Analysis of Dome for Different Pulse Loading History of Blast Load

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Abstract—Different types of loads are Dead load, Wind load, Snow load etc. are acting on dome structure during its entire life period. Due to increasing number of terrorist attacks, it is very important to analyze and design dome structure to be safer against the blast load. The dome structure can be subjected to any arbitrary pulse but for our benefit it is assumed to have some specific shape. But till date very less research has been established on the analytical study of arbitrary pulses. In this study, blast pressure is calculated as per IS: 4991 – 1968. Using this blast pressure different pulses are converted in form of time vs. acceleration. Pulses are converted in C sharp and different pulse time history is applied on the dome structure. This modeling of dome structure is done in SAP2000. Generating maximum stresses and acceleration are studied from different pulse time history acting on dome structure and also studied which type of pulse shape is more critical.

Key Words—Dome structure; Blast load; Pulse time history; C sharp; Acceleration; Stresses.

I. INTRODUCTION

Dome - It may be defined as a thin shell generated by the revolution of a regular curve about one of its vertical axes. The pre-eminence of domes is in their strength and stiffness that they stand without support of columns. The shape of the dome depends upon the type of the curve and the direction of the axis of revolution. The dome area of shell may be spherical, parabolic or elliptical, covering circular or polygonal. The stresses in the dome are generally membrane compressive stresses in major part of the shell except circumferential tensile stresses near the edge. The domes are one of the most efficient shapes in the world. It is lightest structure to cover up the circular shape.

Pulse activity - Due to blast, air pressure generate on a structure above ground level is basically a single pulse and can frequently idealize by simple shapes.

Numbers of researchers have acquired the dynamic characteristics of large reinforced concrete domes. Tahaseen et al. [1] has studied on Reinforced Cement Concrete (RCC) dome design. The analysis and design of RCC domes were clearly explained and after the analysis and design, we get the hoop reinforcement in a dome, meridional reinforcement and ring beam reinforcement. The dynamic response of shell under the blast loading using the finite element program conclude that the dome structure under blast loading are sensitive to the TNT equivalent weights of explosive and the rise-span ratio of the reticulated shell. Lam and Mendis [2] have worked on the parametric study involving time-history analysis of cantilevered wall models. They have analysed to the structure based on pre-defined pressure function to study basic trends. This study is the identification of the direct relationship between the corner period and the clearing time for the blast. The model has been designed and assessment of cantilevered walls for its performance under blast load is carried out. Also, numerical solution of conversion of pressure into acceleration is given.
II. MODELING AND ANALYSIS

(A) Analysis of dome by pulse time history

Dome structure data

Diameter (D) = 13.7 m
Height (H) = 6.85 m
Radius (R) = 6.85 m
Thickness (t) = 0.15 m
Dome type = Spherical

Material property

Weight per unit volume (Concrete) = 25 kN/m³

Figure 2 3D model in sap 2000 version19

(B) Steps to be followed to check the effect of different pulse on dome structure

1. Calculate the blast pressure as per IS 4991-1968.
2. Convert pulse (Time vs. Pressure) in form of pulse time history (Time vs. Acceleration).
3. Apply that pulse time history on the dome structure.
4. Analysis of dome by different pulse time history.

(1) Calculation of blast pressure

- Calculation of blast pressure as per IS: 4991 – 1968

Blast parameters due to the detonation of 0.1 tonne explosive are evaluated on a above structure, situated at 30 m from ground zero.

- As per IS 4991-1968

Blast Pressure = 33 kN/m²

(2) Blast pressure in form of acceleration

Structure Data

Blast load = 33 kN/m²
Area = 295 m²
Total mass = 110 Tonne
Total blast load = 33 x 295 = 9735 kN

Acceleration = (total blast load / total mass)

= (9735 / 110)

= 88.5 m / sec²

(3) Idealized pulse of blast loading

1. Rectangular Pulse
2. First-Half Triangular Pulse
3. Half Cycle Cosine Pulse
4. Full Cycle Cosine Pulse
5. Half + and Half – Triangular Pulse
6. Half Lower Arrow Pulse
7. Half Upper Arrow Pulse
8. Triangular and Inverse Triangular Pulse
9. Pulse no.10

Shape of pulses are as follows:

Figure 3 Rectangular pulse
Figure 4 First-half triangular pulse

Figure 5 Half cycle cosine pulse

Figure 6 Full cycle cosine pulse

Figure 7 Half + and half – triangular pulse

Figure 8 Half- lower arrow pulse

Figure 9 Half - upper arrow pulse
- Procedure to develop different blast pulse in form of time vs. acceleration.

To develop pulse, program has been made using C sharp. This is made in two phases. In first phase from Fig. 12 using parameters such as Force, Pulse Duration, Time Step Then Pulse time history data are generated in form of pressure.

**Develop rectangular pulse**

- Force (Blast pressure) = 9735 kN
- Initial pulse duration = 0 second
- Final pulse duration = 2 second
- Time step = 0.005 second
- Pulse type = Rectangular Pulse

In second phase of this program, from fig. 13 using parameter such as Mass (m) then pulse loading history is generated in form of time vs. acceleration.

- Mass = 110 Tonne
This is the rectangular pulse of blast loading in form of time vs. acceleration. Some other different pulse develops in program using C sharp are following.

- Figure 15 First-half triangular pulse loading history
- Figure 16 Half cycle cosine pulse loading history
- Figure 17 Full cycle cosine pulse loading history
- Figure 18 Half + and half – triangular pulse loading history
- Figure 19 Half lower arrow pulse loading history
- Figure 20 Half upper arrow pulse loading history
These are the pulse of blast loading in form of time vs. acceleration (Time history).

- Apply that pulse time history on the dome structure in SAP 2000.
III. ANALYTICAL RESULTS

These different pulse time histories are applied on the dome structure. After the analyzing following are the results generated in form of maximum acceleration and stresses.

(A) Maximum acceleration of dome structure under the different pulse time history are following:
(B) Maximum compression stresses (Hoop stresses or circumferential stresses) of Dome Structure Under the effect of Different Pulse Time History are following:

(C) Maximum meridional compression of dome structure under the effect of different Pulse time history are following:
IV. CONCLUSION

Different nine shapes of pulse loading have been analyzed for blast load of 0.1 tonne explosion on dome structure. The following conclusions have been derived after the analysis.

1. The results of lower arrow pulse and upper arrow pulse are found to be similar as the pulse shapes are similar by considering horizontal axis as a plane of symmetry. Also, for half cycle cosine pulse and full cycle cosine pulse the results are similar as the pattern of pulse shape is same.

2. After the analysis of dome structure under different nine pulse history, the maximum acceleration developed is 81.7 m/sec^2 due to half + and half - triangular Pulse for 0.1 tonne explosive weight and it exceeds the permissible limit. Stresses for remaining pulse are in permissible limit as per IS 456: 2000, table 21.

3. The maximum compression stress (Hoop stress or circumferential stress) developed is 9.00 MPa due to and half + and half - triangular Pulse for 0.1 tonne explosive on dome structure at the distance of 30 m and it exceeds the permissible limit of 8.5 MPa as per IS 456:2000. Stresses for other eight pulses are within the permissible limit as per IS 456: 2000, table 21.

4. After the analysis, the maximum meridional compression stress developed is 9.6 MPa due to half + and half - triangular Pulse for 0.1 tonne explosive weight and it exceeds the permissible limit. Stresses for remaining pulse are in permissible limit as per IS 456: 2000, table 21.

5. Half + and half – triangular pulse is the most critical shape for loading in which the stresses and acceleration are maximum.

References


