Non-Linear Analysis of Steel Domes Coated with GFRP having Circular Cutouts

Ganganath C P [1], Lekshmi L[2]

[1]PG Student, Dept. of Civil Engineering, Vimal Jyothi Engineering College, Kerala, India
[2]Asst. Professor, Dept. of Civil Engineering, Vimal Jyothi Engineering College, Kerala, India

---

Abstract - *In modern industries the dome roofs are commonly using type of structures. Since there is no need of internal supports for the dome roofs and it can cover large span, many number of industrial buildings prefer dome shaped roofs. Due to the purpose of exhaust and ventilation reasons the cutouts are inevitable in structures. In this project five numbers of models are made. One model is the steel dome without cutouts. All the other models are made of steel coated with GFRP and having three circular cutouts which are radially placed on the dome surface. Two types of stacking sequences are selected for these models and two of them are radially restrained at holes. The variation in load and deflection, and the strength of each model are analysed with ANSYS 16.1 software version. The model of the dome with steel and GFRP having three circular cutouts with radial restrain at their holes gave better result.*

***Key Words*: Steel dome, circular cut-out, fiber orientation, GFRP**

1. INTRODUCTION

Domes are curved structures that have no angles or corners and enclose an enormous amount of space without using any supporting columns. The hemispherical domes roofs are light weight and self supporting. The domes of the modern world can be found over religious buildings, industrial buildings, sports stadiums, and a variety of functional structures. Steel domes can be formed by half arches. Domes may be constructed of masonry, timber, steel and reinforced cement concrete. Domes enclose maximum amount of space with minimum surface. Nowadays steel domes are widely used one in industrial buildings, also the use of composite structures has accelerated due to the combination of properties it possesses.

Here analysis were done by coating the steel domes with Glass Fiber Reinforced Polymer (GFRP). The properties that can be emphasized by lamination are strength, low weight, corrosion resistance, wear resistance, acoustical insulation etc. In some cases due to the purpose of exhaust and ventilation reasons cutouts are to be provided in the dome roofs of civil structures. In actual applications strength, stiffness and inertia may be reduced due to cutouts but they are inevitable in buildings.

It is clear from the previous studies that due to the need of cutouts in roofs some difficulties were appeared in steel dome constructions. Since GFRP can be used for both interior and exterior fixtures in a variety of shapes, styles, and textures etc, while coating the steel dome with GFRP the properties like high strength, lightweight, resistance and durability can be improved.

The steel dome without cutouts is analysed. To improve the properties of the dome structure with cutouts, it is coated with the GFRP on the top portion of the dome. Since fiber orientation has some effect on the strength of the structure, two different stacking sequences are selected for the analysis. The performance of dome roofs with different stacking sequences, and radial restrain the variation in load, deflection, and strength is analyzed using ANSYS 16.1. Nonlinear analysis is more accurate one because it employs non-linear, large deflection, static analysis to predict the loads. Its mode of operation is very simple: it gradually increases the applied load until a load level is found whereby the structure becomes unstable.

2. MODELLING AND ANALYSIS OF STEEL DOMES USING FINITE ELEMENT ANALYSIS

The dome structure is assumed to be made of steel and coated with GFRP. Steel plate is with thickness 2 mm and GFRP of 0.3mm thickness in 8 numbers of layers. The load carrying capacity and the deflection occurred in each model is considered to reach a conclusion.

- The software ANSYS 16.1 is used to carry out the finite element analysis in the work.
- The steel dome without cutouts is considered as model 1 and hence it is analyzed.
- Two types of stacking sequences were selected for the GFRP. Sequence 1 (s1) is with fiber orientation +15/-15/+15/-15/+15/-15/+15/-15 and Sequence 2 (s2) is with +60/-60/+60/-60/+60/-60/+60/-60 respectively.

- Model 2 is taken as the steel dome having three circular cutouts. Where the dome is covered with GFRP in 8 layers, each with 0.3mm thickness and the s1 stacking sequence is provided. Here the holes are not given any radial restrain.
- Model 3 is the steel dome with three circular cutouts covered with GFRP in s1 sequence manner. Here the holes are provided with radial restrain.
- Model 4 is considered as the steel dome having three circular cutouts and the dome is covered with GFRP in 8 layers, each with 0.3mm thickness having the s2 stacking sequence. Here the holes are not given any radial restrain.
- Model 5 is the steel dome with three circular cutouts covered with GFRP in s2 sequence manner and the holes are provided with radial restrain.

2.1 Analysis of the model

The models are made to analyze the structure using ANSYS16.1 simulation software. The non-linear analysis of the steel dome without cutouts and the steel dome with GFRP coating having different fiber orientation and radial restrain conditions are conducted. Following tables 1-2 shows the material properties of steel and GFRP which are used for the study.

Table -1: Material properties of the steel

Type of material	Isotropic
Density	7850 kg/mm^3
Yield strength	250 MPa
Modulus of Elasticity	2x 10^5 MPa
Poisson ratio	0.3
Thickness	2 mm
weight	3.648 kg

Table -2: Material properties of the GFRP

Density	1.4x10^{-6}kg/mm^3
Modulus of Elasticity	1.2x 10^5 MPa
Poisson ratio	0.27
Thickness of a layer	0.3 mm
No. of layers	8
Weight	0.8385 kg

The steel domes are assumed to be given fixed support at their peripheral end. The model of the steel dome with 3 circular cutouts and GFRP coating with s1 sequence without radial restrain at holes is as shown in fig1.

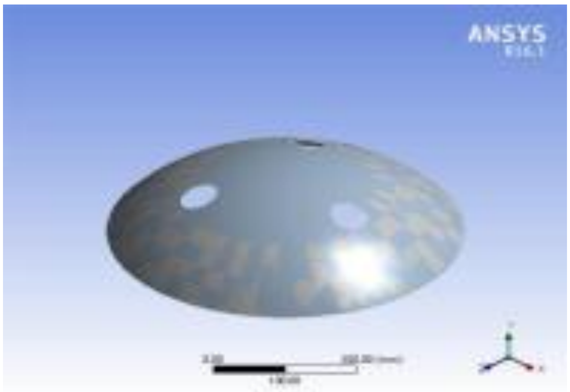

Fig -1: Model 2

In model 2 to 5 the steel domes were coated with carbon epoxy resin in a total thickness of 2.4mm. The cutouts given to the domes are radially restrained in model 3 and 5. For the analysis static nonlinear analysis is performed on the models. A normal pressure of 10MPa is applied to the dome surface. The maximum deflection occurred in the domes are analyzed for the discussion.

3. RESULTS AND DISCUSSIONS

During this study the load acted and the deflection occurred in each dome are taken into consideration. The total deformation diagram obtained for the model 2 and 3 are as shown in fig 2.

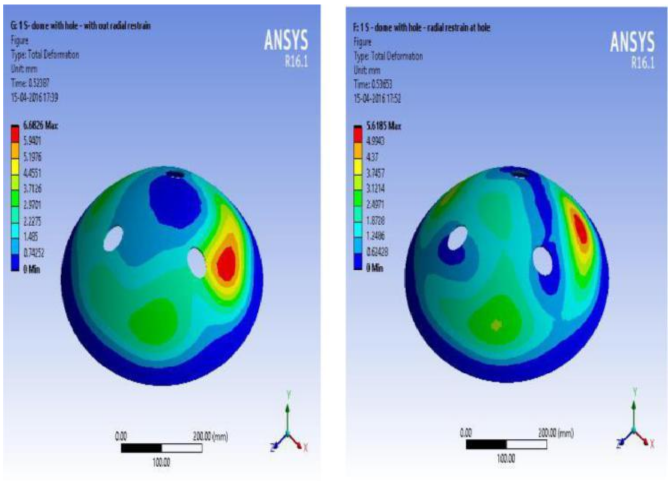

Fig -2: Total deformation of model 2 and 3

The load and the corresponding deformation values of the model 2 and 3 are tabulated in table 3.

Table -3: Load and deformation of model 2 and 3

Model 1		Model 2	
Load(N)	Deflection (mm)	Load(N)	Deflection (mm)
3.81x10^5	0.226	3.81x10^5	0.249
7.63x10^5	1.325	7.62x10^5	0.809
9.06x10^5	3.172	9.06x10^5	1.893
9.78x10^5	5.309	9.78x10^5	3.181
9.87x10^5	5.774	1.01x10^6	4.60
9.96x10^5	6.616	1.02x10^6	5.168
9.98x10^5	6.675	1.02x10^6	5.613
1x10^6	6.682	1.02x10^6	5.618

The model 2 and model 3 consists of the same stacking sequence of GFRP as s1 type. In the case of model 3 the circular holes are radially restrained. So whenever the load increases the deflection occurred in model 3 is less than that in model 2. The radial restrain given at the holes are capable to resist more deformation.

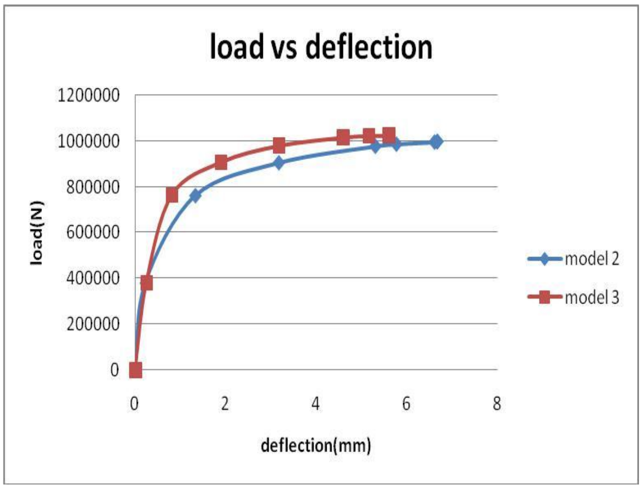

Chart 1: Load-deflection graph of model 2 and 3

Similarly for the models 4 and 5, the load and deflection values are analyzed and are tabulated as shown in table 4

Table -4: Load and deformation of model 4 and 5

Model 1		Model 2	
Load(N)	Deflection (mm)	Load(N)	Deflection (mm)
3.81x10^5	0.258	3.81x10^5	0.258
7.62x10^5	0.69	8.02x10^5	0.690
1.05x10^6	2.230	1.05x10^6	2.230
1.19x10^6	3.707	1.19x10^6	3.707
1.24x10^6	5.024	1.24x10^6	5.024
1.25x10^6	5.255	1.25x10^6	5.255
1.25x10^6	5.693	1.25x10^6	5.445
1.26x10^6	5.697	1.26x10^6	5.454

The model 4 and model 5 consists of the same stacking sequence of GFRP as s2 type. In the case of model 5 the circular holes are radially restrained. So whenever the load increases the deflection occurred in model 5 is less than that in model 4.

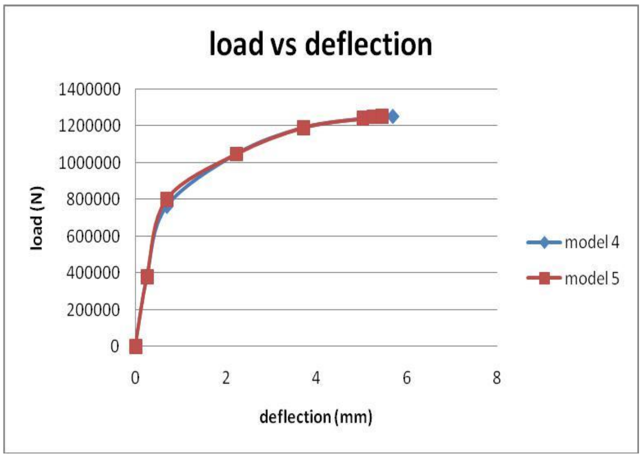

Chart 2: Load-deflection graph of model 4 and 5

Maximum load and deflection for model 4 is observed as $1.26x10^6$ N and 5.693 mm also that off model 5 is $1.26x10^6$ N and 5.453mm respectively. It shows that the radial restrain will give more resisting capacity to the structure against deformation.

While considering the model 3 and 5, the holes are radially restrained. The maximum deflection occurred is higher in the case of s1 stacking sequence. Stacking sequence s2 is better than s1. It is shown in chart 3.

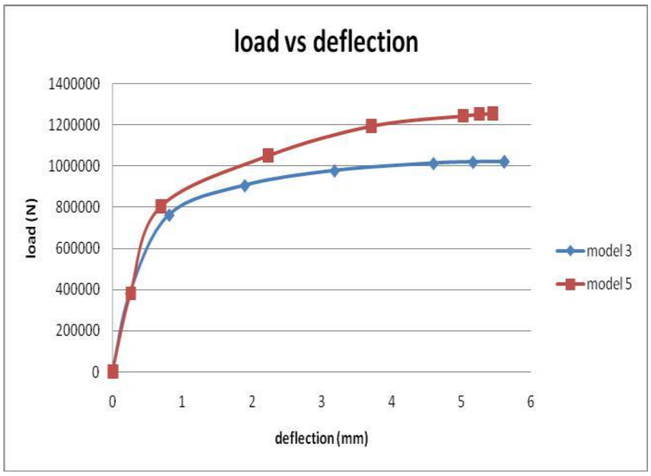

Chart 3: Load-deflection graph of model 3 and 5

The maximum load carrying capacity is observed in the case of model 5.The observations are tabulated as in table 5.

Table -5: Maximum load and deflection of domes

Model	Load (KN)	Deflection (mm)
1	622.74	0.49
2	1023.6	5.61
3	999.79	6.68
4	1259.7	5.45
5	1256.7	5.69

4. CONCLUSIONS

Based on the analyses of building models, the following conclusions are drawn.

- The best sequence is obtained as s2 than s1 since it possesses maximum load carrying capacity.
- The steel dome having GFRP coating and radial restrain at hole with the fiber orientation of +60/-60/+60/-60/+60/-60/+60/-60 gives the maximum strength to the structure.
- The presence of radial restrain at cutouts increases the deflection resisting capacity of the dome structure.

ACKNOWLEDGEMENT

We would like to thank our Principal Dr. Benny Joseph, Head of the Department, Prof. Biju Mathew, our coordinator and my guide Asst. Prof. Lekshmi. L for their valuable advice and technical assistance.

REFERENCES

[1] A.joshi, p. Ravinder reddy (2013), "Buckling analysis of thin carbon/epoxy plate with Circular cut-outs under biaxial compression by using FEA", International journal of research in engineering and technology.

[2] Alireza Fiouz and Mohammad Ebrahim Karbaschi (2012), " Effect of wind loading on spherical single layer space truss steel domes" International Journal of Physical Sciences Vol. 7(16), pp. 2493 – 2505.

[3] Ashim Kanti Dey, Chinmoy Deka2(2012), "Effectiveness of Dome Structures in Reduction of Stresses under Transverse Loadings", Proc. Of Int. Conf. On Advances in Civil Engineering

[4] K.S. Sai Ram, T. Sreedhar Babu (2001), "Study of bending of laminated composite shells. Part II: shells with a cutout" Composite Structures 51, 117-126. Elsevier Science.

[5] N. Ganesan*, ravikiran kadoli(2003), "studies on linear thermoelastic buckling and free Vibration analysis of geometrically perfect hemispherical Shells with cut-out", Journal of sound and vibration 277 (2004) 855–879

[6] S. Fawzia, and M. A. Karim(2009), "Investigation into the Bond between CFRP and Steel Plates", International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:3, No:5

[7] Sandeep m.b , D.Choudhary (2014)," experimental study of effect of fiber orientation onthe flexural strength of glass/epoxy composite material", International journal of research in engineering and technology.