# ANALYSIS OF COMPOSITE PLATES WITH CUT-OUTS FOR UNDER-GROUND CONSTRUCTION

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**Abstract— Composite plates are formed by lamination of matrix phase and reinforcing phase . Composite plates are most widely used to retain soil therefore they can be used in under-ground constructions. Composite plates shows aelotropic behaviour and a single plate can show different property in different direction within a controlled manner.Here steel is used as matrix phase and Kevlar is used as reinforcing phase. As the composite plates are used to retain soil due to presence of water, these plates are subjected to seepage forces. In order to reduce the effect of seepage force cut-outs are provided. Shape of cut-outs, position of cut-outs effect the dynamic behaviour of plates. Cut-outs are provided concentrically or eccentrically (one way and two way) may also effect the dynamic behavior of plates. These variations influence the natural frequency , displacement , stiffness and mode shapes of plate which can be investigated in detailed with the help of ANSYS Workbench 14.O software which work on finite element method. From the observation it can be observed that dynamic behavior of composite plate with circular cut-out is better than that of composite plate with rectangular cut-out . As the cut-outs are provided more eccentrically, the dynamic behavior of plates becomes more better with respect to concentrically placed cut-outs. Plates provided with two way eccentric cut-outs shows better results compare to plates provided with one way eccentric cut-outs.**

**Index Terms- Aelotropic behavior, ANSYS Workbench 14.O, Composite materials, Cut-outs, Eccentrically, Free vibration, Natural frequency, Seepage force, Stiffness .**

## I. INTRODUCTION

Composite materials are heterogenous materials which are formed by combination of two or more different constituents on a macroscopic scale. There are two phases of composite such as reinforcing phase and matrix phase. Matrix phase act as a base in which reinforcing phase is distributed in order to provide strength . The matrix materials can be metal, ceramic or polymer while reinforcing materials are generally polymers. The properties of composite materials are depends upon its constituents, geometry and distributions of phases.

**COMPOSITES ARE CLASSIFIED AS:**

**(a) ON THE BASIS OF MATRIX PHASE:**

- Metal Matrix Composites (MMC)
- Polymer Matrix Composites (PMC)

**(b) ON THE BASIS OF REINFORCING PHASE:**

- Particulate Composites
- Composites with preferred orientation of particles

## II. OBJECTIVES OF PRESENT WORK

Most of the work done on laminated composite plates are analytical based on central cut-out, effect of eccentric cut-outs on free vibrational analysis of composite plate not to be studied. In current study I am going to study the influence of shape of cut-outs, position of cut-outs, one way and two way eccentricity of cut-outs on dynamic behaviour of composite plates. Plates are taken to be in space under fixed boundary condition in order to generate actual working condition. Results are going to be compared with the composite plate without cut-outs of same conditions. Plates taken for study are thin therefore effect of shear and bending both plays important role during study of behaviour of composite plates.

The aim of this research work is to study the dynamic behaviour of composite plates with cut-outs under different conditions when plates are subjected to free vibration-

A. Analyse the effect of shape of cut-outs on the dynamic behaviour (formation of mode shapes , displacement, natural frequency, stiffness) of ordinary steel plate and composite plate
B. Analyse the effect of one way eccentricity and two way eccentricity of cut-outs on the dynamic behaviour of composite plates.

## III. METHOD OF ANALYSIS

**Software used- Ansys Workbench 14.O**

For the study software used is ANSYS Workbench 14 .O. This software was developed in 1987 by John A. Swanson. Software belongs to a company named Ansys.in . ANSYS is a powerful and integrated structural analysis and testing software. This software mainly used for dynamic analysis of structural members made of composite materials. This software is based on FEM and FEA approach. Free vibration of plates done by using Finite Element Approach.

**Method used- Finite Element Method**

Finite element method (FEM), is a numerical method to solve a problem related to engineering, physics.In this method the entire structure is devides into small parts called finite elements. Algebraic equations are develoved for these finite elements and analysis to be done, then these these finite elements are assembled in order to form the entire problem. In this way with help of finite element method , errors associated with problem can be minimized by breaking it in to finite elements.

## IV. DETAILS OF THE PLATES

**Size of plate:-**

Plan: Square- 1m x 1m
Thickness: 12mm
Number of layers : 6
Support condition: all sides fixed

**Cut outs:-**

**Concentric**
Square- 200mm x200mm
Circular- 225.67mm(diameter)

**Eccentric**
Best section of above at 250mm eccentricity from center of plate

**Materials properties:** Table -1 shows

| Material | | Modulus of elasticity GPa | Shear modulus GPa | Poisson's ratio (μ) | Mass density ($\rho$) $Kg/m^3$ |
|---|---|---|---|---|---|
| Matri-x | Steel | 210 | 79.3 | 0.3 | 7850 |
| Reinforcement | Kevlar fiber | 19.6 | 1.2 | 0.09 | 1440 |

**Table-1** Material properties

## IV. PROBLEM FORMULATION

| MODES | FREQUENCY(Hz) | | | | |
|---|---|---|---|---|---|
| | **Solid plate** | **Circular concentric** | | **Square concentric** | |
| | | **frequency** | **% variation** | **Frequency** | **% variation** |
| 1 | 165.19 | 168.71 | 2.13(+) | 167.25 | 1.24(+) |
| 2 | 336.1 | 320.95 | 4.50 | 316.75 | 5.75 |
| 3 | 336.1 | 320.95 | 4.50 | 316.76 | 5.75 |
| 4 | 494.43 | 479.65 | 2.98 | 475.79 | 3.78 |
| 5 | 600.52 | 578.52 | 3.66 | 579.75 | 3.45 |
| 6 | 603.49 | 584.17 | 3.20 | 586.59 | 2.80 |
| Avg % | | | 3.49 | | 3.89 |

### (A) EFFECT OF VARIATION IN SHAPE OF CUT-OUTS:

- Circular cut outs
- Square cut outs

### (B) EFFECT OF ECCENTRICITY IN CUT OUTS:

- One way eccentricity
- Two way eccentricity

- Cut-outs are provided at a distance of 250mm from the center of plate in x-direction and in y-direction.

- Composite plate made of steel and Kevlar, which analysed to know the dynamic behaviour of plate when cut-outs are provided. For the analysis purpose Ansys Workbench 14.0 software used which is based on Finite Element Method.

- In finite element method analysis is done by using Finite Element Approach. Free vibration analysis of composite plate done for different shape of cut-outs provided eccentrically.

- The best arrangement obtained from the above condition is also analysed for one way and two way eccentricity of cut-outs in order to know the variation in dynamic behaviour with respect to eccentricity of cut-outs. All analysis is done by providing fix support at all sides.

- Behaviour of plates is compared on the basis of following parameters-

- Mode shapes
- Displacement
- Natural frequency
- Dynamic stiffness

Stiffness represents the effect of both frequency and mass of the plate therefore it can be considered as main parameter for comparision of dynamic behaviour of plates..Stiffness can be calculated as follows-

$$T=2\pi\sqrt{(M/K)}$$

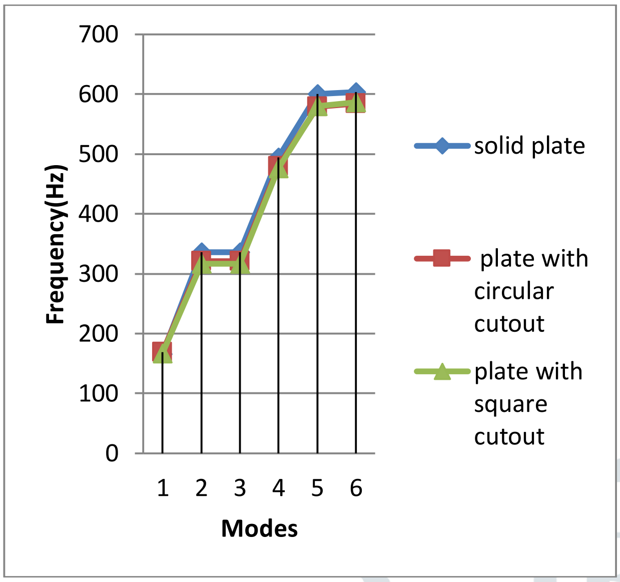
Here,
K represents Stiffness
M represents Mass of plate in Kg
T represents Natural time period is in seconds

## V. RESULTS AND DISCUSSIONS

### (A) VARIATION IN SHAPE OF CUT-OUTS

**A.1 NATURAL FREQUENCY**
Table A.1 Frequency corresponding to different mode for different shape of cutout

From the Table A.1 it can be seen that when cut-outs provided circular in shape, reduction in natural frequency is lesser as compare to when cut-outs are provided in square in shape. Mode 1 shows higher frequency in case of cut-outs because cout-out is provided at center and in case of mode 1 central area of plate mainly contributed in vibration. In other modes natural frequency of composite plate with cut-outs is less with respect to solid plate.It can be analysed that as cut-outs are provided reduction in natural frequency occurs. For same area of cut-outs higher the area is placed away from the center , higher the reduction in natural frequency occurs. Graph A.1 represents the variation in natural frequency corresponding to different modes for circular and square shape cut-outs in the form of lines.



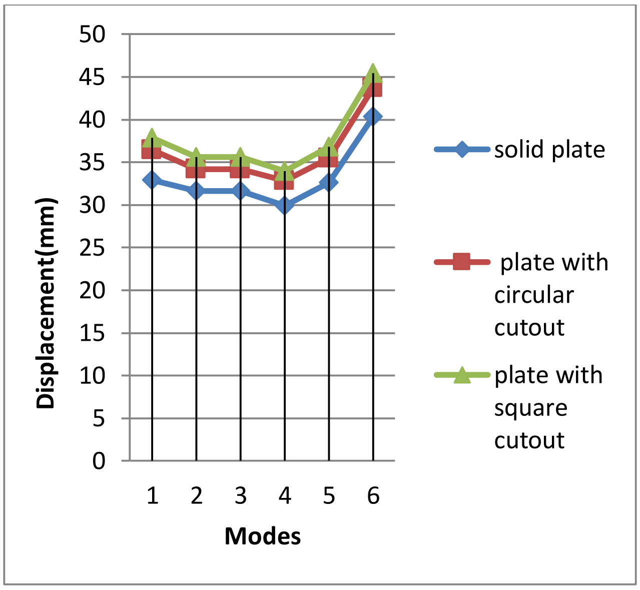

Graph A.1 Frequency corresponding to different mode for different shape of cutout

**A.2 COMPARISION OF DISPLACEMENTS (mm):**

| MODES | DISPLACEMENTS (mm ) | | | | |
|---|---|---|---|---|---|
| | solid plate | Circular concentric | | Square concentric | |
| | | displacements | % variation | displacements | % variation |
| 1 | 32.929 | 36.458 | 10.71 | 37.834 | 14.89 |
| 2 | 31.622 | 34.161 | 8.02 | 35.593 | 12.56 |
| 3 | 31.622 | 34.161 | 8.02 | 35.593 | 12.56 |
| 4 | 29.89 | 32.82 | 9.80 | 33.955 | 13.60 |
| 5 | 32.625 | 35.453 | 8.67 | 36.801 | 12.80 |
| 6 | 40.338 | 43.69 | 8.31 | 45.432 | 12.632 |
| Avg % | | | 8.92 | | 13.17 |

Table A.2 Displacement corresponding to different mode for different shape of cutouts

From the Table A.2 it can be seen that when cut-outs provided circular in shape, displacement increases less as compare to when cut-outs are provided in square in shape. In case of all modes displacement in case of composite plate with cut-outs is higher than that of solid steel plate. As mass reduction occurs due to cut-outs displacement increases. In case of composite plate with circular cut-out increase in displacement is lesser as compare to square cut-out because lesser area of cut-out is placed away from the center. Graph A.2 represents the variation in displacement corresponding to different modes for composite plate with circular and square shape cut-outs in the form of lines.



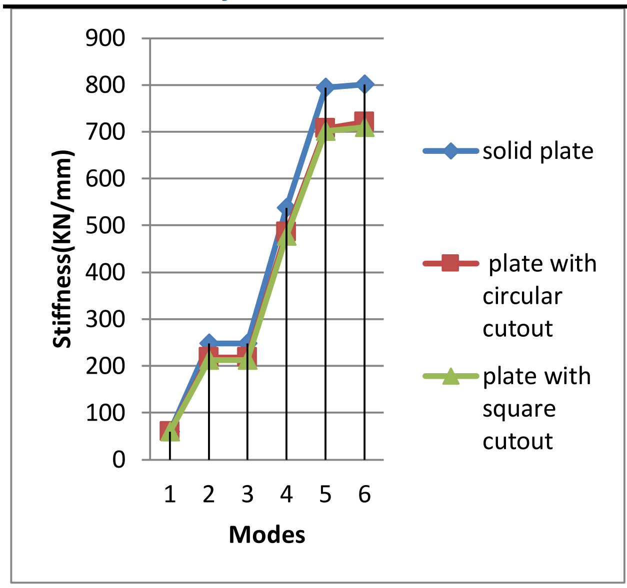

Graph A.2 Displacement corresponding to different mode for different shape of cutout

**A.3 COMPARISION OF DYNAMIC STIFFNESS (KN/mm):**

| MODES | STIFFNESS (KN/mm) | | | | |
|---|---|---|---|---|---|
| | solid plate | Circular concentric | | Square concentric | |
| | | Stiffn-ess | % variation | Stiffn-ess | % variation |
| 1 | 60.04 | 59.98 | 0.09 | 59.06 | 1.63 |
| 2 | 248.57 | 217.52 | 12.49 | 211.86 | 14.76 |
| 3 | 248.57 | 217.52 | 12.49 | 211.86 | 14.76 |
| 4 | 537.94 | 485.82 | 9.68 | 478.03 | 11.13 |
| 5 | 793.56 | 706.75 | 10.93 | 700.76 | 11.69 |
| 6 | 801.43 | 719.84 | 10.18 | 710.06 | 11.40 |
| Avg % | | | 9.31 | | 10.89 |

Table A.3 Stiffness corresponding to different mode for different shape of cutouts

From the Table A.3 it can be seen that when cut-outs provided circular in shape, reduction in stiffness is lesser as compare to when cut-outs are provided in square in shape. Mode 1 shows nearly equal stiffnes of composite plate with cot-out and composite plate without cut-out. In other modes stiffness of composite plate with cut-outs is less with respect to solid plate. From the results it can be seen that as cut-outs are provided reduction in siffness occurs. For same area of cut-outs higher the area is placed away from the center , higher the reduction in sitffness occurs. Graph A.3 represents the variation in stiffness of composite plate corresponding to different modes for circular and square shape cut-outs in the form of lines.




Graph A.3 Stiffness corresponding to different mode for different shape of cutout

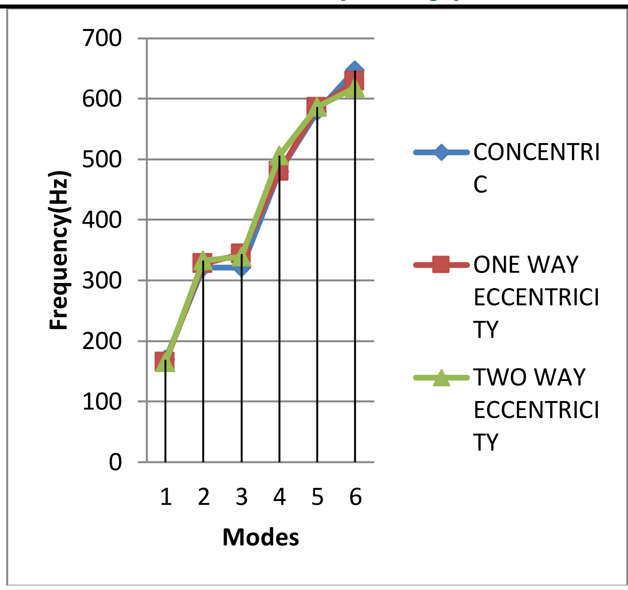
**(B) EFFECT OF ECCENTRICITY OF CUT-OUTS**

**B.1 NATURAL FREQUENCY**

| MODES | FREQUENCY(Hz) (CIRCULAR CUT OUT) | | | | |
|---|---|---|---|---|---|
| | Conce-ntric | Eccentric | | | |
| | | One way eccentricity | | Two way eccentricity | |
| | | Freq-uency | % variation | Freq-uency | % variation |
| 1 | 168.71 | 164.95 | 2.22(-) | 165.23 | 2.06(-) |
| 2 | 320.95 | 327.39 | 2.00 | 332.95 | 3.73 |
| 3 | 320.95 | 343.16 | 6.92 | 338.72 | 5.53 |
| 4 | 479.65 | 479.43 | 0.045 | 505.94 | 5.48 |
| 5 | 578.52 | 584.85 | 1.09 | 586.37 | 1.35 |
| 6 | 584.17 | 628.26 | 7.54 | 618.5 | 5.87 |
| Avg % | | | 2.56 | | 3.32 |

Table B.1 Frequency corresponding to different mode for eccentric cutouts

From the Table B.1 it can be seen that when cut-outs provided at certain eccentricity natural frequency of the plate increases. Mode 1 shows lesser frequency in case of eccentric cut-outs while in other modes frequency is higher with respect to plate with concentric cut-out. Natural frequency of plate with 2 way eccentric cut-out have higher frequency then plate with 1 way eccentric cut-out because cut-out is provided at higher distance from the center in case of 2 way eccentricity. Graph B.1 represents the variation in natural frequency corresponding to different modes for concentric, 1 way eccentric and 2 way eccentric cut-outs in the form of lines.



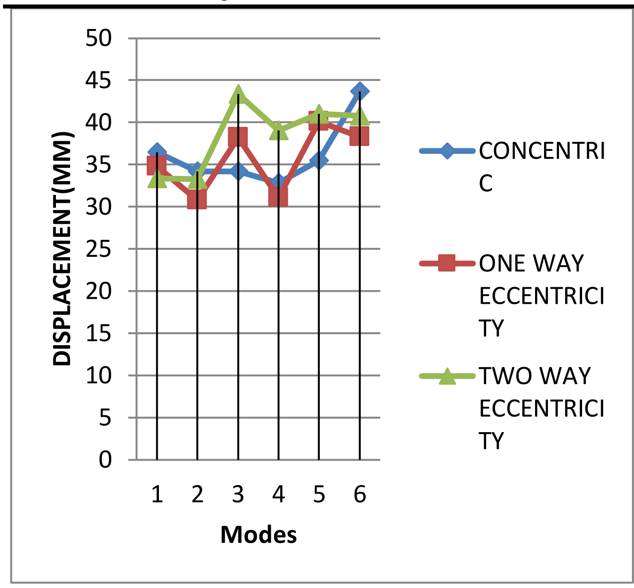

Graph B.1 Frequency corresponding to different mode for eccentric cutouts

**B.2 COMPARISION OF DISPLACEMENTS (mm):**

| MODES | DISPLACEMENTS (mm ) (CIRCULAR CUT OUT) | | | | |
|---|---|---|---|---|---|
| | Concentric | Eccentric | | | |
| | | One way eccentricity | | Two way eccentricity | |
| | | displacements | % variation | Displacements | % variation |
| 1 | 36.458 | 34.811 | 4.51(-) | 33.365 | 8.48(-) |
| 2 | 34.161 | 30.794 | 9.85(-) | 33.258 | 2.64(-) |
| 3 | 34.161 | 38.171 | 11.73 | 43.372 | 26.96 |
| 4 | 32.82 | 31.077 | 5.31(-) | 39.031 | 18.92 |
| 5 | 35.453 | 40.073 | 13.03 | 41.02 | 4.01(-) |
| 6 | 43.69 | 38.26 | 12.61(-) | 40.752 | 6.72(-) |
| Avg % | | | 9.32(-) | | 5.46(-) |

Table B.2 Displacement corresponding to different mode for eccentric cutouts

From the Table B.2 it can be seen that when cut-outs provided at eccentricity , displacement is lesser as compare to when cut-outs are provided concentrically. Mode 1 and mode 5 shows higher displacement in case of 1 way eccentric cut-outs as compare to 2 way ecccentric cut-out. In other modes of composite plate with 1 way eccentric cut-outs shows less displacement with respect to plate with 2 way ecccentric cut-out. Reduction in displacement is more in 1 way eccentric cut-out as compare to 2 way eccentric cut-out. Graph B.2 represents the variation in displacement corresponding to different modes for eccentric and concentric cut-outs in the form of lines.



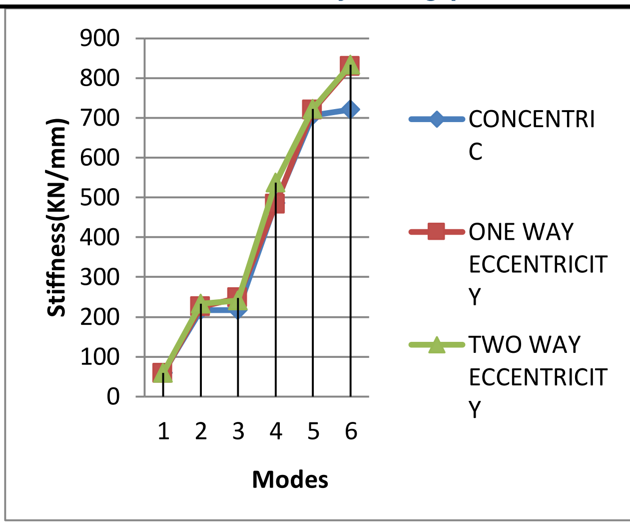

Graph B.2 Displacement corresponding to different mode for eccentric cutouts

**B.3 COMPARISION OF DYNAMIC STIFFNESS (KN/mm):**

| MODES | STIFFNESS (KN/mm) (CIRCULAR CUT OUT) | | | | |
|---|---|---|---|---|---|
| | Concentric | Eccentric | | | |
| | | One way eccentricity | | Two way eccentricity | |
| | | Stiffn - ess | % variation | Stiffn - ess | % variation |
| 1 | 59.98 | 57.14 | 4.73(-) | 59.23 | 1.25(-) |
| 2 | 217.52 | 225.11 | 3.49 | 232.82 | 7.03 |
| 3 | 217.52 | 247.32 | 13.70 | 240.96 | 10.77 |
| 4 | 485.82 | 482.75 | 0.63133(-) | 537.61 | 10.66 |
| 5 | 706.75 | 718.39 | 1.64 | 722.13 | 2.17 |
| 6 | 719.84 | 828.99 | 15.16 | 833.43 | 15.78 |
| Avg % | | | 6.56 | | 7.94 |

Table B.3 Stiffness corresponding to different mode for eccentric cutouts

From the Table B.3 it can be seen that when cut-outs provided eccentrically their is an increase in stiffness as compare to when cut-outs are provided concentrically. Plate with 2 way eccentric cut-out shows more stiffness then plate with 1 way eccentric cut-out because in case of 2 way eccentric cut-out , cut-out is placed at higher distance from the center of plate. Mode 3 shows higher stiffnes of composite plate with 1 way eccentric cut-out compare to plate with 2 way eccentric cut-out. In other modes stiffnes of composite plate with 1 way eccentric cut-out is less compare to plate with 2 way eccentric cut-out. Graph B.3 represents the variation in stiffness of composite plate corresponding to different modes for plate with eccentric and concentric cut-outs in the form of lines.




Graph B.3 Stiffness corresponding to different mode for eccentric cutouts

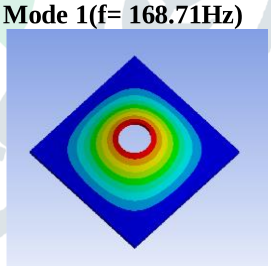
**MODE SHAPES:**

Mode shape is analysis technique for showing the linear response of structures to dynamic loading. Mode is an instantaneous representation which represents the shape of plate when it is subjected to resonance by which we can understand that plate is subjected to bending or torsion or bath. In model analysis we decompose the response of the structure into several vibration modes. A mode is defined by its frequency and shape.. The instant at which amplitude changes its sign from positive to negative or negative to positive is called mode. Mode 1 shows bending while mode 2 , mode 3 , mode 4 , mode 5 , mode 6 shows bending as well as torsion.

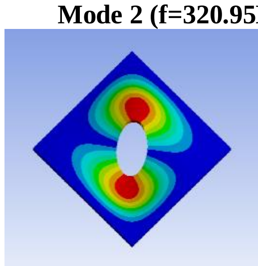
Mode shapes generated due to free vibration of composite plate with cut-outs made by the composition of steel and Kevlar-

**Concentric plate**

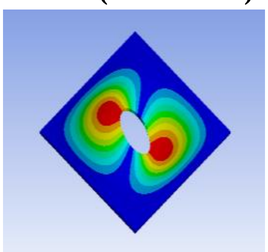
**Mode 1(f= 168.71Hz)**



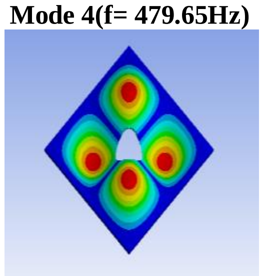
**Mode 2 (f=320.95Hz)**



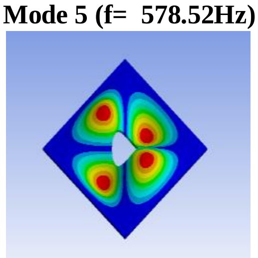
**Mode 3 (f= 320.95Hz)**



**Mode 4(f= 479.65Hz)**



**Mode 5 (f= 578.52Hz)**



**Mode 6( f= 584.17Hz)**

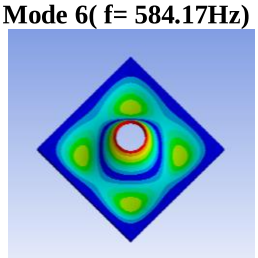
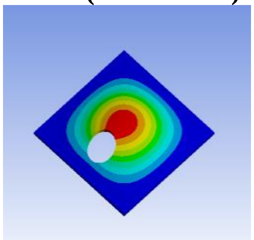
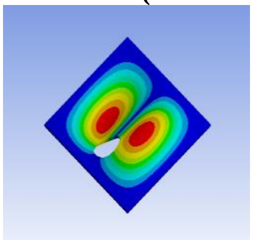


**Plate with 1 way eccentric cut-out**

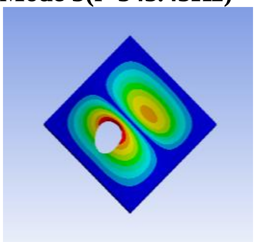
**Mode 1(f= 164.95Hz)**



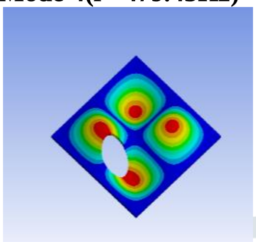
**Mode 2 (f=327.39Hz)**



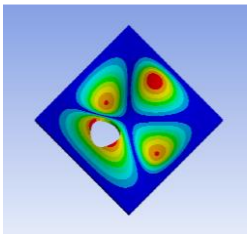
**Mode 3(f=343.43Hz)**



**Mode 4(f= 479.43Hz)**



**Mode 5 (f= 584.85Hz)**



**Mode 6( f= 628.26Hz)**

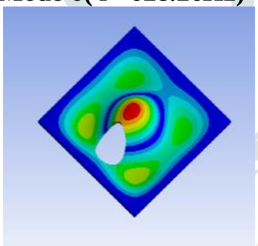
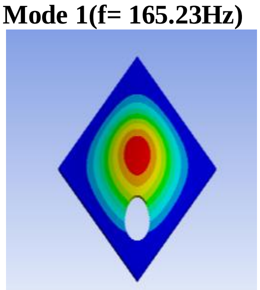
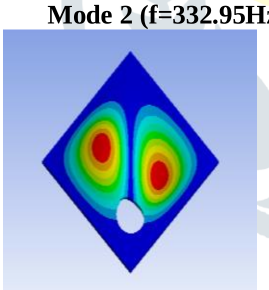


**Plate with 2 way eccentric cut-out**

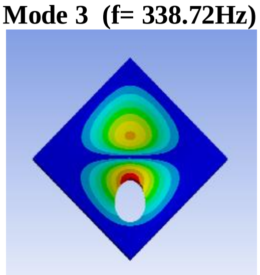
**Mode 1(f= 165.23Hz)**



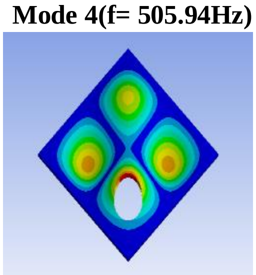
**Mode 2 (f=332.95Hz)**



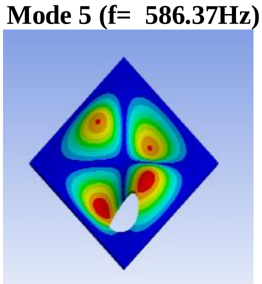
**Mode 3 (f= 338.72Hz)**



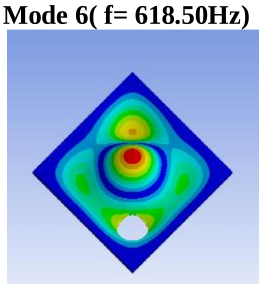
**Mode 4(f= 505.94Hz)**



**Mode 5 (f= 586.37Hz)**



**Mode 6( f= 618.50Hz)**



## CONCLUSIONS:

**A.** Free vibration analysis of steel+Kevlar composite plate of thickness 12mm and fixed boundary condition in order to show the effect of cutouts of different shape placed concentrically-

**For frequency**

- Frequency of cicular cutout plate is 3.495% less than that of solid plate
- Frequency of square cutout plate is 3.89% less than that of solid plate

**For displacement**

- Displacement of cicular cutout plate is 8.92% higher than that of solid plate
- Displacement of square cutout plate is 13.17% higher than that of solid plate

**For stiffness**

- Stiffness of cicular cutout plate is 9.31% less than that of solid plate
- Stiffness of square cutout plate is 10.89% less than that of solid plate

From the observations it can be determined that due to cutouts dynamic resistivity of the plate decreases but it is not significant.Circular cut-out shows better results than square cutouts as area placed more nearer to centre as compare to square one.

**B.** Free vibration analysis of steel+Kevlar composite plate of thickness 12mm and fixed boundary condition in order to show effect of eccentricity in cutouts of circular shape

**For Frequency**

- Frequency of one way eccentric plate is 2.56% higher than that of concentric plate
- Frequency of two way eccentric plate is 3.32% higher than that of concentric plate

**For displacement**

- Displacement of one way eccentric plate is 9.32% less than that of concentric plate
- Displacement of two way eccentric plate is 5.46% less than that of concentric plate

**For stiffness**

- Stiffness of one way eccentric plate is 6.56% higher than that of concentric plate
- Stiffness of two way eccentric plate is 7.94% higher than that of concentric plate

From the observation it can be obtained that if two way eccentric cut outs are created, the plate shows more better resistivity as compare to when cut outs are created either concentric or one way eccentric.

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