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# Design of Curved Beam with Hexagonal Opening

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**ABSTRACT:-** Reinforced concrete beam with transverse web opening is a facility that allows the services such as telephone lines air conditioning and ventilating ducts, to pass through the structure. Because of the change in the beam section the corners of the opening are subjected to large concentration of stress, possibly producing oblique cracks in the beam. The region nearby the openings are measured as the weaker part of the beam. Therefore, a decline in bearing capability and also a change in the load transport mechanism is experienced. This thesis investigates the analytical study on the influence of various opening shapes with constant area on shear behaviour of RC beams without extra shear reinforcement around the opening. In this thesis nonlinear analysis using ANSYS 18.1 is used to analyse the beam. The RC beam with opening is a method that permits the services to move towards the construction. Due to rapid changes in the beams cross-section, the edges of the opening stimulate crosswise cracks and can be subjected to high stress concentrations. The reliability and constancy of the beam will then be considered compromised, and the regions nearby the opening is the weakest element of the beam. Therefore, a decline in the bearing capability and also a change in the load transport mechanism is experienced. If safety actions are not in use, preventable accidents are likely to ensue.

**KEYWORDS:**(Size 10 & Bold) Key word1, Key word2, Key word3, etc (Minimum 5 to 8 key words)...

## I. INTRODUCTION

Sandwich beams are composite systems with horizontally curved, semi-circular, reinforced concrete beams that are utilized in a variety of applications, such as the building of circular water tanks, ring beam carrying domes, circular balconies, etc. An opening in a reinforced concrete beam's web causes a variety of issues with the beam's behaviour, including decreased stiffness, excessive cracking, excessive deflection, and decreased strength. Furthermore, the abrupt change in the beam's cross-sectional size caused a concentration of high stress at the corners of the aperture, which could result in cracking that is undesirable from an aesthetic and durability perspective. In addition, excessive deflection under service load may occur from the beam's lower stiffness, which will also cause a significant redistribution of internal forces and moments in a continuous beam.

### Different Types of Openings in beam:

1. Square Opening
2. Rectangular Opening
3. Circular Opening
4. Pentagon Opening
5. Hexagonal Opening



6. Octagonal Opening
7. Elliptical opening

### The Application Areas of Curve Beam and Hexagonal shaped beam

1. Elevated freeways
2. Intersection of highway
3. Modern Building Construction
4. Curved balconies
5. Curved or Hexagonal shaped canopy and balconies
6. Half hexagonal or curved domes
7. Curved and Hexagonal water tank

A technique that enables the services to move closer to the structure is the RC beam with opening. The edges of the hole can experience large stress concentrations and crosswise cracking because to the fast changes in the beams' cross-section. The beam's dependability and consistency will subsequently be deemed to be weakened, with the areas immediately surrounding the opening constituting the beam's weakest component. As a result, both a decrease in bearing capacity and a modification to the load transmission system are observed. Preventable incidents are likely to occur if safety precautions are not taken. An opening in the beam causes them to behave in an unfavourable way, which affects serviceability. The ability of the beams to support a weight is diminished by cracks that form close to the opening. Therefore, it is crucial to understand how opening the beams will affect them so that it can be added as a structural element without lowering their carrying capacities. To ensure the dependability and consistency of the structure with shear apertures, adequate care and attention must be given. The shear collapse will be catastrophic in nature because there will be no prior notice of it. The concrete structure's fragile nature and its intensity The structural components are strengthened utilising a variety of techniques, such as external FRP wrapping and strengthening using different fibre materials.

FRP is a great alternative to traditional steel reinforcements in RC structures because it is lightweight, has excellent mechanical strength, and is extremely resistant to the corrosive nature of hostile compounds over a wide temperature range. On the basis of their size and locations, the web vacancies are categorised. Various shapes of web holes, including elliptical, circular, square, rectangular, triangular, hexagonal, and even irregular shapes, have been discovered. The most popular shapes are square, circle, and rectangle. Apertures that are 0.25 times the web depth in diameter are regarded as big openings. When an opening is present, beam type behaviour ceases to exist, and the opening is then deemed to be a huge opening. A variety of academics conducted experimental, numerical, and analytical studies to determine the impact of opening. In order to study the behaviour of RC



beams with openings in shear regions, Bashir H. Osman et al. (2016) combined experimental and FE methods. Effective span depth ratio, opening position, and opening size are the primary factors taken into account. Results demonstrate that early beam breakage is caused by openings located in a significant shear area. Additionally, it was completed in a way that both results agreed by comparing the results with those of the nonlinear FE analysis. Bashir H. Osman and others (2017) In order to successfully strengthen RC beams, this research describes a strengthening technique for sheets made of Aramid Fiber Reinforced Polymers. The results show that the orientation of FRP and the break level that is already present have a significant impact on strengthening and mode of failure. Compared to the control beam, the specimen's strength increased and the crack's width shrank. 2014 saw the completion of a fresh study on RC beams with and without multiple web openings by BengiAykac et al. The stirrups have an impact on the ductility of an opening-supported RC beam, in the absence of diagonal reinforcement. It has been discovered that RC beams with circular openings have greater load capacity and ductility



than those with rectangular openings when the same reinforcement details are used. According to the experiment, posts between the apertures should be avoided to avoid Vierendeel truss action and to increase the beam's ductility and bending capacity.

**1.1 TYPE OF BEAM AND THEIR OPENINGS COSNIDERRED IN THIS PROJECT**

1. Straight Beam
2. Curved Beam
3. Hexagonal Beam

|                            | Straight Beam   | Curved Beam  |
|----------------------------|---|--|
| Look                       |                              |  |
| Number of nodes            | 2   | 3  |
| Degree of freedom per node | Translations X, Y (2D)<br>Translations X, Y, Z (3D)<br>Rotations $R_z$ (2D)<br>Rotations $R_x, R_y, R_z$ (3D) |  |
| For modelling              | Axial, bending, transverse shear and torsional stresses   |  |
| Shape                      | Only model linear variation   | Can model quadratic variation due to introduction of a mid-side node               |

1.1.1 Straight Beam:

Curved beams must carry bending moment, shear force, and torsional moment in addition to the bending moment and shear force carried by straight beams. The beam's geometry is to blame for the torsional moment since its centroid of geometry (C.G.) does not lie on its length. This torsional moment is caused by the force that results in C.G. acting on the beam supports. The resultant force and the lever arm between the C.G. and supports will produce the torsional moment.

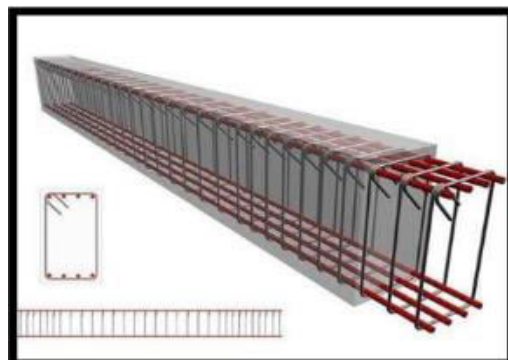


Fig.1.1.1: Straight Beam



### 1.1.2 Curved Beam:

We have been researching initially straight members up until this point. In this chapter, we'll look at how originally curved beams can bend. To achieve this, we limit our analysis to situations in which bending occurs in the plane of curvature. This occurs when the bending force acts in the plane of the beam's curvature and the cross section of the beam is symmetrical about that plane. We first arrive at the answer, as we did for straight beams, assuming that originally planar parts stay that way after bending.

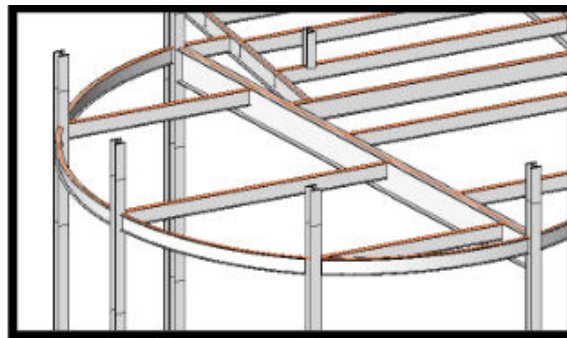


Fig.1.1.2 : Curved Beam

## IV. METHODOLOGY

### 4.1.1 CATIA V5



A CATIA V5 CATIA was first made available in 1977 by Dassault Systems, who are still in charge of maintaining and expanding the programme. The Dassault Mirage fighter plane was the initial target of CATIA's development. CATIA has evolved over time to become much more than a CAD (Computer Aided Design) software suite. These days, it is a software suite that includes the following features: CAD, CAM.

CATIA is capable in many different fields. Most customers do not need all of CATIA's features, which has a substantial financial impact on the user or organization. Dassault has consequently pre-defined CATIA licenses that are divided up to contain necessary capabilities. Additional workbenches and/or additional tools inside existing workbenches are made available based on the licensing. Workbenches in CATIA operate similarly to other CATIA-held software. They enable the user to carry out various tasks.

#### 4.1.2 ANSYS 16.2



With the help of ANSYS 16.0, engineers will be able to validate full virtual prototypes throughout the company's entire portfolio, which includes solutions for structures, fluids, electronics, and systems engineering.

According to Jim Cashman, ANSYS' president and chief executive officer stated that "global enterprises have already recognized ANSYS as the engineering simulation standard for proven physics, high performance computing solutions.", and a unified modelling environment." "ANSYS 16.0 adds even more paradigm-shifting features to its 45-year history. Enterprises can launch their goods more quickly by minimizing or doing away with the need for physical prototypes by utilizing these new capabilities. And they may realise the potential of their products by fully utilizing the features of this new release."

#### 4.2 STEPS INVOLVED

The methodology takes into account the analysis of straight, curved, and half-hexagonal beams using ANSYS software. The following steps comprise the entire thesis project.

The process for the thesis project is shown in the flowchart below.

1. Modeling
  - a. Modeling is done using CATIA software.
2. Dimensional Information
3. Material Properties
4. Meshing and Loading
5. Beams Analysis
  - a. Analysis will do using ANSYS software

#### 4.3 MATERIAL PROPERTIES

**4.3.1 CONCRETE M45:** Concrete is a construction material made of cement, fine aggregates (sand), and coarse aggregates. Concrete hardens over time. The most popular type of cement used in the manufacturing of concrete is Portland cement. Concrete technology focuses on researching the properties of concrete and its useful applications. The foundations, columns, beams, slabs, and other load-bearing parts of structures are all constructed out of concrete. Other binding agents, such as bitumen for asphalt concrete, which is utilized in the construction of roadways, and cement are also employed. Examples of these are lime for lime concrete and bitumen for asphalt concrete. Cements with varying grades and applications are used for concrete projects. Other cement varieties include Portland Pozzolana Cement (PPC), cement that hardens quickly, cement resistant to sulphates, and others.

**4.3.2 FE550:** Fe 550 CRS bars have an ultimate tensile strength of 585 N/mm<sup>2</sup> and a yield of 550 N/mm<sup>2</sup>. It is clear that their increased tensile strength justifies the need for fewer Fe-550 CRS TMT bars to support the structure than Fe-500 CRS. Concrete and Moira Fe 550 CRS TMT bars make an excellent complement to each other in construction because of their high tensile strength. This grade of our bars is frequently utilised in marine, coastal,



or underground building projects. Due to its better structural strength, Moira's Fe 550 CRS grade bars offer 10% cost savings over other bars.

| MATERIAL | DENSITY<br>KG/M <sup>3</sup> | YOUNGS<br>MODULUS PA | POSITIONS<br>RATIO | COMPRSSIVE<br>STRENGTH PA | TENSILE<br>STRENGTH |
|----------|------------------------------|----------------------|--------------------|---------------------------|---------------------|
| CONCRETE | 2390                         | 1.70E+10             | 0.18               | 49125000                  | 2.50E+06            |
| STEEL    | 7850                         | 2.10E+11             | 3.00E-01           | 5.50E+08                  | 5.85E+08            |

Table.4.3.2: Material Properties

4.3.3 MIXED PROPERTIES AVEREGE

| MATERIAL | DENSITY<br>KG/M <sup>3</sup> | YOUNGS<br>MODULUS PA | POSITIONS<br>RATIO | COMPRSSIVE<br>STRENGTH PA | TENSILE<br>STRENGTH |
|----------|------------------------------|----------------------|--------------------|---------------------------|---------------------|
| FINAL    | 5120                         | 1.135E+11            | 0.24               | 299562500                 | 2.94E+08            |

Table.4.3.3: Mixed Average Properties

4.4 BEAM DESIGN:

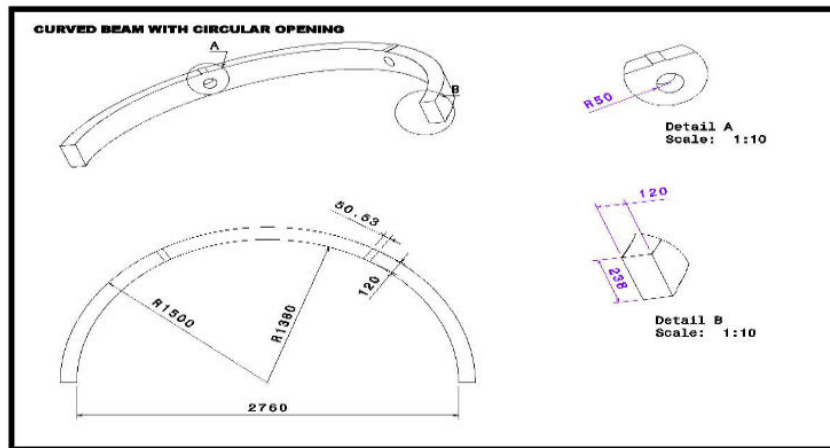


Fig.4.4: CAD Drawing

4.5 CATIA MODEL:

4.5.1 MODEL WITH CIRCULAR OPENING:

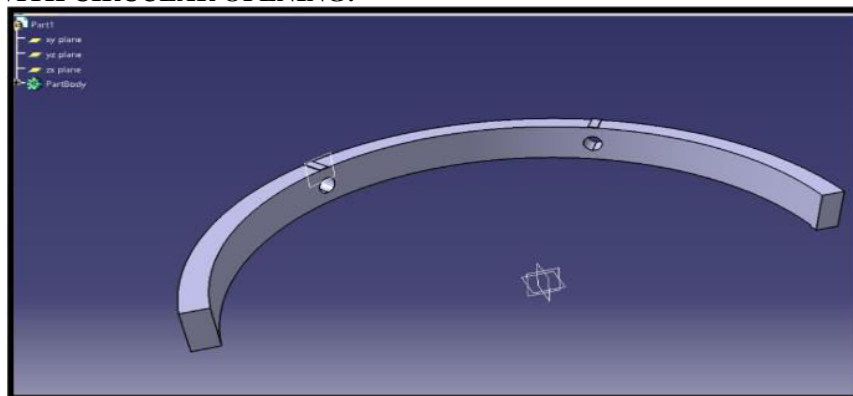


Fig.4.5.1.1 : 3D Model and Plates Above for Loading

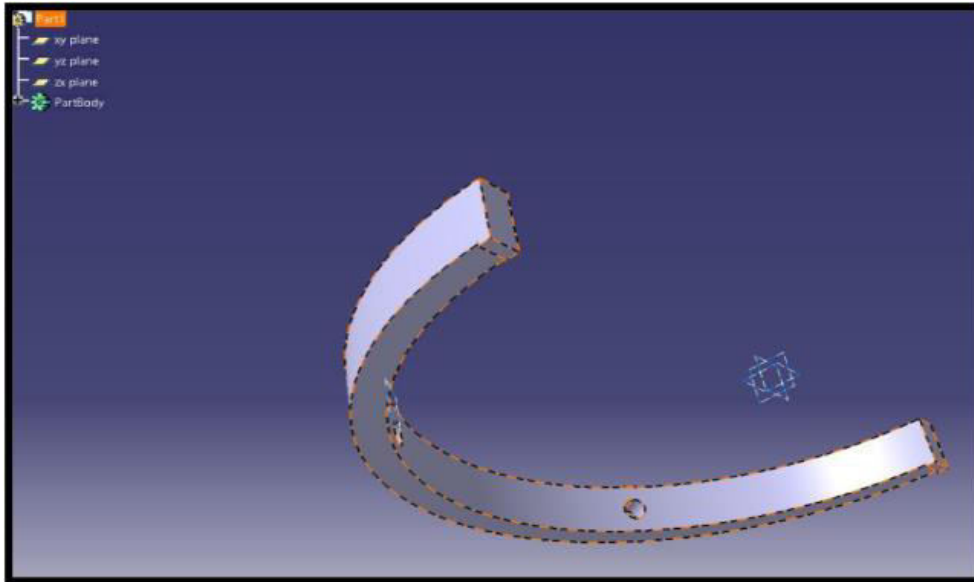


Fig.4.5.1.2 : 3D Model and Plates Below For Fixed Support

4.5.2 MODEL WITH HEXAGONAL OPENING:

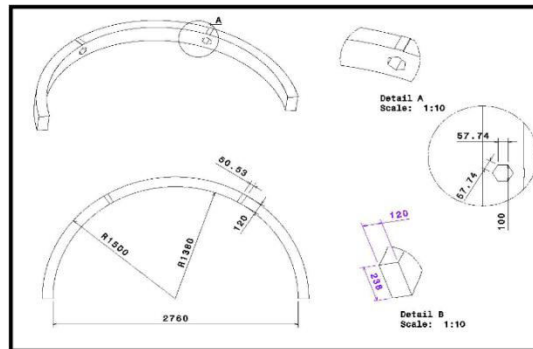


Fig.4.5.2 : Cad Drawing

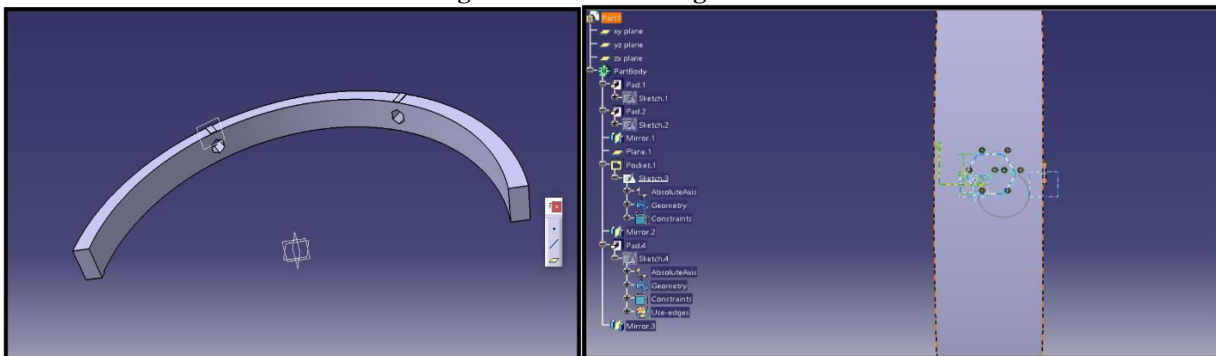


Fig.4.5.2.3 : 3D Model with Hexagonal Hole



4.8 ANALYSIS OF THE MODELS

4.8.1 MODEL

CONCRETE

IMPORT OF MODEL TO ANSYS

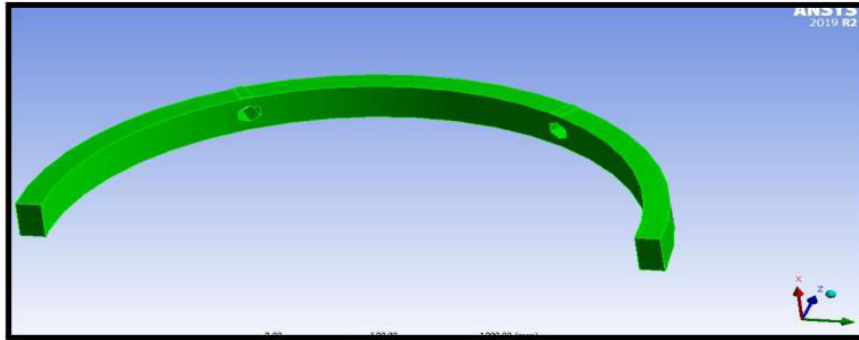


Fig.4.8.1: Import of Model to Ansys

| Details of "Fixed Support" |                    |
|----------------------------|--------------------|
| <b>Scope</b>               |                    |
| Scoping Method             | Geometry Selection |
| Geometry                   | 2 Faces            |
| <b>Definition</b>          |                    |
| Type                       | Fixed Support      |
| Suppressed                 | No                 |

Table.4.8.2: Details of Fixed Support

4.9 STEP-2: MODEL WITH 100 KN LOADING

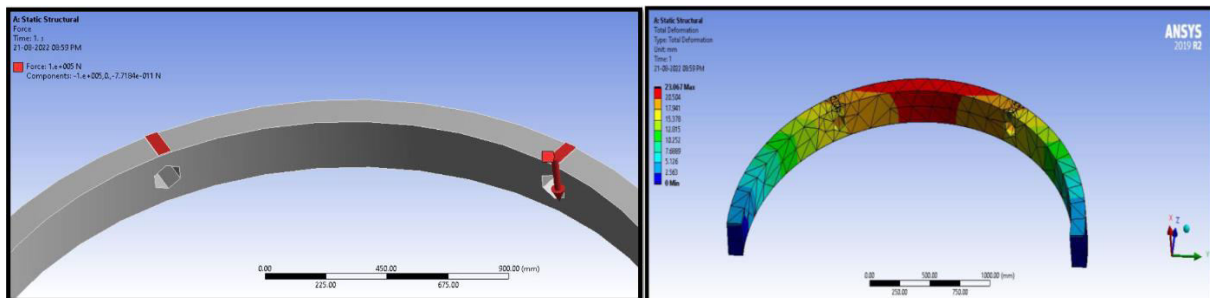


Fig.4.9.1.1: Total Deformation Under 100KN Loading

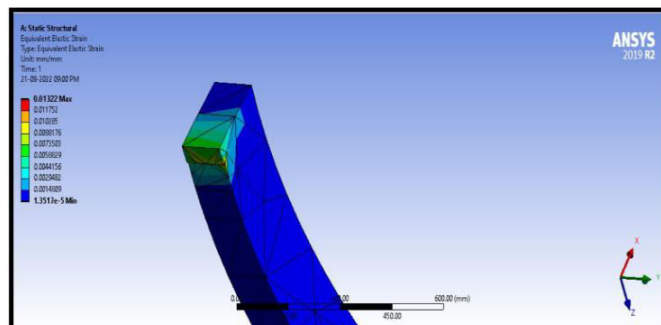


Fig.4.9.1.2 : Strain Under 100KN Loading

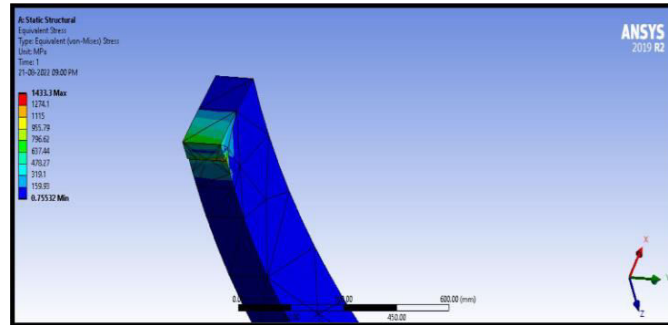


Fig.4.9.1.3 : Stress Under 100KN Loading

#### 4.10 MODEL WITH 200KN LOADING

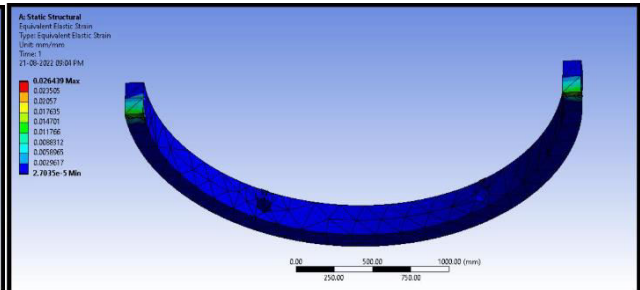
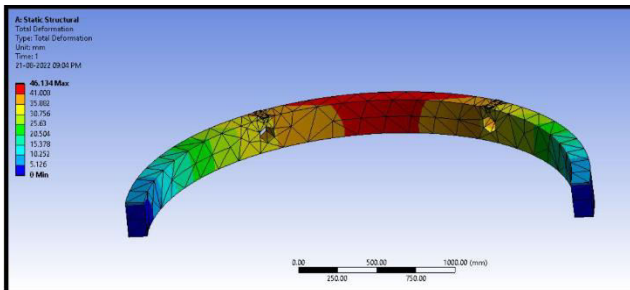


Fig.4.10.1: Total Deformation Under 200KN Loading Fig.4.10.2: Stain Under 200KN Loading

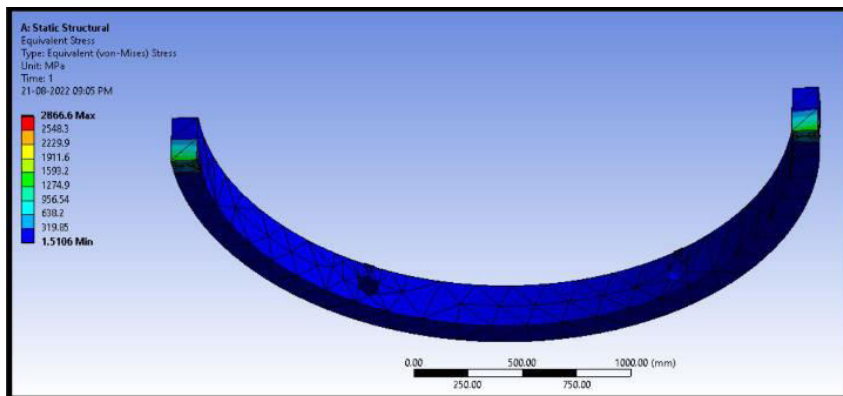


Fig.4.10.3 : Stress Under 200KN Loading

#### 4.11 MODEL WITH 300KN LOADING

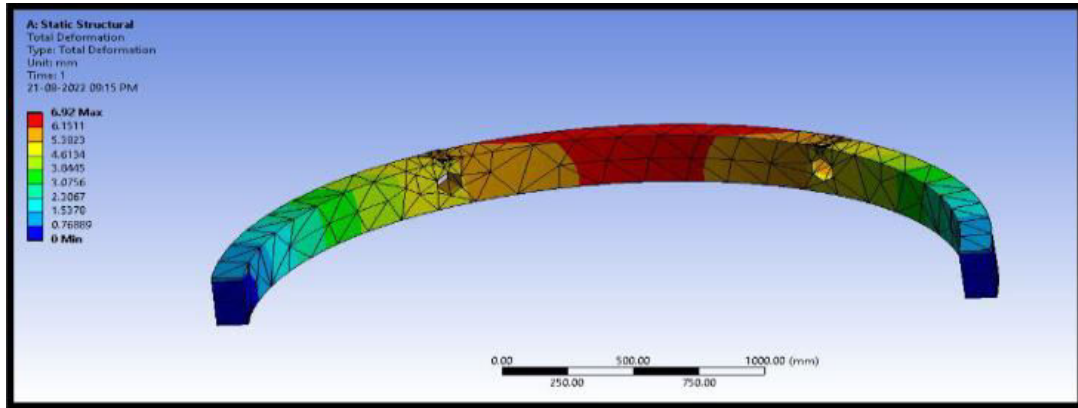


Fig.4.11.1 : Total Deformation Under 300KN Loading

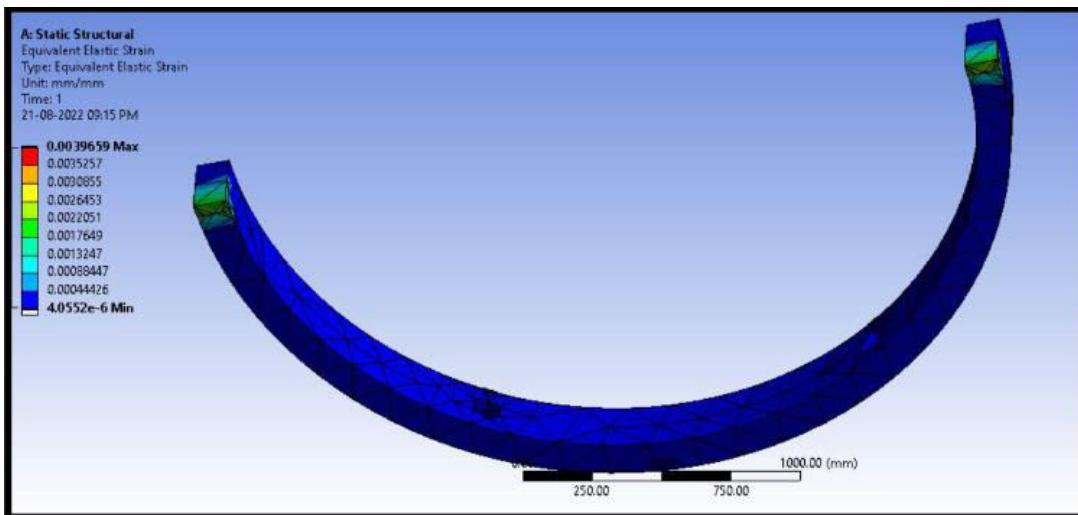


Fig.4.11.2 : Stain Under 300KN Loading

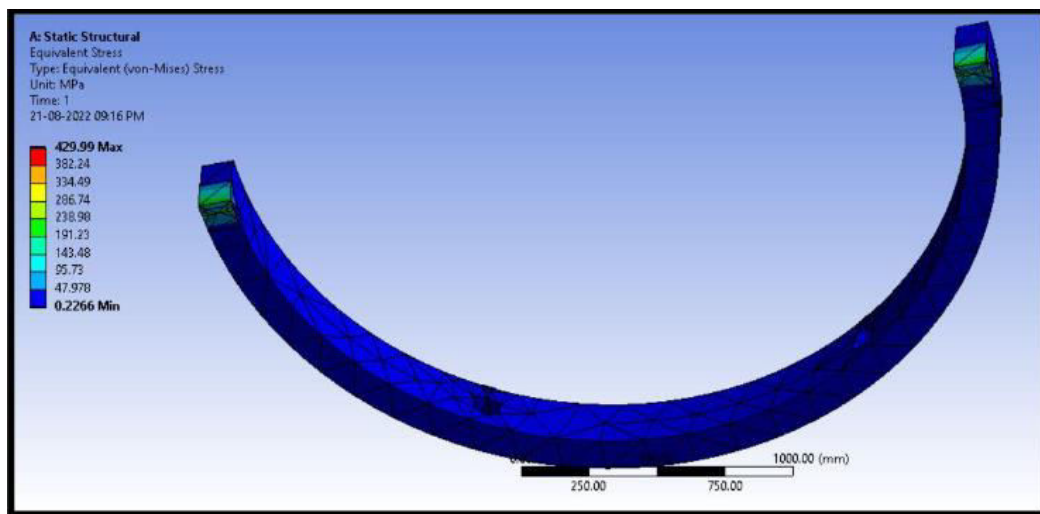
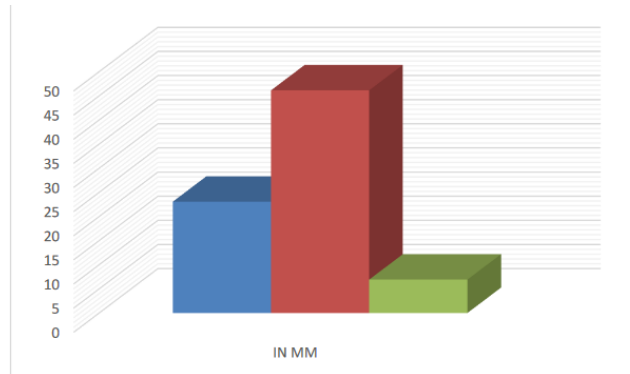


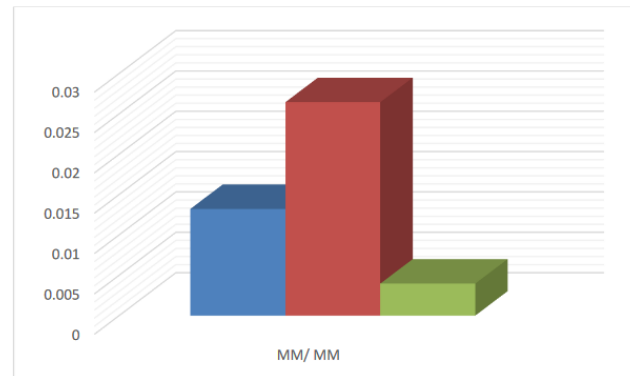
Fig.4.11.3 : Stress Under 300KN Loading



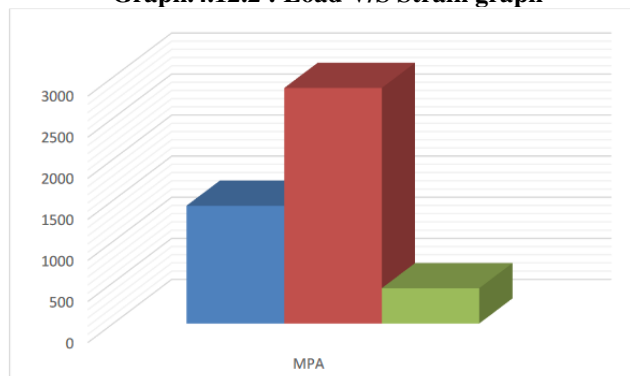
V. EXPERIMENTAL RESULTS



Graph.4.12.1 : Load V/S Deformation graph



Graph.4.12.2 : Load V/S Strain graph



Graph.4.12.3 : Load V/S Stress graph

From the above Results we can Clearly see that under Stress the Performance for Curved Beam with Hexagonal openings show better performance for 200KN when compared with 300KN. The value for 200KN shows that it leads to less amount of Stress and leads to good life span of the Structure. As in another point of view the 100KN Loaded Beams also shows very less amount of Stress and the 300KN model fails to Tolerate the Stress.

VI. CONCLUSION

1. It is evident from the results that, for curved beams with hexagonal holes, the performance for 200KN is superior than 300KN under total deformation. The value of 200 KN demonstrates that it causes less deformation and promotes a long



structural life. From a different angle, the 100KN loaded beams exhibit very little distortion, and the 300KN model is unable to account for the deformation.

2. Under Strain the Performance for Curved Beam with Hexagonal openings show better performance for 200KN when compared with 300KN. The value for 200KN shows that it leads to less amount of Strain and leads to good life span of the Structure. As in another point of view the 100KN Loaded Beams also shows very less amount of Strain and the 300KN model fails to Tolerate the Strain.

3. Under Stress the Performance for Curved Beam with Hexagonal openings show better performance for 200KN when compared with 300KN. The value for 200KN shows that it leads to less amount of Stress and leads to good life span of the Structure. As in another point of view the 100KN Loaded Beams also shows very less amount of Stress and the 300KN model fails to Tolerate the Stress.

4. Seeing all the Results and Comparison the Curved beam With Hexagonal Openings Performance Better in 100KN, 200KN when compared with all 300KN and our Model is Best to Perform for 100KN & 200KN remains as an better choice..

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