ANALYSIS & DESIGN OF DOME USING VBA APPLICATION

Jayanti Dangar[1], Arpit Parikh[2],

[1]P.G.Student (M.E.Structure), Department of Civil Engineering,
P.I.E.T., Gujarat technological University.
[1]jayanti.everest@gmail.com

[2]Formely Expert (Civil & Structure) EPC Firm, JAPAN
Currently Assistant Professor (Civil & Structure) Department of Civil Engineering,
P.I.E.T., Gujarat technological University.
[2]arpitparikh2000@yahoo.co.in

ABSTRACT: Various forms of shell structure are available for covering large area but as Dome is a highly indeterminate structure it involves complex mathematical calculations. Approximate methods like, membrane theory and beam theory are used for geometrical Dome shapes and boundary conditions. Membrane analysis method is very much suited for analysis of dome structure because of its flexibility in accounting for arbitrary geometry, loading, variation in material properties and complex support condition. There are many software for analysis and design of shell or dome structure but the Microsoft excel is efficient for better understanding and determination. VBA is one of the efficient designing function of Microsoft excel. There are three types of Domes such as spherical, conical and canopy Domes are chosen for study. In this work all the chosen examples are first written in Excel spreadsheet and then converted in VBA programming for better solution.

***KEY WORDS*: Conventional method for Analysis of Dome, Programming by visual basic**

INTRODUCTION

A Dome is an element of architecture that resembles the hollow upper half of a sphere. Dome structures, made of various materials, have a long architectural lineage extending into prehistory. A dome can be thought of as an arch which has been rotated around its central vertical axis. Thus domes, like arches, have a great deal of structural strength when properly built and can span large open spaces without interior supports.

Domes have been constructed from a wide variety of building materials over the centuries: from mud to stone, wood, brick, concrete, metal, glass and plastic.

Domes can be divided into two kinds: simple and compound, depending on the use of pendentives. In the case of the simple dome, the pendentives are part of the same sphere as the dome itself; however, such domes are rare.

In the case of the more common compound dome, the pendentives are part of the surface of a larger sphere below that of the dome itself and form a circular base for either the dome or a drum section

A covering of buildings and structures, serving as a roof over spaces, normally those with a circular, polygonal, or elliptical floor plan. The shape of the dome follows a curve that is convex to the exterior of the building. Stresses existing in a dome consist not only of the basic compression loads, which transmit the weight of the roof to the supports, but also of horizontal thrusts. To accommodate the horizontal forces, special tension structures are sometimes provided, such as support rings at the base of the dome.

Membrane Analysis for shell:

In spherical dome design, dead load is taken as acting along the curved length of shell, and live load is taken as acting on the plan area only. It can be shown mathematically for a uniform distributed dead load that the forces developed under symmetric loading will be only the meridinal stress **NØ** and the hoop stress along the latitude or horizontal bands. As uniform dead load on the shell will produce the same **Nθ** the latitude, we can infer that the shear stress in such a surface will be zero under such uniform

© 2013 IJAIR. ALL RIGHTS RESERVED

loading. Hence, we assume that the only two stresses that act on the main body of shell.

Following figure shoes the meridinal and hoop stresses according to their direction.

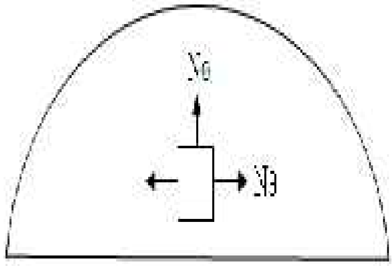


Fig: 1 Direction of membrane force

PLANNING BEFORE ANALYSIS

1).When the domes are under dead load, domes with full 90º half central angle will have no incompatibility with the reaction from the support it rest on. There is no ring tension.

2).On the other hand, segment domes with less than 52º central angle will be fully in compression, but end will required ring beam to take the horizontal component of the meridinal compression.

3). If we have an opening at its apex, there should be a ring beam at the top to balance the horizontal compression of the meridinal stress at the top.

4). It is also important that the shell should be so designed that concreting is easy. It is very difficult to lay concrete on any slopes greater than 40º. Hence, we always plan for a half central angle equal to or less the 40º.

5).With high rise, the stress will be low. Accordingly, a rise-span ratio of 1/5–1/8 is usually used in practice.

6). Minimum thickness specified by IS 2210 is 50 mm but for practice purpose, we should adopt at least 75–100 mm.

7). Domes up to a span 60 meters can be built with R.C. ring beam. Larger domes will require prestressing of ring beams.

Number of cases in shell analysis for various loading such as:

1) Uniform dead load on a full shell surface with a central load on the apex.
2) Uniform live load over surface on the top of shell with skylight.
3) Uniform live load assumed constant over the projected area of shell surfaces.
4) Shell with a thickening of the edges and consequent variation of dead load.

Stresses on shell for different cases:

NØ=Meridenial Stress
N_θ =Hoop Stress

1). Spherical Dome:

$$N_\phi = \frac{wR}{(1+\cos\phi)} + \frac{W}{(2\pi R * \sin^2\phi)}$$

$$N_\theta = wR\cos\phi - \left[\frac{wR}{(1+\cos\phi)} + \frac{W}{(2\pi R * \sin^2\phi)}\right]$$

2). Conical Dome

$$N_\phi = \frac{w*z*sce^2\alpha}{2}$$

$$N_\theta = w*z*\tan^2\alpha$$

3). Dome with a Canopy:

$$N_\phi = \frac{wR(\cos\phi_1-\cos\phi) + (P*\sin\phi_1)}{\sin^2\phi}$$

$$N_\theta = wR\cos\phi - N_\phi$$

Where,
w= dead load
W= concentrated load at crown
h= height
R= radius

DESCRIPTION OF STEP FOR ANALYSIS:
WIND LOAD ANALYSIS ON FOLDED PLATE

Step 1: Input the Dome dimension and material properties as per necessity.

© 2013 IJAIR. ALL RIGHTS RESERVED

Step 2: Calculate the Load calculation.
Step 3: Stress Calculation.
Step 4: Check for Buckling.
Step 5: Design of ring Beam.
Step 6: Design of shear between ring and Dome shell.

Example: Analysis and Design of Spherical Dome in Excel.

Step 1: Input Data.

Here the input data for Spherical Dome are taken as per its requirement and other geometrical and material properties are calculated from their equation. In this, material properties like grade of steel, grade of concrete, allowable stresses, size of reinforcement bars are given for calculation.

Input Data:

Span(S)=	[illegible]	m
[illegible]	6.25?	m
[illegible]	0.1?	
Height(h)=	[illegible]	m
Thickness(t)=	0.12?	m
Radius of shell(R)=	10.77?	m
Angle(Φ)=	35.15	degree
W	0	kN

Grade of steel=	250	N/mm^2
Grade of Concrete(fck)=	20	N/mm^2
Allowable steel stress=	140	N/mm^2
σ_{cc}=	2	N/mm^2
Size of reinforced bar for shell=	8	mm
Size of reinforced bar for beam=	16	mm
Modul of elasticity of concrete=	22361	N/mm^2
Module of elasticity of steel(E)=	200000	N/mm^2
Modular ratio(m)=	18	

Step 2: Calculate the Load calculation.

In this step Total load applying on the Dome area is calculated by summering of all loads like Dead Load, Live Load, and Water proofing Load

Load Calculation:

Dead load of shell=	[illegible]	kN/m^2
Live load=	1.5	kN/m^2
Water proofing=	0.9	kN/m^2
Total (w)=	[illegible]	kN/m^2

Step 3: Stress Calculation.

.In this step, the stresses are calculated up to the maximum angle of the Dome Curvature. For the different angle of the Dome Curvature stresses are calculated and the maximum stress is taken for calculation. From the maximum stress the area of steel required for shear is calculated.

Ø	$\frac{wR}{1+\cos Ø}$	$\frac{W}{2\pi R^2 \sin^2 Ø}$	wRcosØ	Nθ	Nφ
0	33.12?	0	66.74	33.12	33.12?
10	33.37	0	65.73	33.37	31.86?
20	34.15	0	62.74	34.15	28.59?
30	35.50	0	57.35	35.50	21.85?
35.15	35.44	0	54.15	35.44	17.77

Step 4: Check for Buckling.

According to safety factor the maximum stress in the shell have to be greater than the stress of concrete used in the construction.

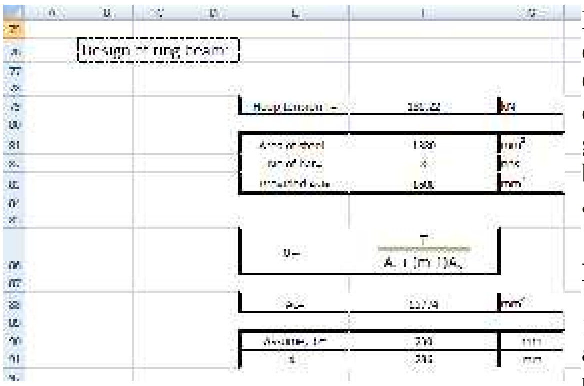
Check for buckling:

σ_{cr}=	Et / [illegible]	[illegible]
Safety factor=	4	
Stress=	[illegible]	[illegible]

Step 5: Design of ring Beam.

To support the hoop force of Dome shear, the ring Beam is provide at the bottom of Dome shell. Beam is designed for maximum Hoop Tension applied to the beam.

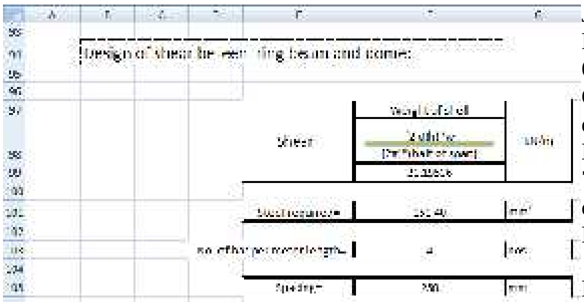
© 2013 IJAIR. ALL RIGHTS RESERVED



Step 6: Design of shear between ring and Dome shell.

The vertical component of the thrust between the shell and ring beams at the bottom produces shear between the junction of the shell and ring beam. This shear at junction should be checked and the extra tension steel provides should enable the concrete to carry the shear without vertical stripus.

This shear will also be the total weight of dome transferred at the junction between the ring beam and the dome.



CONCLUSION

In all the software like Stadd, Ansys, Etabs etc., we have to first create their geometry then load apply and after that the analysis performed at every new design. While in the Excel sheet, by changing their properties in one table solution will be taken easily.To learn the Excel software is quite easy compare to other software. By applying the VBA programming the work will understand easily.

ACKNOWLEDGMENT

I express my heartfelt thanks to Prof. Arpit A. Parikh for his initial spark, inspiring guidance, invaluable suggestions and constant encouragement during entire period of my work. His teaching background has helped me in formulating the strategy and methodology for my thesis work, which indeed is the core of the topic. His critical inputs and able guidance have enriched the value of the thesis. The blessings of God and my family members make the way for completion of major project, I am very much grateful to them. The friends, who are always bears and motivate me throughout this course, I am thankful to them.

REFERENCES

1) Carl T.F. Ross, Philipp Koster, Andrew P.F. Little and Giles Tewkesbury, "Vibration of a thin-walled prolate dome under external water pressure", Ocean Engineering 34(2007) Page 560-575

2) Mamoru Kawaguchi, Ikuo Tatemichi and Pei Shan Chen, "Optimum shapes of a cable dome structure", Engineering Structures 21 (1999) Page 719–725

3) Yasushi Uematsu, Motohiko Yamada, Akira Inoue and Takeshi Hongo, "Wind loads and wind-induced dynamic behavior of a single-layer latticed dome", Journal of Wind Engineering and Industrial Aerodynamics 89 (2001) Page 1671–1687

4) Hoang Chi Tran, Hyo Seon Park and Jaehong Lee, "A unique feasible mode of prestress design for cable domes", Finite Elements in Analysis and Design 59 (2012) Page 44–54

5) S. Kitipornchai, Wenjiang Kang, Heung-Fai Lam and F. Albermani, "Factors affecting the design and construction of Lamella suspen dome systems", Journal of Constructional Steel Research 61 (2005) Page 764–785

6) Wenjiang Kang, Zhihua Chen, Heung-Fai Lam and Chenran, "Analysis and design of the general and outmost-ring stiffened suspen-dome structures", Engineering Structures 25 (2003) Page1685–1695

7) X.F. Yuan and S.L., "Integral feasible pre stress of cable domes", Computers and Structures 81 (2003) Page 2111–2119

BOOK & I.S CODES REFERENCES

1) IS 2210, Criteria for design of reinforced concrete shell structure and folded plate, 1992

2) P.C.Varghese. Design of reinforced concret shells and folded plate. PHI learning private limited, New Delhi, 2008.

3) Microsoft Excel 2010 Bible by John Walkenbach

4) Excel 2007 VBA Programmer's Reference by John Green, Stephen Bullen Rob Bovey and Michael Alexander

5) Excel 2007 VBA Programming for DUMMIES by John Walkenbach

© 2013 IJAIR. ALL RIGHTS RESERVED