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Address:-Ashok Yakkaldevi 258/34, Raviwar Peth, Solapur - 413 005 Maharashtra, India
Cell : 9595 359 435, Ph No: 02172372010 Email: ayisrj@yahoo.in Website: www.isrj.net

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ORIGINAL ARTICLE

"PARAMETRIC STUDY OF DOUBLE LAYER STEEL DOME WITH REFERENCE TO SPAN TO HEIGHT RATIO"

AJIT S. PATIL AND H. S. JADHAV

Student, Civil Engineering Department; Rajarambapu Institute of Technology
Rajaramnagar, Islampur (Dt:Sangli), Maharashtra-India.
Professor and Head,
Civil Engineering Department; Rajarambapu Institute of Technology
Rajaramnagar, Islampur (Dt:Sangli), Maharashtra-India

Abstract:

Optimum design of double layer dome of different span to height ratio(two cases- span to height ratio 2 and 4) and different supporting conditions(all bottom nodes supported, alternate bottom nodes supported and two alternate bottom nodes supported) for a given span is carried out. The former programming software is used for configurations of double layer dome. The hollow circular pipe sections are used to construct the double layer dome and for connection, the MERO joint is used. Basically the dome have large exposed area there for the wind force are predominant, hence the domes are analyze and design for wind forces. For optimum design of the structure, it is analyzed by using the software "SAP-14". In the analytical part, forces in the top layer are considered in groups and separate section will be designed for each group, the design will be based on IS800:2007. Similar procedure will be adopted for bracing system and bottom layer

The results are compared with different span to height ratios and support conditions for the deflection, weight of structure and concrete for pedestal, to determine optimum configuration by overall.

KEYWORDS:

Double layer steel dome.

INTRODUCTION:

Architects and engineers are always seeking new ways of solving the problem of space enclosure. The search for new structural forms to accommodate large unobstructed areas has always been the main objective of architects and engineers. With the industrialization and development of the modern world, there is a demand for efficient and adaptable long-span structures. Space structures are a valuable tool for the architect or engineer in the search for new forms, owing to their wide diversity and flexibility. A growing interest in space frame structures has been witnessed worldwide over the last half century. With the advent of new building techniques and construction materials, space frames frequently provide the right answer and satisfy the requirements for lightness, economy, and speedy construction. Significant progress has been made in the process of the development of the space frame. A large amount of theoretical and experimental research programs was carried out by many universities and research institutions in various countries. As a result, a great deal of useful information has been disseminated and fruitful results have been put into practice.

Most structures in common use consist of elements such as beams, columns, trusses and portal frames which are basically two dimensional structural members, the point of view of analysis as well as design. Interconnecting members in the third dimension (e.g. purlins) are always of a secondary, character present merely for the purpose of transferring load and not supporting function of the structure. The fundamental advantage and economy of a form of structural assembly in which there is integrated load sharing is obvious, since every part of the structure makes effective contribution. In such a system no single member is necessarily a principle one and failure in an individual member is not a matter of structural consequence.

Space structure in which the above three dimensional function is realized are thus of considerable importance. These structures are being used in the construction industry to an increasing extent. They essentially involve analysis and design in three rather than two dimension.

THEORETICAL BACKGROUND:

A space structure is a structural system in the form of a three dimensional assembly of elements, resisting loads which can be applied at any point, inclined at any angle to the surface of the structure and acting in any direction. The individual members may be made up of rolled, extruded or fabricated sections. The three dimensional character includes flat surfaces with loading perpendicular to the plane as well as curved surfaces.

The space frame can be constructed either in a flat or a curved surface. The earliest form of space frame structures is a single layer grid. By adding intermediate grids and including rigid connecting to the joist and girder framing system, the single layer grid is formed. The major characteristic of grid construction is the omni-directional spreading of the load as opposed to the linear transfer of the load in an ordinary framing system. Since such load transfer is mainly by bending, for large spans, the bending stiffness is increased most efficiently by going to a double layer system. The load transfer mechanism of curved surface space frame is essentially different from the grid system that is primarily membrane-like action.

As per the state of the art report by IASS, space frames are defined as below: "A space frame is a structural system assembled of linear elements which transfers the that forces in three dimensional manners. In some cases constituent elements may be two dimensional. Macroscopically, a space frame often takes the form of flat or curved surface".

MODELING OF STRUCTURE:

1. Modeling by FORMEX software:

The geometry of the double layer dome is prepared by using FORMEX software, for the Double layer dome, by the program are as follows

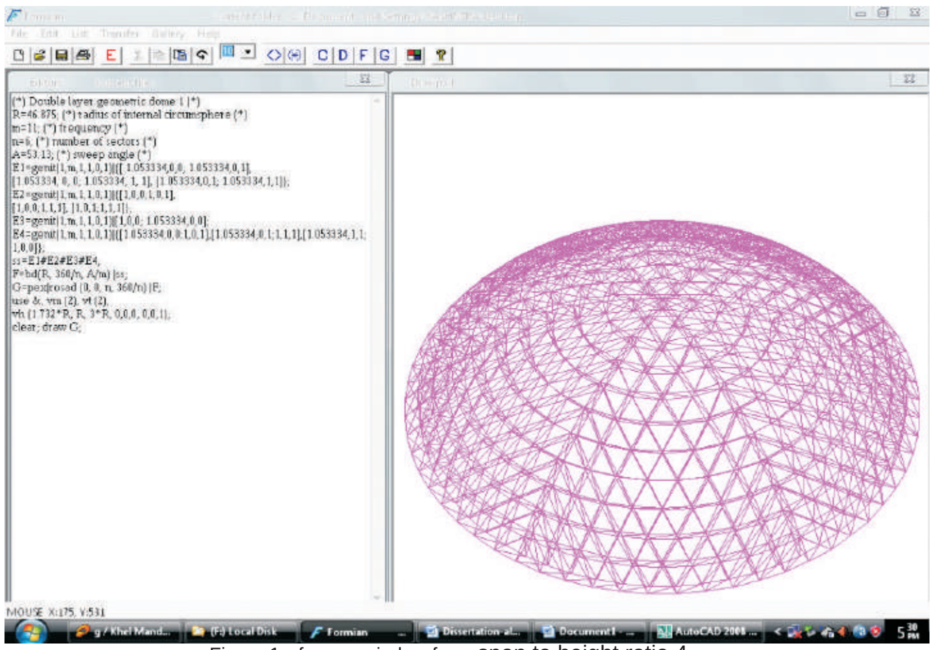


Figure 1 - formex window for span to height ratio 4

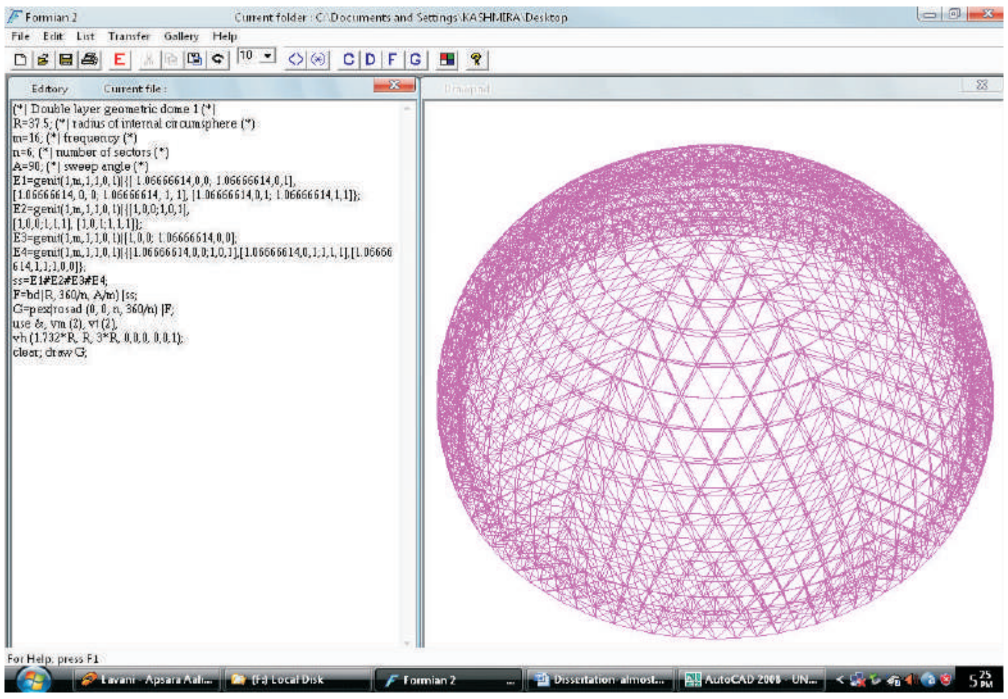
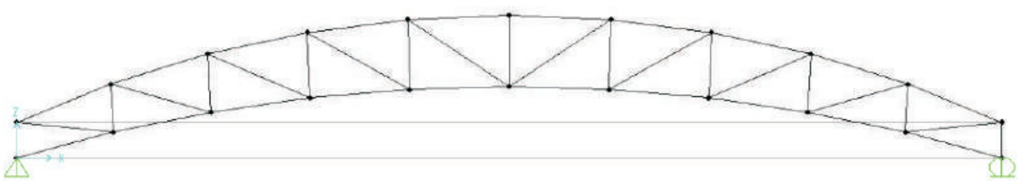


Figure 2- formex window for span to height ratio 2

2.Modeling by SAPsoftware:

The model developed in formex software is then imported in to SAP further final model generation is as follows,



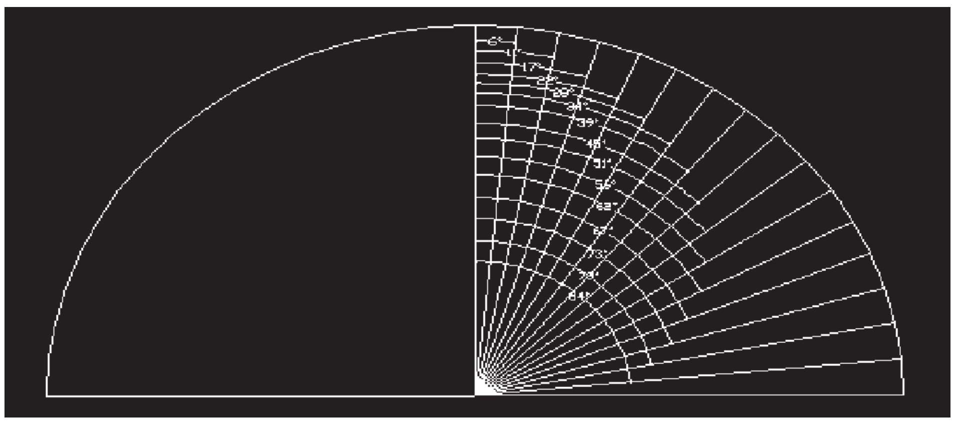


Figure 3- Angle in elevation for span to height ratio 2

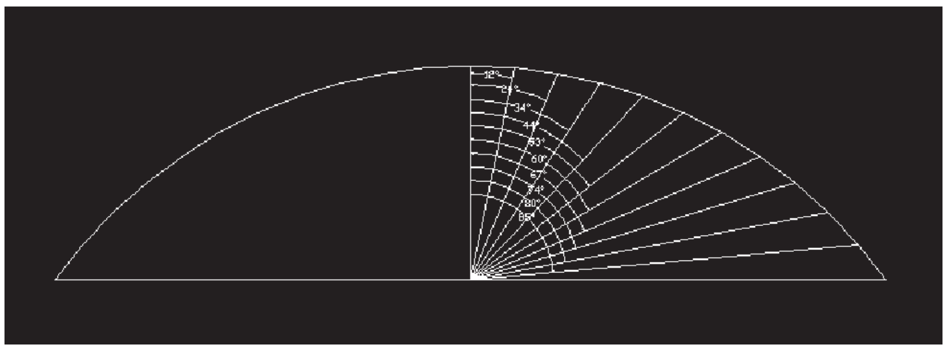


Figure 4- Angle in elevation for span to height ratio 4

DESIGN AND ANALYSIS OF DOME:

Table 1- Properties of Circular dome

Sr. No.	Height of dome (m)	Span to height ratio	Sweep Angle	Radius (m)
A	18.75	4	53.13	46.875
B	37.50	2	90	37.500

LOAD COMBINATIONS FOR ANALYSIS OF DOMES:-

As per IS: 800-2007
1) 1.5(DL+LL),
2) 1.5(DD+WL),
3) 1.2(DL+LL+WL),
4) 0.9DL+1.2LL+1.2WL

Table No. : - 2 Wind load on dome of span to height ratio 2

Node No.	Cartesian co-ordinates			Sperical co-ordinates		Cpe	Cpi	Area (Sqm)	F Normal to Surface (kN)	Fx (kN)	Fy (kN)	Fz (kN)
	X (m)	Y (m)	Z (m)	è (deg)	Ö (deg)							
1	4.18	0.00	39.78	6	0	-1.0	0.2	15.36	-17.06	-1.78	0.00	-16.96
2	2.09	3.62	39.78	6	60	-1.2	0.2	15.36	-19.90	-1.04	-1.80	-19.79
3	-2.09	3.62	39.78	6	120	-1.2	0.2	15.36	-19.90	1.04	-1.80	-19.79
4	-4.18	0.00	39.78	6	180	-1.2	0.2	15.36	-19.90	2.08	0.00	-19.79
5	-2.09	-3.62	39.78	6	240	-1.2	0.2	15.36	-19.90	1.04	1.80	-19.79
6	2.09	-3.62	39.78	6	300	-1.2	0.2	15.36	-19.90	-1.04	1.80	-19.79
7	20.08	0.00	45.11	11	0	-0.8	0.2	15.88	-14.70	-2.80	0.00	-14.43
8	17.39	10.04	45.11	11	30	-0.8	0.2	16.11	-14.91	-2.46	-1.42	-14.64
9	10.04	17.39	45.11	11	60	-1.0	0.2	15.88	-17.64	-1.68	-2.91	-17.31
10	0.00	20.08	45.11	11	90	-1.0	0.2	16.11	-17.89	0.00	-3.41	-17.57
11	-10.04	17.39	45.11	11	120	-1.0	0.2	15.88	-17.64	1.68	-2.91	-17.31
12	-17.39	10.04	45.11	11	150	-1.0	0.2	16.11	-17.89	2.96	-1.71	-17.57
13	-20.08	0.00	45.11	11	180	-1.0	0.2	15.88	-17.64	3.37	0.00	-17.31
14	-17.39	-10.04	45.11	11	210	-1.0	0.2	16.11	-17.89	2.96	1.71	-17.57
15	-10.04	-17.39	45.11	11	240	-1.0	0.2	15.88	-17.64	1.68	2.91	-17.31
16	0.00	-20.08	45.11	11	270	-1.0	0.2	16.11	-17.89	0.00	3.41	-17.57
17	10.04	-17.39	45.11	11	300	-1.0	0.2	15.88	-17.64	-1.68	2.91	-17.31
18	17.39	-10.04	45.11	11	330	-0.8	0.2	16.11	-14.91	-2.46	1.42	-14.64

Table No. 3 Member group forces and section for span to height ratio 2 all bottom nodes supported

Member Groups	Max Comp. kN	Max Tension. kN	Length m	Section mm
Top layer				
Horizontal Member				
A	36.594	74.986	2.934	50-60.3-3.6
B	29.523	108.672	3.481	65-76.1-3.2
C	30.743	92.239	3.793	65-76.1-3.2
D	103.23	50.489	3.942	90-101.6-3.6
E	138.739	1.621	4.033	100-114.3-3.6
Diagonal Member				
A	156.511	20.859	4.667	110-127-4.5
B	106.225	33.106	4.715	100-114.3-3.6
C	124.841	16.862	4.745	100-114.3-4.5
D	130.797	0	4.562	100-114.3-4.5
Chord Member				
A	96.271	41.058	4.985	100-114.3-3.6
B	74.795	53.433	5.219	90-101.6-4
C	118.274	49.354	5.305	110-127-4.5
D	162.393	16.042	5.246	110-127-4.8
Bottom layer				
Horizontal Member				
A	16.238	68.112	2.751	40-48.3-2.9
B	0	100.056	3.147	40-48.3-3.2
C	2.664	96.852	3.468	40-48.3-3.2
D	60.003	54.216	3.696	80-88.9-3.2
E	90.617	18.744	3.781	80-88.9-4
Diagonal Member				
A	142.703	25.691	4.508	100-114.3-4.5
B	149.184	22.885	4.637	110-127-4.5
C	120.014	35.871	4.634	100-114.3-4.5
D	106.954	20.555	4.277	90-101.6-4

Chord Member				
A	136.719	37.327	4.648	100-114.3-4.5
B	140.039	21.138	4.893	110-127-4.5
C	96.645	38.427	4.973	100-114.3-3.6
D	99.716	35.024	4.918	100-114.3-3.6
Bracing 1				
A	0	58.075	2.5	25-33.7-3.2
B	8.356	29.599	2.5	25-33.7-3.2
C	6.723	38.818	2.5	25-33.7-2.6
D	15.411	43.235	2.5	32-42.4-2.6
Bracing 2				
A	37.278	23.293	3.767	65-76.1-3.2
B	30.242	21.53	4.17	65-76.1-3.2
C	49.416	11.375	4.452	80-88.9-3.2
D	64.621	9.628	4.533	80-88.9-4
A	118.033	0	5.024	100-114.3-3.6
B	71.241	0	5.381	90-101.6-4
C	15.937	6.025	5.582	65-76.1-3.2
D	34.855	1.946	5.62	80-88.9-3.2
E	55.552	4.245	5.468	90-101.6-3.6
A	22.887	41.919	5.177	65-76.1-3.2
B	72.587	16.508	5.381	90-101.6-4
C	77.278	6.831	5.441	100-114.3-3.6
D	64.273	2.314	5.62	90-101.6-4
E	58.286	0	5.61	90-101.6-3.6

Table No. 4 Member group forces and section for span to height ratio-4 all bottom nodes supported

Member Groups	MAX COMP. kN	MAX TENS. kN	LEMGTH m	SECTION mm
Top				
Horizontal Member				
A	19.213	57.916	3.95	50-60.3-2.9
B	62.049	61.346	4.17	80-88.9-3.2
C	145.704	5.431	4.29	100-114.3-4.5
D	182.618	0	4.29	110-127-4.5
Diagonal Member				
A	48.357	45.277	5.3064	80-88.9-4
B	118.635	36.226	5.3067	110-127-4.5
C	154.84	6.651	5.1692	110-127-4.5
D	151.682	0	4.5194	110-127-4.5
Chord Member				
A	7.6	44.66	5.5229	50-60.3-2.9
B	121.985	55.716	5.6567	110-127-4.5
C	211.652	20.545	5.6335	135-152.4-4.5
D	190.466	0	4.1611	110-127-4.5
Bottom				
Horizontal Member				
A	22.188	70.518	3.6634	50-60.3-2.9
B	28.942	71.847	3.8984	65-76.1-3.2
C	97.64	37.875	4.0485	90-101.6-3.6
D	129.795	0	4.0733	100-114.3-3.6
Diagonal Member				
A	212.472	0	5.0376	125-139.7-4.8
B	171.295	0	5.038	110-127-4.8
C	128.155	17.655	4.9074	100-114.3-4.5
D	120.459	0	4.2905	100-114.3-3.6

Chord Member				
A	136.809	0	5.2888	110-127-4.5
B	159.62	0	5.3264	110-127-4.8
C	126.564	11.284	5.3702	110-127-4.5
D	140.951	19.961	5.3483	110-127-4.5
E	114.007	0	5.3702	110-127-4.5
Bracing 1				
A	18.086	43.858	2.5	32-42.4-3.2
B	6.187	41.919	2.5	25-33.7-2.6
C	0	47.611	2.5	25-33.7-2.6
D	17.335	0	2.5	32-42.4-3.2
Bracing 2				
A	45.837	18.431	4.179	50-60.3-2.9
B	62.249	41.867	4.236	80-88.9-4
C	46.677	9.035	4.414	80-88.9-3.2
D	53.922	0	4.321	80-88.9-3.2
A	12.099	13.492	5.308	50-60.3-2.9
B	19.672	21.365	5.408	65-76.1-3.2
C	36.845	6.337	5.408	80-88.9-3.2
D	45.945	0	5.346	80-88.9-4
E	59.598	23.466	5.033	90-101.6-3.6
A	92.758	1.016	5.308	100-114.3-3.6
B	74.012	0	5.408	100-114.3-3.6
C	61.328	0	5.408	90-101.6-3.6
D	58.878	0	5.346	90-101.6-3.6
E	42.506	0	5.033	80-88.9-3.2

Table No. 5 Foundation Details

Sr. No	Span to Height ratio	Support Condition	Size of base plate mm	Thickness of Plate mm	No. & Dia. Of Anchor bolt	Length of anchor bolt mm	Pedestal size mm	Hub Dia. mm	Weld length of plate & hub mm
1	2-A	All Node	375 x 375	16	8-24mm Ø	410	1000x1000 x 425	125	375
2	2-B	All Node	275x 275	12	4-12mm Ø	315	500 x 500 x 325	65	100
3	2-A	Alternate Node	450 x450	20	8-30mm Ø	530	1250x1250 x 550	200	628.4
4	2-B	Alternate Node	300 x 300	16	4-20mm Ø	445	750 x 750 x 460	80	215
5	2-A	2-Alternate Node	550 x 550	16	12-36mm Ø	425	1500x1500 x 450	300	800
6	2-B	2- Alternate Node	375 x 375	16	8-24mm Ø	390	1000x1000 x 400	125	350
7	4	All Node	375 x 375	16	8-24mm Ø	340	900x900x 350	100	300
8	4	Alternate Node	475 x 475	16	8-30mm Ø	510	1250x1250 x 525	200	600
9	4	2- Alternate Node	575 x 575	16	12-36mm Ø	470	1600x1600 x 490	300	910

DISCUSSION OF RESULT:

The domes of span 75m with different span to height ratio as well as different support condition are designed for wind load. The members of dome are designed for axial tension or compression in such a way to get optimum weight of member. The results shown in figure 5 to 14 of this chapter are for the weight of base plat, volume of concrete for pedestal, weight of member and deflection of domes.

1.WEIGHT OF DOME

Table No.6 Weight of base plate and volume of concrete

Span (m)	Height (m)	Span to Height ratio	Radius (m)	Sweep Angle (deg.)	Support Condition	No. of footing	Base plate weight kN	Volume of Concrete m^3
75	37.5	2	37.5	90	All node	192	46.75	97.2
					Alternate node	96	40.64	107.34
					Two alternate node	64	34.99	90.40
75	18.75	4	46.875	53.13	All node	66	11.45	18.711
					Alternate node	33	9.19	27.070
					Two alternate node	22	8.97	27.597

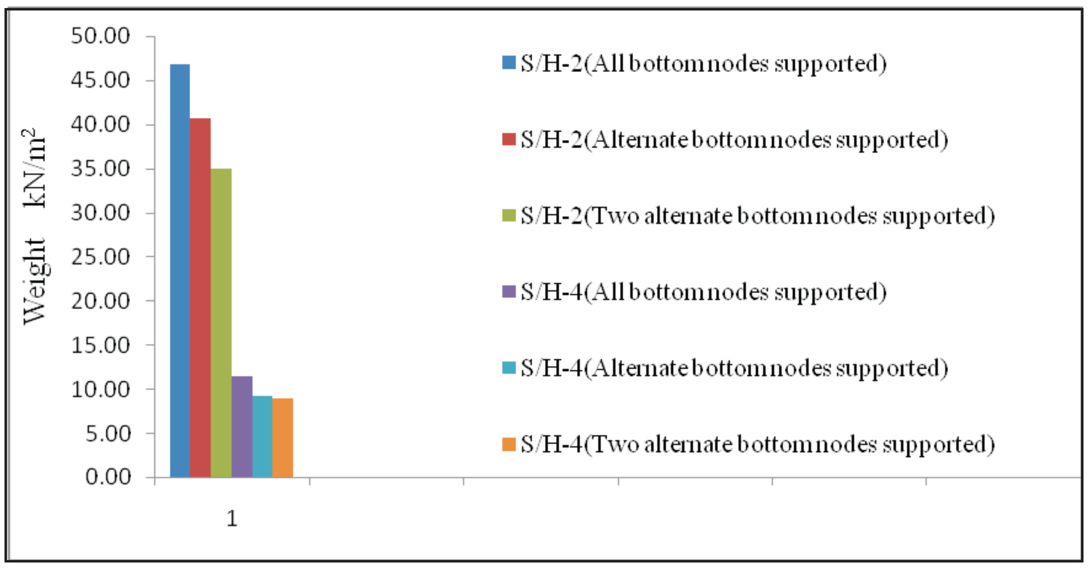


Figure 5 Weight of base plate

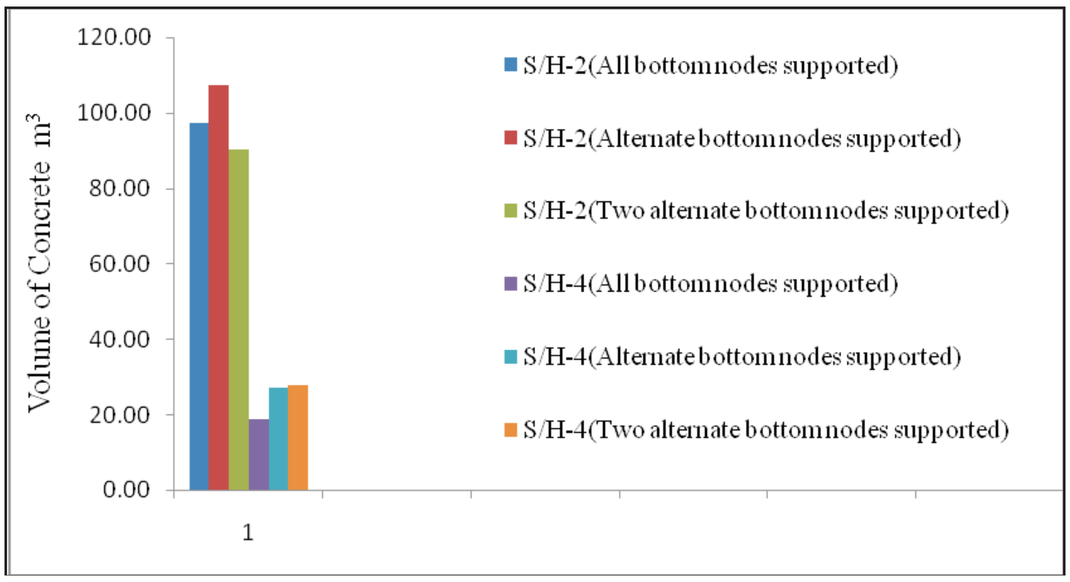


Figure 6 Volume of concrete for pedestal

The Table No. 5 and figure 6 shows the weight of dome for different supporting condition, with Span to Height ratio 4 (all bottom nodes supported) gives lowest weight 2.18 kN/m2 derived from all cases.

Table 7 Results of domes

Span (m)	Height (m)	Span to Height ratio	Radius (m)	Sweep Angle (deg.)	Support Condition	Weight (kN)	Max. Compression (KN)	Max Tension (kN)
75	37.5	2	37.5	90	All node	15428.506	162.393	108.672
					Alternate node	15792.932	270.942	119.317
					Two alternate node	15595.613	371.686	157.721
75	18.75	4	46.875	53.13	All node	9623.782	212.472	71.847
					Alternate node	9837.803	384.41	127.148
					Two alternate node	9936.219	543.89	188.076

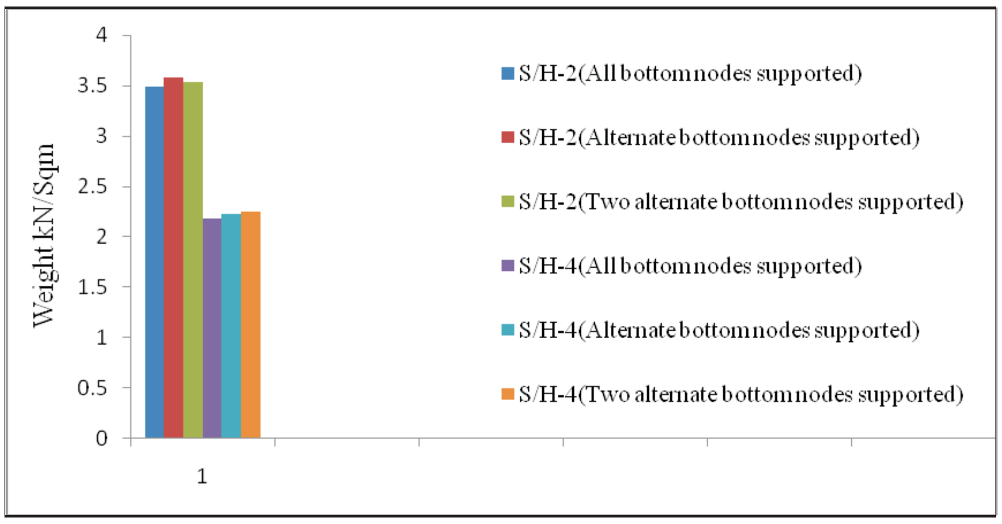


Figure 7 Weight of members

2. DEFLECTION OF DOME:

The following figures show the deflection of dome [Ref. figure 8 to 14] for different support condition, the maximum deflection of different domes is tabulated in table No. 7 and figure 14.

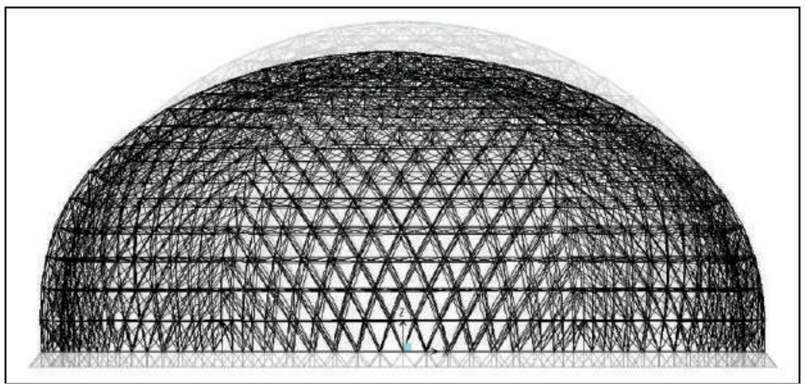


Figure 8 –Deflection of Span to Height ratio two at all bottom nodes supported

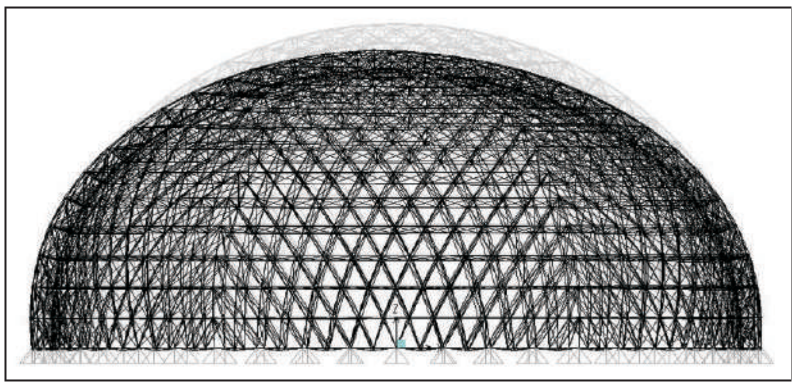


Figure 9–Deflection of Span to Height ratio two at alternate bottom nodes supported

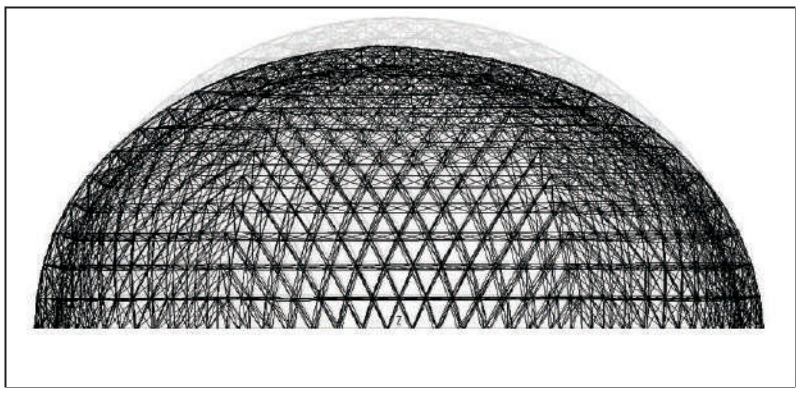


Figure 10–Deflection of Span to Height ratio two at two alternate bottom nodes supported

Figure 11 –Deflection of Span to Height ratio foure at all bottom nodes supported