

Thermal Performance Of RC Dome

Spruha Wanjari¹, S M Rangari²

¹ PG student, Saraswati College Of Engineering, Kharghar, Maharashtra, India
spruhawanjari@gmail.com

² Professor, Saraswati College Of Engineering, Kharghar, Maharashtra, India
smrangari@gmail.com

Abstract: In ancient times domed roof was prominent roofing structure all across the world. All major monuments such as worship places, palaces, auditoriums and many more had domed roof. There were many reasons for it and one of the reason was its thermal behaviour that is energy management. This paper deals with the study of performance of RC dome structure to temperature variation especially in dry and hot region. Also advantage of dome shape to flat roof response to UV solar radiation is studied. RC Dome of 35m radius is modeled in Staad Pro software and applied to temperature loading. Results show temperature stress location and temperature load capacity of dome.

Key Words: Dome, Thermal Response, energy conservation, UV rays, hot and dry regions

Introduction

Ancient construction show major use of dome element for the most of the structures. Till today dome structures are common architectural feature for most of the hot and dry regions such as Rajasthan in India. Dome roofs have traditionally been used throughout the world to cover large area and spans. They play significant role in reducing the total heat gain from the roof and provide a passive cooling effect for the buildings they served. Thus dome roof gains advantage over flat roof.

Nowadays, low cost housing development is one of the upcoming industries. Consequently energy conservation and optimum utilization of energy is also on top priority of construction industry. Thus, dome element of structure is chosen for its structural strength as well as the savings envisaged by replacing a conventional roofing system with a monolithic element. Dome is a doubly curved shell structure and so it's doubly curved surface allows to carry its self weight very effectively. The load is carried primarily by membrane action. Due to efficient thermal performance of dome structure low-cost housing and optimum energy conservation is consequently obtained. Habib Sadid studied the effect of wind velocity on dome, Mohammadjaved studied the effect of shape of dome roof on effect of energy loss in hot and dry regions.

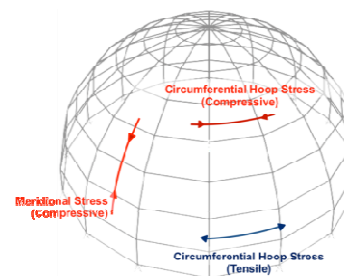


Fig.1: Stresses in dome reference

Fig.1 shows forces and stresses in dome structure. Moments and shear are limited to the boundary of the shell. Stiff horizontal

rings around the shell limit the deformation in the meridian direction.

In this paper thermal performance of RC dome especially in hot and dry regions is studied.

Problem Statement

Response of shape of RC dome of 35m to UV solar radiation is studied. Same RC dome of 35m radius is subjected to temperature load in StaadPro software and temperature analysis is performed.

Thickness of dome is varied and effect of temperature on each type is compared.

Concrete M25 is used.
HYSD bars Fe415 is used for reinforcement.

Methodology

Thermal performance of RC dome is studied is in two parts viz:

1. Response of dome shape to UV solar radiation.
2. Effect of temperature load on RC dome using Staad Pro software.

In hot and dry region average day/summer temperature is 45 to 50°C and average night/winter temperature is 0 to 5°C. So average temperature variation applied to dome model is 45°C.(ref.IRC6)

Response of dome shape to solar radiation:

Dome roofs have great structural advantages that is it is very stiff owing to its shape but also have some significant

thermal advantages due to their response to incident solar radiation. Dome distribute forces only through compression. RC dome is solid non-compressible structure that can carry great weight and span large distances. RC dome have high thermal mass.

In a flat roof, as shown in (fig 2) its entire planar surface is always exposed to sun throughout the day.

The intensity of the radiation on the flat roof will be low as sun rays in early morning strike it from relatively low angle. However, as the sun rises in the sky, the angle of strike comes closer to normal incidence and the entire surface is subjected to full intensity of solar rays which could be as high as 900w/m².

When subjected to incident solar radiation the outer surface of flat roof heats up, and transmits that heat to the inner surface of the roof consequently increasing the temperature of enclosed area.

Contradict to flat roof when a dome is exposed to solar radiation, as shown in (fig 3) only a small part of its surface area receives radiation directly at normal incidence. The rest of its surface is either self-shaded or receives the radiation at much greater incidence angle, more importantly the areas exposed to radiation change throughout the day as the sun moves through the sky. The area of greatest incidence can be clearly seen to travel across the surface from east to west side.

Thus as much smaller area of dome roof is exposed to full intensity of the sun and even then for a much shorter amount of time. There is not the same slow build-up of solar air temperature over the whole day as with the flat roof. So, the peak heat flows

are much less and occur from different parts of the inside surface of the dome at different times of the day.

Convection currents occur in a well ventilated domes allowing more even temperature. Dome has a high thermal mass and this feature makes dome (of high heat capacity) store fair amount of heat

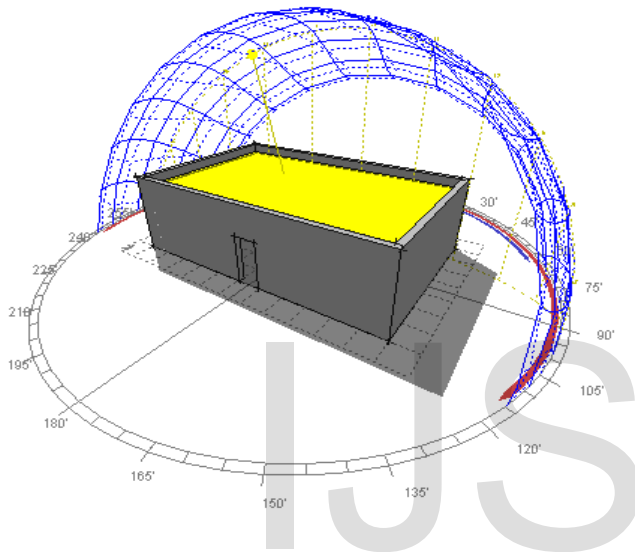


Fig:2 Flat roof exposed to solar radiation

during hot day/summer and (a low thermal conductivity) retains the heat it stores and releases it during cold nights/winter in enclosed area. This process is called Thermal Insulation, and makes dome advantageous structure over flat roof in hot and dry region

Thermal Analysis of RC dome in Staad Pro software:

Dome structure is very stiff owing to its shape as discussed earlier. Efficient dome is that produce least tension and the most usable space. Regions of high tension exists around openings especially under temperature proper attention can be durable architecturally and structurally efficient with low cost.

As said earlier, load in dome is carried primarily by membrane action and the results obtained by thermal analysis will show membrane stresses.

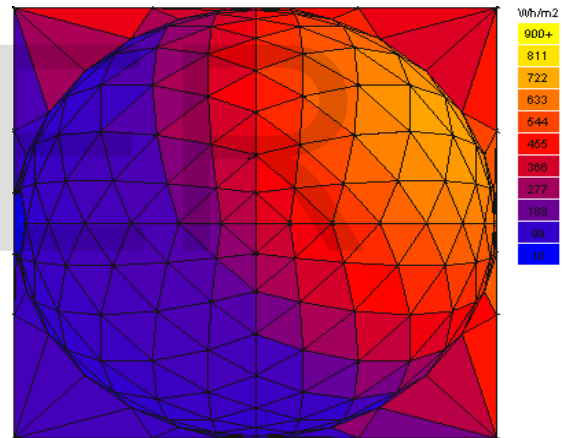


Fig:3 dome roof exposed to solar radiation

Modeling Process:

RC dome of 35m is modeled in Staad Pro software with an opening at the top for skylight.

Dome model is made by meshing triangular plate elements in.

Thickness of plate is 0.15m as we are analyzing thin shells.

Temperature load of 45⁰c is applies to RC dome modeled in Staad.

Mathematical Modeling of dome in Staad:

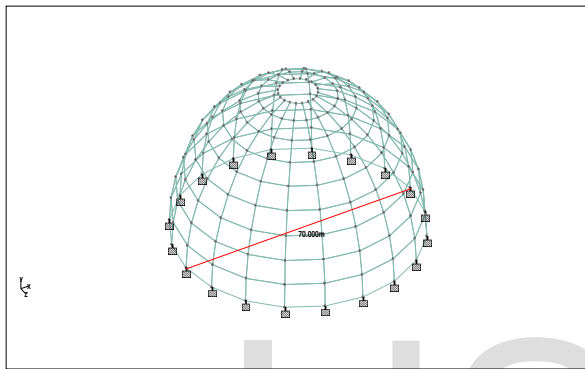


Fig.4: Modeling of dome in Staad Pro

Fig.4: showing RC dome of height 46m and radius of 35m.

Thermal Analysis In Staad of Modeled RC dome:

Case 1: Thickness is 0.005m

Case 2: Thickness is 0.1m

Case 3: Thickness is 0.15m

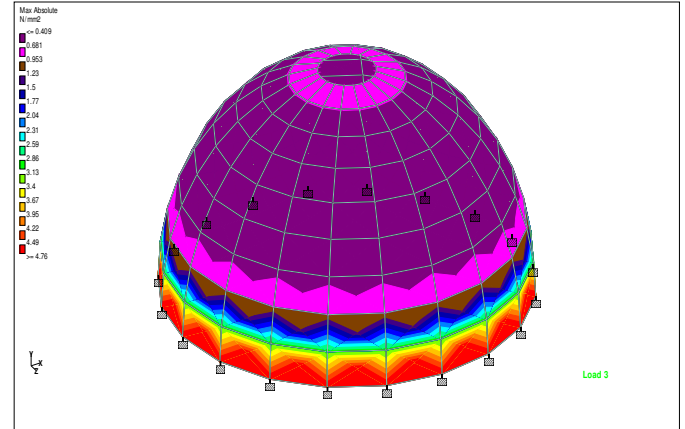


Fig.5: Max. Absolute Stress Contour in dome for case 1

Results

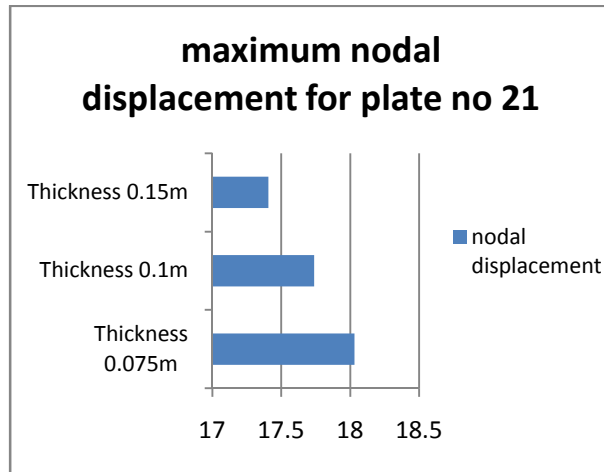
Since the dome structure is symmetrical stress in each plate along circumference will be same, therefore results for only 9 plates along meridian are shown.

Load in dome is carried by membrane action so only dominant membrane stresses are shown in results for case 1,2 and 3.

Table 1: Membrane stresses in centre of plate (SXY is zero for all cases)

Plate thickness -->	0.075m		0.1m		0.15m	
	SX (local) N/mm2	SY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2
1	-4.733	-0.753	-4.792	-0.753	-4.733	-0.753
21	1.176	-0.652	1.18	-0.652	1.176	-0.652
41	0.108	-0.58	0.109	-0.58	0.108	-0.58
61	0.149	-0.521	0.147	-0.52	0.149	-0.521
81	-0.059	-0.475	-0.059	-0.475	-0.059	-0.475
101	-0.164	-0.435	-0.167	-0.435	-0.164	-0.435
121	-0.268	-0.397	-0.268	-0.398	-0.268	-0.397
141	-0.456	-0.34	-0.438	-0.34	-0.456	-0.34
161	-0.525	-0.309	-0.54	-0.296	-0.525	-0.309
note:negative sign is tension						

Graph 1: Thickness v/s max. nodal displacement



From the analysis done in Staad ,maximum nodal displacement occurs for plate no 21

Above graph 1 shows that as the thickness on dome is increased nodal displacement decreases, maximum nodal displacements with reference of thickness of dome.

Conclusion

Tensile strength of concrete is $0.7(f_{ck})^{1/2}=3.5N/mm^2$

where,

fck=characteristic strength of concrete used

From above obtained membrane stresses shown in table no.1 for case 1,2 and 3 we can observe that change of thickness of dome does not have much effect on membrane stresses.

However, we can see that high tensile stresses are developed around both top and bottom openings.

Tensile reinforcement is required at these location.

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