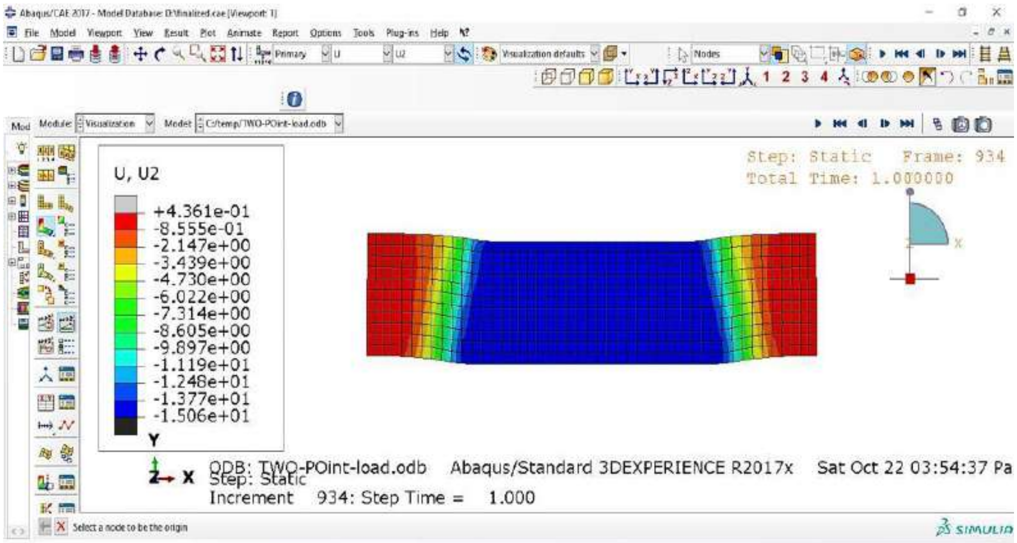


Figure 5.13: Displacement in beam

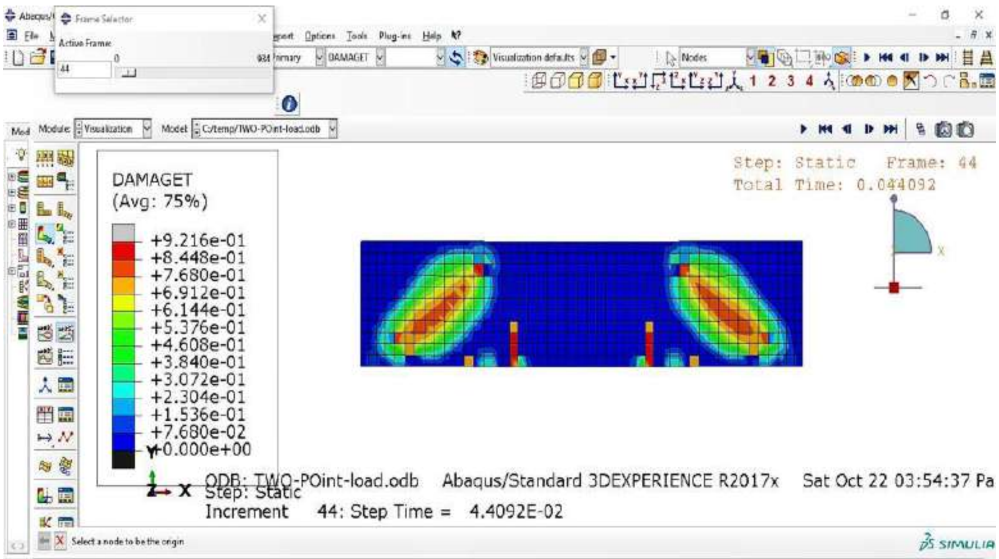


Figure 5.14: Cracks appearing in beam

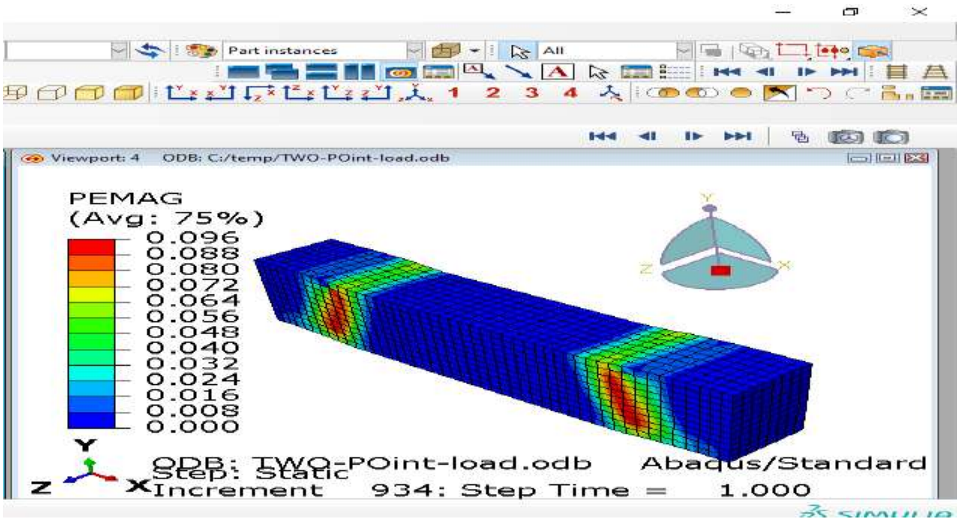


Figure 5.14a: Cracks

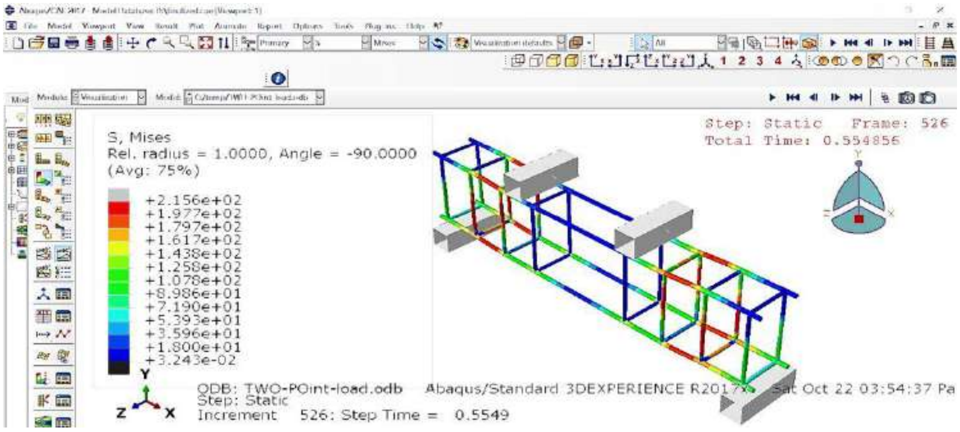


Figure 5.15: Stress distribution in reinforcement

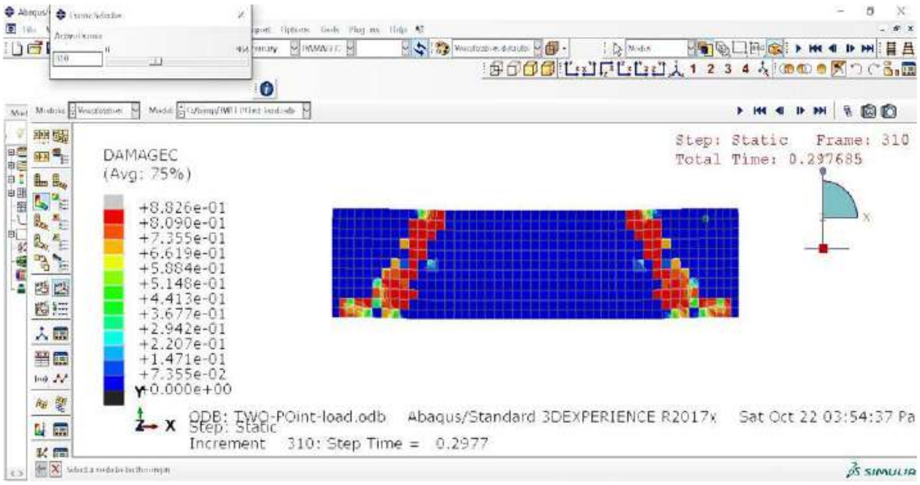


Figure 5.16: Damagec(cracks) patterns in beam

5.7.2 FRP BEAM SIMULATIONS

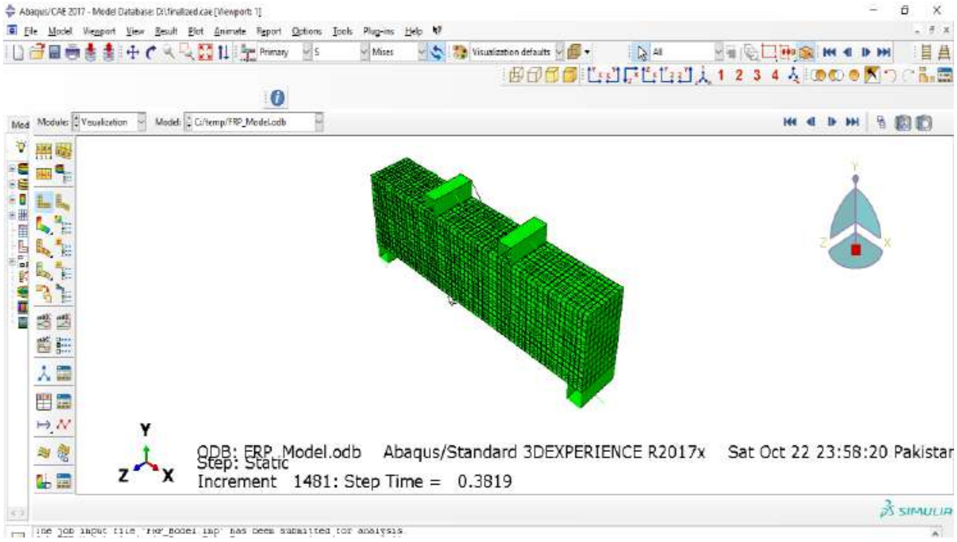


Figure 5.17: FRP BEAM MODEL

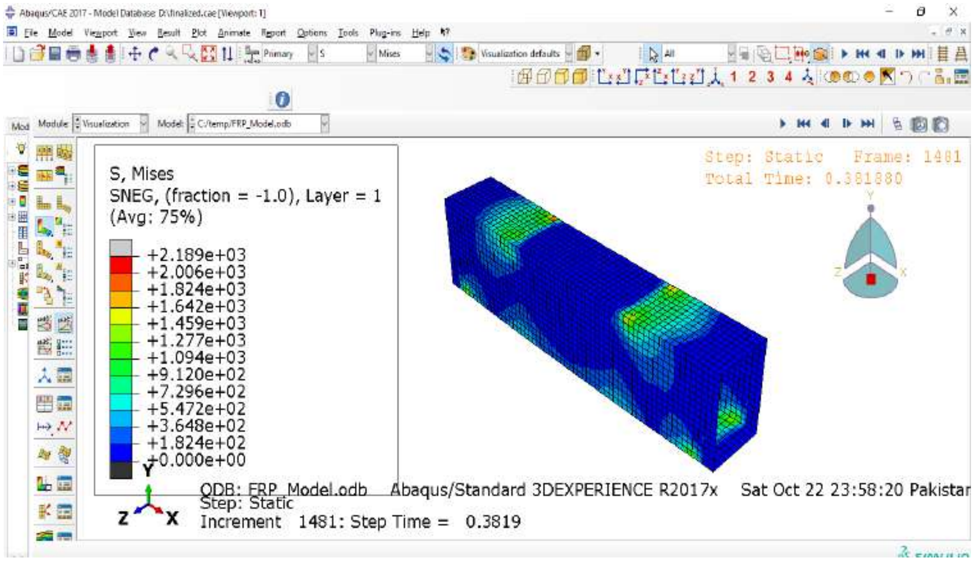


Figure 5.18: Stresses inducing in beam

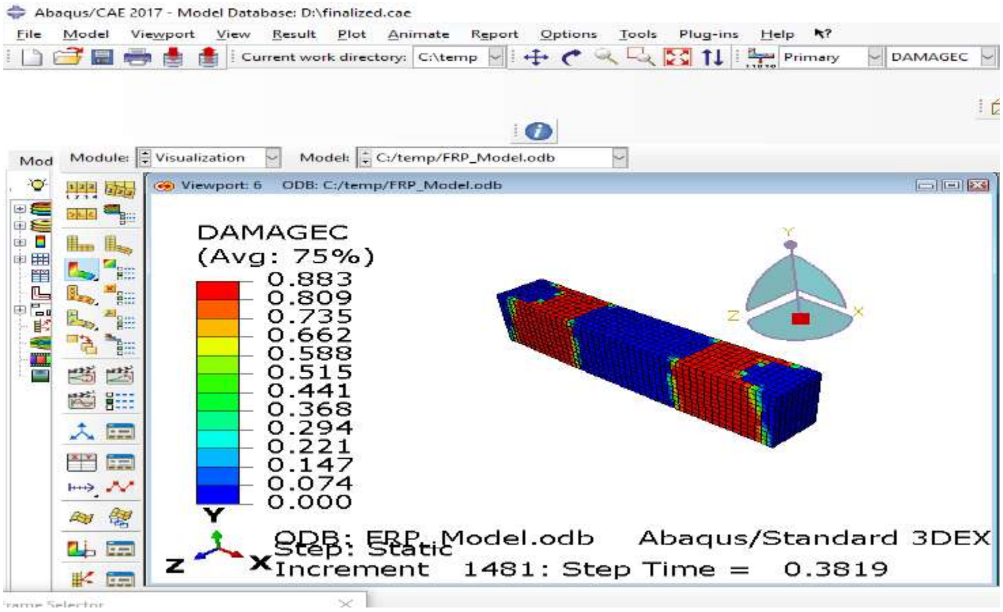


Figure 5.19: Damagec (cracks) patterns in beam

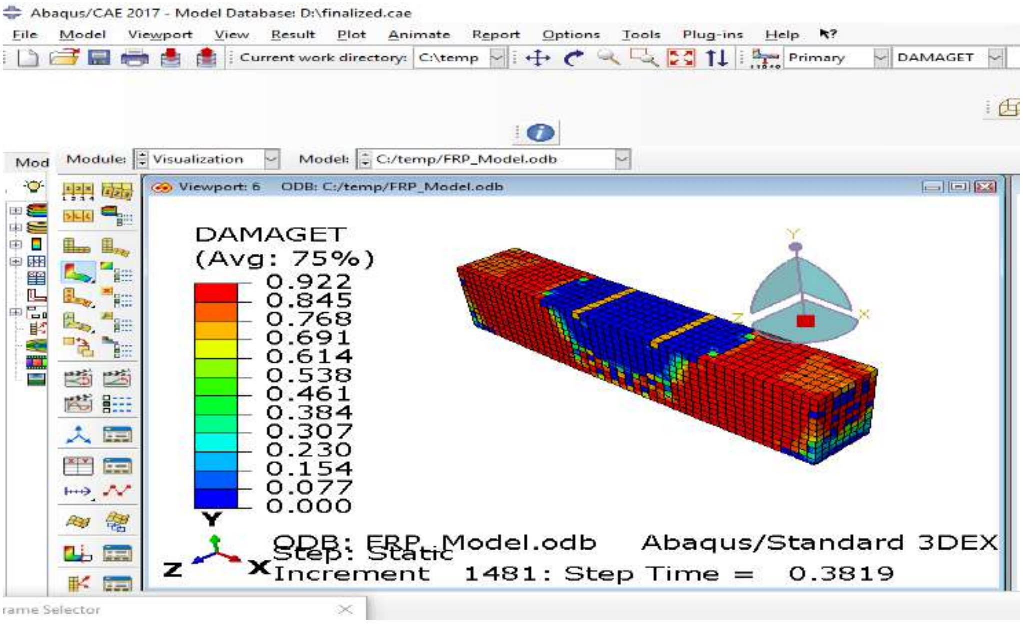


Figure 5.20: Cracks appearing in beam

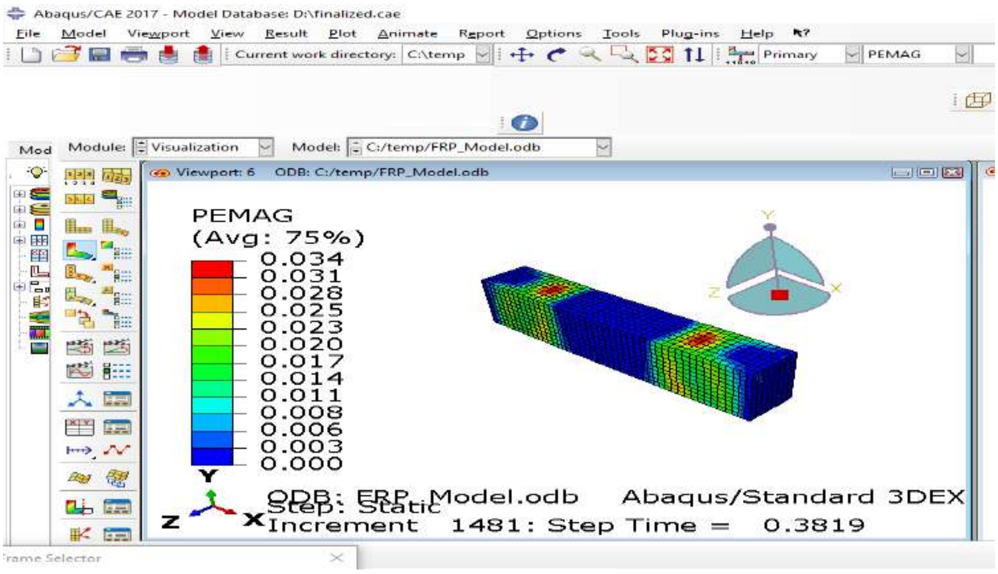


Figure 5.20a: Cracks

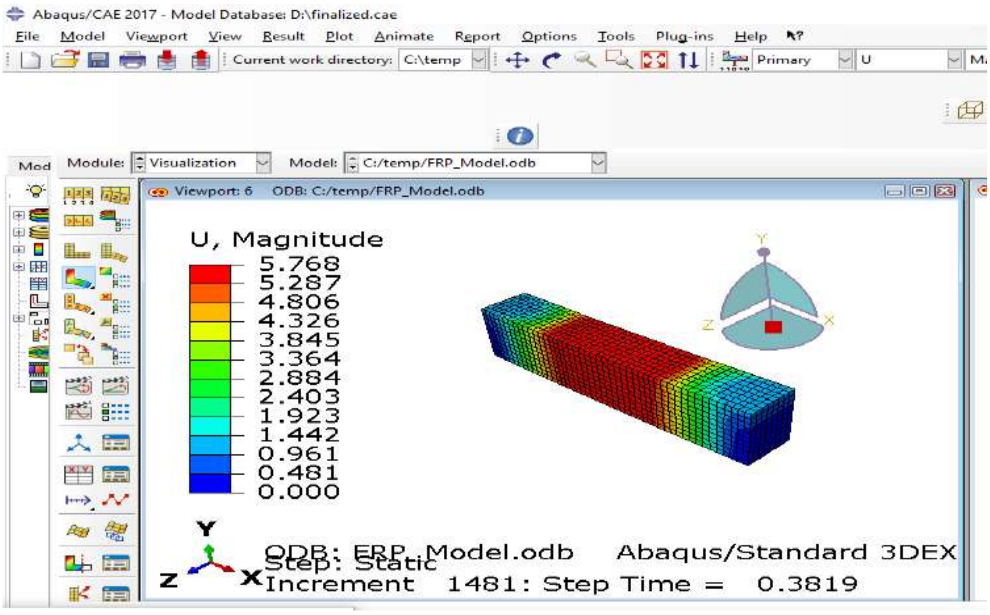
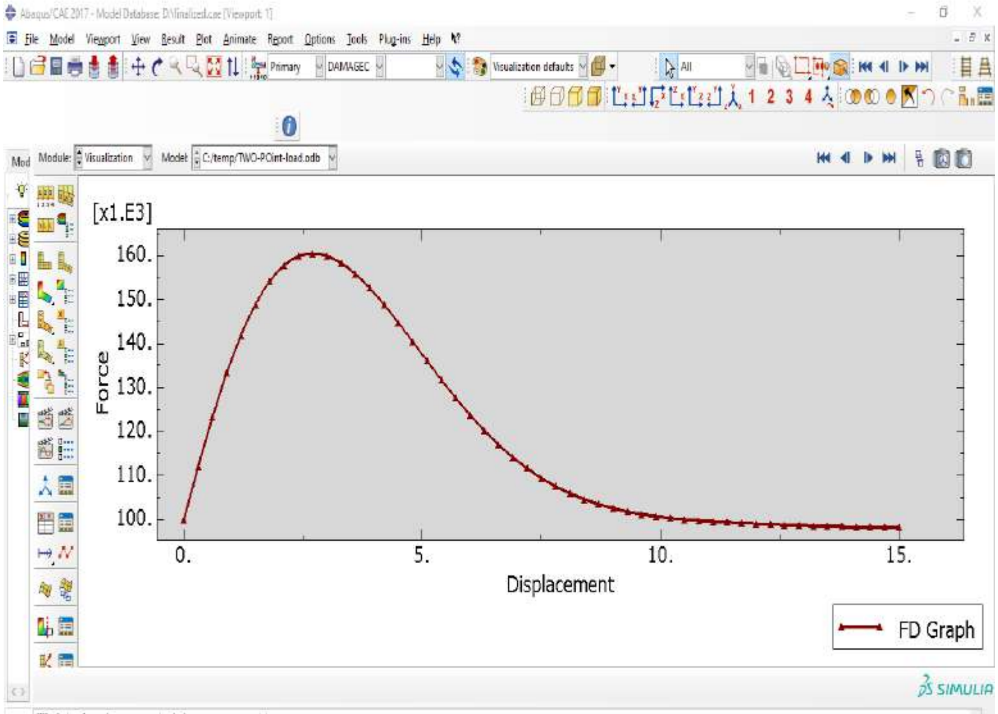


Figure 5.21: Magnitude

5.8 RESULT AND GRAPH

➢ **Load Displacement Graph and Result of Steel Reinforcement**

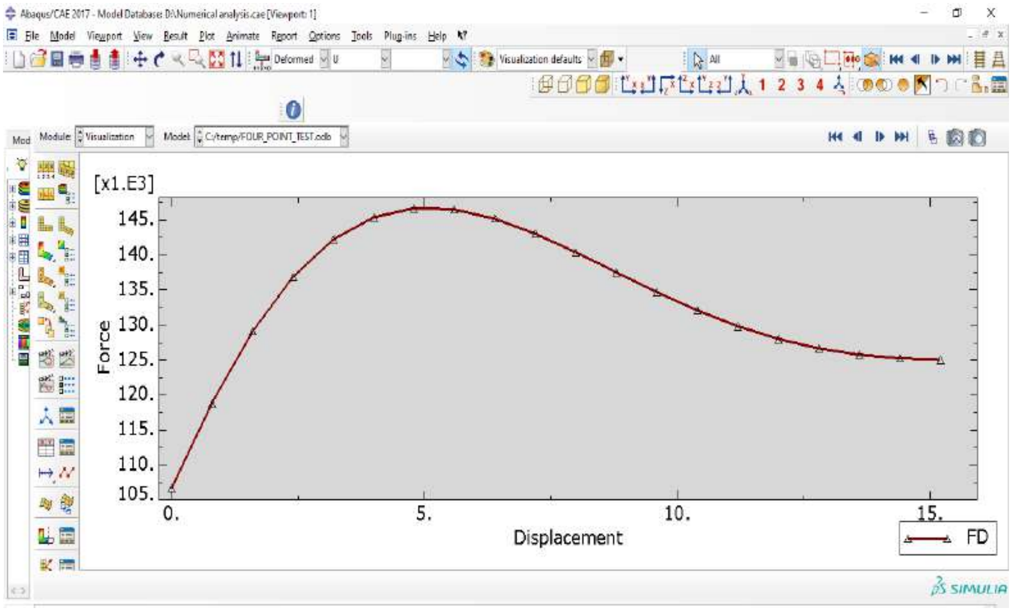


Graph 1: Load Displacement of Steel Beam

Table-5.2: Load Displacement Results

S.No	Ultimate Load (at failure) (KN)	Displacement (mm)	Remarks
01	160	3.7	Shear & Flexural Cracks

➢ Load Displacement Graph and Result of FRP Reinforcement



Graph 2: Load Displacement of Steel Beam

Table-5.4: Load Displacement Results

S.No	Ultimate Load (at failure) (KN)	Displacement (mm)	Remarks
01	147	5.2	Shear & Flexural Cracks

5.10 CONCLUSION

Numerical investigation	Ultimate load(at failure) (KN)	Displacement average(mm)
Steel beam	160	3.7
FRP beam	147	5.2

In this study,an attempt has been made for numerical investigation of concrete reinforced with Steel and FRP beam under flexural action which consisted of the six concrete beams.

The simulations of each beam was detected and failure mode of both beams were observed which is shown above in table.

The load-displacement behavior of beams were noted in which there were little variations in displacement values of each beams at different ultimate load.

Chapter 06
RESULTS AND DISCUSSIONS

6.1 EXPERIMENTAL AND NUMERICAL CRACKS BEHAVIOUR OF BEAM UNDER FLEXURAL ACTION

➢ **EXPERIMENTALLY**

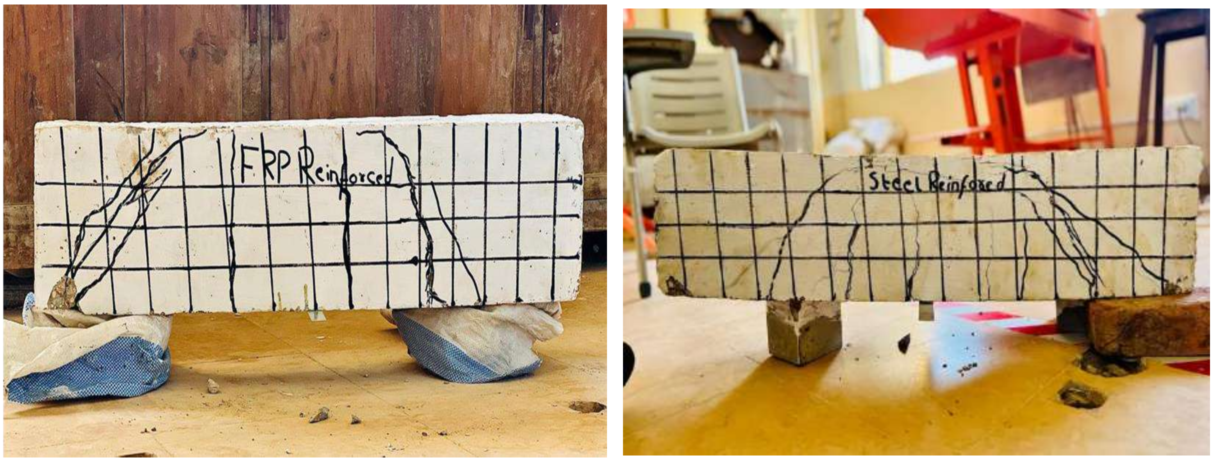
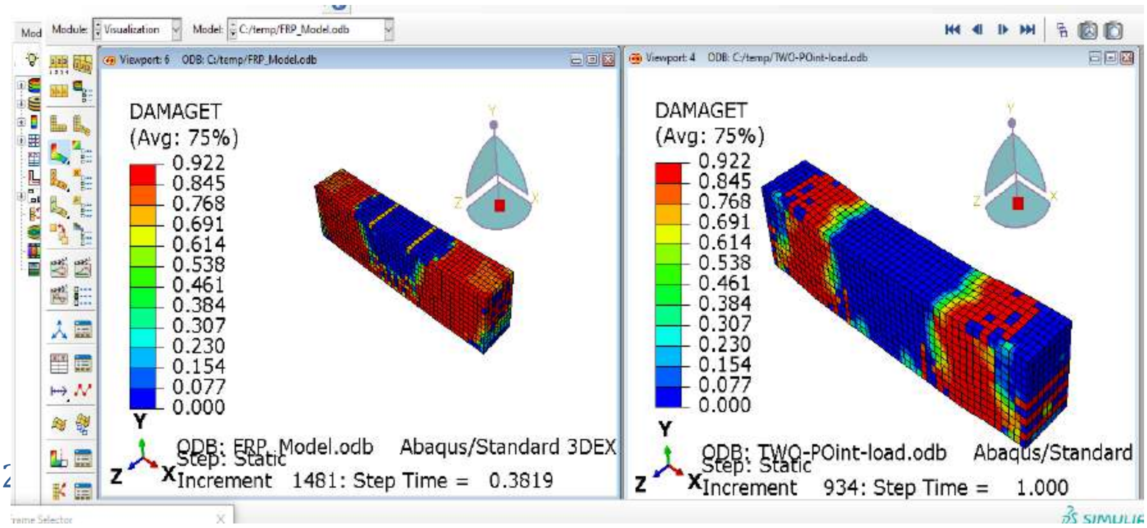


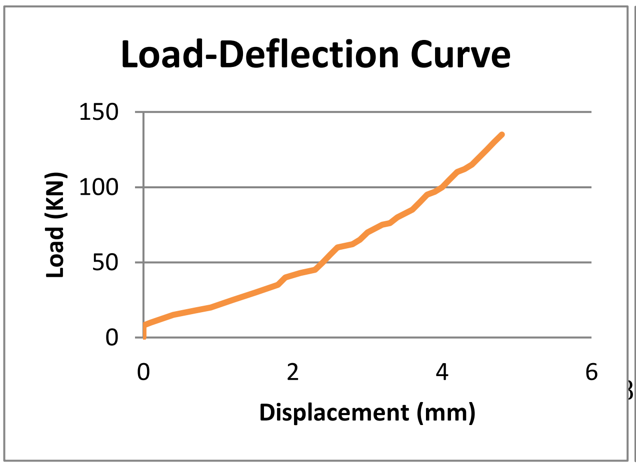
Figure 6.1: FRP Versus Steel Beam Cracks Behavior

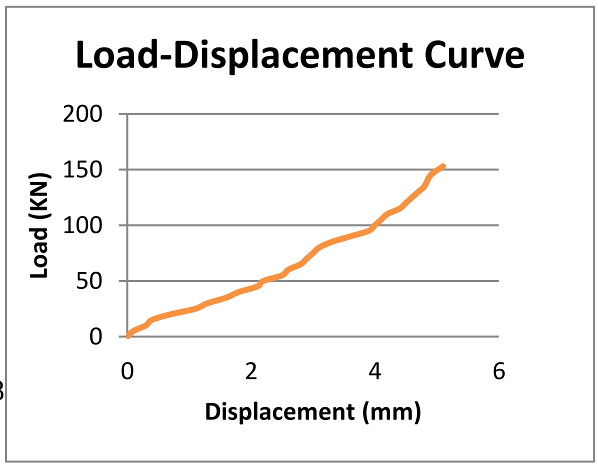
➢ **NUMERICALLY**



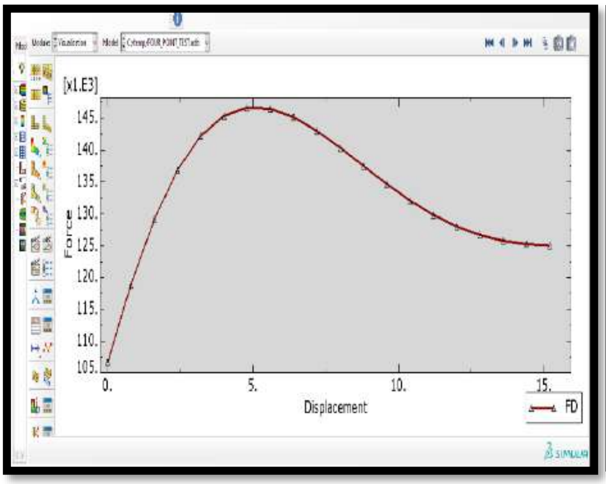
6.2

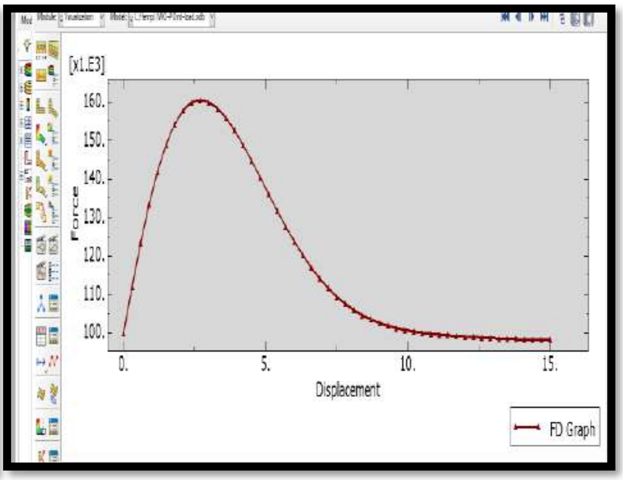
FRP VS STEEL (EXPERIMENTALLY)





FRP VS STEEL(NUMERICALLY)





6.3 STRESS GENERATED IN BEAMS (NUMERICALLY)

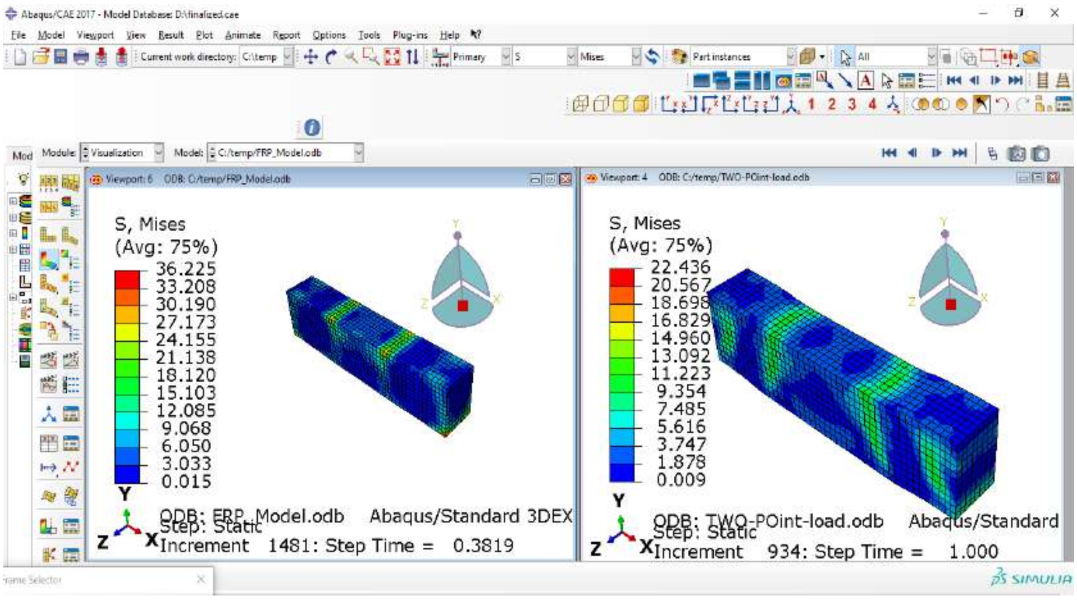


Figure 6.3: FRP Versus Steel Beam Stresses

6.4 DISPLACEMENT (NUMERICALLY)

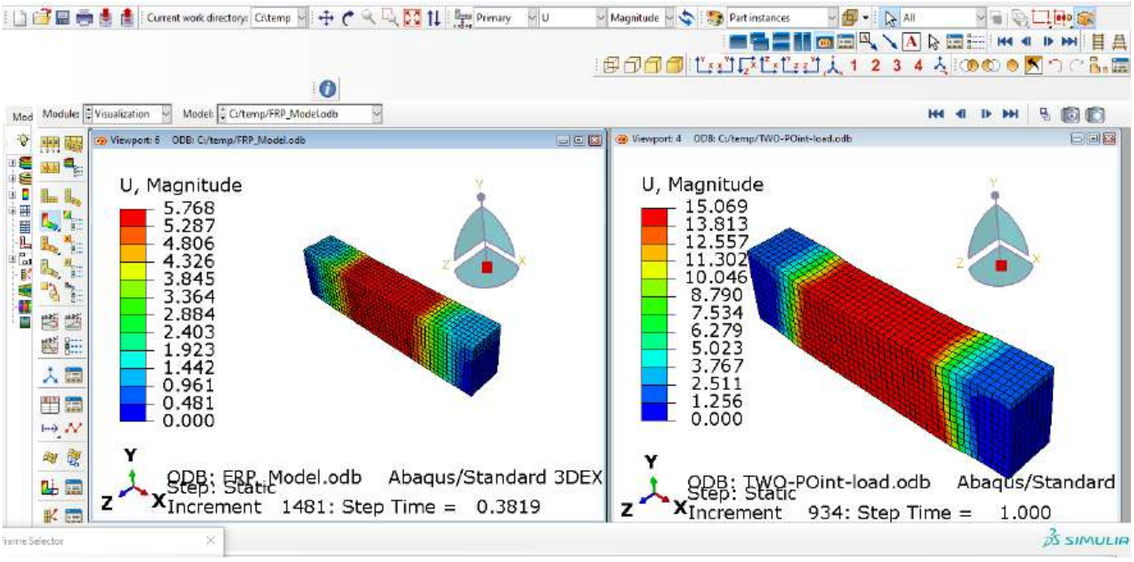


Figure 6.3: FRP Versus Steel Beam Displacement

6.5 RESULTS

Table 6.1: Load displacement results at ultimate load

S.No	Beam Investigation	Reinforcement	Load (at Failure) KN	Displacement (mm)	Remarks
01	Experimentally	Steel	161	5.2	Shear & Flexural Cracks
		FRP	144.6	5.9	Shear & Flexural Cracks
02	Numerically	Steel	160	3.7	Shear & Flexural Cracks
		FRP	147	5.2	Shear & Flexural Cracks

6.6 COMPARSION

Load-displacement curves of Steel and FRP beams obtained from experimental investigation, which is compared with load-displacement curves of Steel and FRP beams numerically using Abaqus, the results of displacement of experimentally and numerically using ABAQUS are an agreement to each other, where the maximum displacement of Steel beam experimentally and numerically is 5.2 mm and 3.7mm respectively. However, the results of displacement of FRP beams experimentally as well as Numerically is 5.9 mm and 5.2 respectively, experimentally results are very close with the numerically by using Abaqus software. The cracks behavior of steel and FRP beams under flexural action generate Shear and flexural cracks experimentally as well as numerically by using Abaqus Software.

6.7 CONCLUSION

The following are the conclusions based on the experimental and numerical Investigation reported in this study.

- Experiment and numerical research on the flexural behavior of steel and FRP reinforced beams.
- An experimental and numerical study was conducted to anticipate the fluctuation of ultimate flexural load and beam displacement.
- To compare experimental work results with numerical simulation using Abaqus software.
- Steel and fibre reinforced polymer (FRP) reinforcement altered the flexural behavior of concrete beam specimens, resulting in a change in the load-displacement curve.
- The fractures behavior of the beam was examined numerically and experimentally, revealing shear and flexural cracks.
- All specimens had a similar beginning rigidity, however as cracks formed, the rigidity of the specimens with FRP reinforcement steadily decreased compared to the specimens with steel reinforcement.
- Although the specimen with FRP reinforcement had a low elasticity modulus, its displacement at maximum strength was greater than the displacement of the specimen with steel reinforcement at its yield strength. Furthermore, the specimen reinforced with FRP produced more fissures.
- A finite element analysis model was used to calculate the strain for each load and the load-deflection curve values for all specimens. when the finite element compared the maximal moment with the experimental value in both circumstances, the load-deflection curves behave differently. As a result, the analysis model's dependability has been confirmed, and it will be used as a database for future variable analysis.

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