Influence of Support Systems on the Structural Behaviour of Cylindrical Shells

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***Abstract*— the present study is intended to assess the influence of support system on the structural behaviour of cylindrical shells. Single and Multiple cylindrical shells supported on end diaphragms with free longitudinal edges, rigid support such as walls and flexible support with edge beams resting on columns are considered. Structural behaviour under gravity loads is assessed through linear static FE analysis. Develop automation tools using Excel for the Design of Circular Cylindrical Shell Roof with Rigid and Flexible Supports using ASCE procedure. The results obtained from this method are used to validate the FE results. FE analysis is done using NISA Design Studio. Stress resultants are compared with the values as per ASCE manual. Semi-Circular Roof on Rigid Support and a circular cylindrical shell roof for the following cases is examined.**

Case 1: Longitudinal edges free supported on Traverse only

Case 2: Flexible support - Shell with edge beams 300 mm x1800 mm

Case 3: Rigid support - Shell resting on wall along the curved edge

Keywords—Tx – direct force in the longitudinal direction,TØ-direct force in transverse direction, S-tangential shear force,MØ-bending moment in radial direction.

I. INTRODUCTION

Reinforced concrete cylindrical shell roofs are chosen commonly for covering large clear areas using the minimum of intermediate supports, such as in factory buildings, power station, garages, island platforms of railway stations, stadia.
Shell structures support applied external forces efficiently by virtue of their geometric forms. "Thin shells are the example of strength through form as opposed to strength through mass". The effort in the design is to make the shell as thin as practical requirements will permit so that the dead weight is reduced and the structure functions as a membrane free from the large bending stresses. By this means, a minimum of materials is used to the maximum structural advantage.
Cylindrical Shell surface can be generated by a straight line known as generator moving over a plane curve named as directrix (arc of circle, semi ellipse, parabola, cycloid and catenary). Edge beams are optional.

II. STRUCTURAL ANALYSIS

A. ASCE METHOD OF ANALYSIS

ASCE Method is similar in principles to the classical method of analysis of Indeterminate structures, we first make the structure determinate (membrane analysis) and then make corrections to satisfy the equilibrium of the original structure. In the case of cylindrical shells, we first find out the membrane forces (which are determinate) and then make corrections to satisfy the boundary conditions. In the correction analysis, we have to use the Bending theory of shells as bending moments are also produced when we apply correction forces on the boundary of the shell. The solution obtained is purely based on the principle of superposition.

B. FINITE ELEMENT (FE) ANALYSIS

A complete analysis of various thin shell forms would require an appropriate moment theory, which is to be combined with the membrane theory. FEM techniques are developed and most of the FEM software's have the capacity of such an analysis. Shell Elements are developed for this purpose. Due to the versatility of the finite element method, shell structures are analyzed using this technique. .

III. METHODOLOGY

1. Develop automation tools using Excel for the Design of Circular Cylindrical Shell Roof with Rigid and Flexible Supports using ASCE procedure. The results obtained from this method are used to validate the FE results.

2. FE analysis is done using NISA Design Studio. Stress resultants are compared with the values as per ASCE manual.

Primary stress resultants in a shell such as Tx, TØ, S, MØ are monitored.

3. Establish the limits for idealizing the supports to be either rigid or flexible.

IV. RESULTS AND DISCUSSIONS

A. FE analysis is done using NISA Design Studio. Stress resultants are compared with the values as per ASCE manual design procedure. The variation of resultants Tx, TØ, S, MØ are obtained for all the three cases. Semi-Circular Roof on Rigid Support and to assess the influence of support system, a circular cylindrical shell roof for the following cases is examined.

i. Case 1: Longitudinal edges free supported on Traverse only

ii. Case 2: Flexible support - Shell with edge beams 300 mm x1800 mm

iii. Case 3: Rigid support - Shell resting on wall along the curved edge

B. Figures and Tables

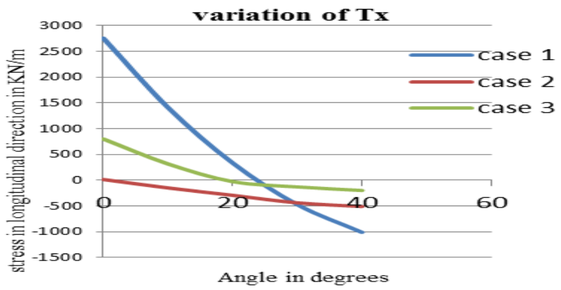
TABLE I. VARIATION OF Tx, TØ, S, MØ FOR DIFFERENT SUPPORT CONDITION

Variation of Tx

Ø	0	10	20	30	40
Case1	*2758*	*1412*	*335*	*-472*	*-1011*
Case2	*13.89*	*-149*	*-293*	*-438*	*-510*
Case3	*801*	*317*	*-27*	*-130*	*-199*

From the above results, it can be inferred that the support conditions along the curved and longitudinal edges have considerable influence on TX near the edge zone of the shell.

In the crown zone, even though the magnitudes vary considerably, the nature of stresses is same.

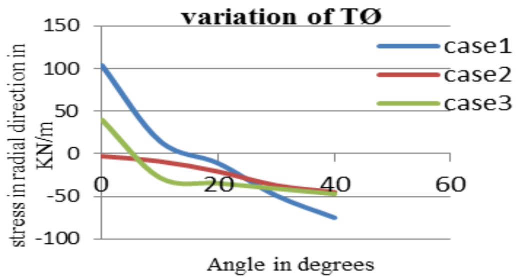


Variation of TØ

Ø	0	10	20	30	40
Case1	*104*	*15*	*-11*	*-49*	*-75*
Case2	*-2.7*	*-8.8*	*-20.8*	*-37*	*-45*
Case3	*40*	*-28*	*-34.5*	*-40.8*	*-47*

Support conditions have influence on TØ near the edge zone of the shell both on magnitude and nature

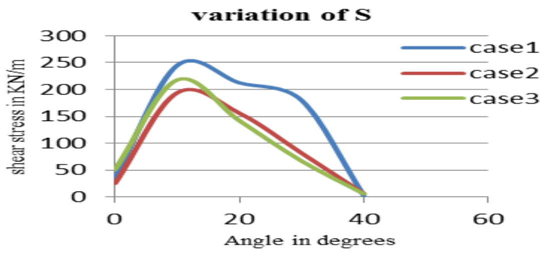
In the crown zone, even though the magnitudes vary, the nature of stresses are same



Variation of S

Ø	0	10	20	30	40
Case1	*35.4*	*245*	*212.5*	*180*	*3.13*
Case2	*25.4*	*194*	*156*	*81.8*	*6.6*
Case3	*51.5*	*218*	*142*	*67*	*6*

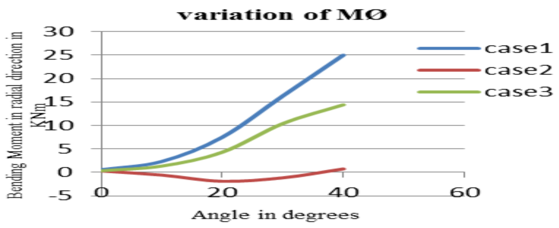
Support conditions have some influence on S along the shell surface



Variation of MØ

Ø	0	10	20	30	40
Case1	*0.59*	*2.33*	*7.5*	*16.3*	*25*
Case2	*0.3*	*-0.57*	*-1.9*	*-1.15*	*0.74*
Case3	*0.35*	*1.35*	*4.3*	*10.4*	*14.4*

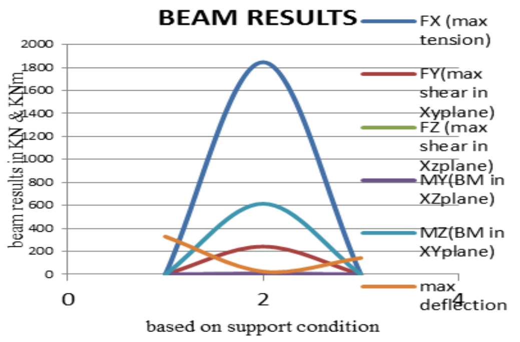
Support conditions have some influence on MØ along the shell surface, particularly in changing the nature of moment, which is an important aspect in the design of RC Shells.



Beam Results and Deflection in Shell

	FX	Fy	Fz	MY	MZ	Def(mm)
case1	*0*	*0*	*0*	*0*	*0*	*328.8*
case2	*1846*	*241*	*3.19*	*6.8*	*615*	*24.4*
case3	*0*	*0*	*0*	*0*	*0*	*142.5*

Edge beams drastically reduces the deflection shell.



FE Model Data: for rigid support condition

Span: 20m, Chord width:12m, Thickness of shell: 100mm,Radius: 6m, Central rise: 6m;Boundary condition: Hinged support and Longitudinal edges free; Material property: young's modulus =22360Mpa, Poisons ratio =0.2;Pressure load on the shell: 3 KN/m^2

	AT CROWN		AT EDGE	
	ASCE	FE result	ASCE	FE result
Tx(kN/m)	-54	-55.13	12	14
TØ(kN/m)	-18	-18.3	0	-0.24
S(kN/m)	0	0	50	49.48

As the shell is supported only along the curved edges and the longitudinal edges are free, membrane stress state exists throughout the shell surface. FE Results match with membrane analysis results computed as per ASCE manual. This validates the FE approach adopted in the present study.

FE Model Data: for flexible support condition(300x1800mm)

Span: 30m, Chord width: 10m, Thickness of shell: 80mm, Radius: 7.8m, Central rise: 1.8m, Diaphragm height: 1.8m, Thickness: 80mm, Column section: 300x300mm, Edge beam: 300mmx1800mm;Material property: young's modulus =22360Mpa, Poisons ratio =0.2;Pressure load on the shell:3.64 kN/m^2

Ø	**Tx(kN/m)**		**TØ(kN/m)**		**S(kN/m)**		**MØ(kNm)**	
	ASCE	FE	ASCE	FE	ASCE	FE	ASCE	FE
0	1841	13.8	0	-2.7	7	25	0	0.3
10	355	-149	-10	-8.8	138	194	-2	-0.57
20	-295	-293	-29	-21	134	156	-6	-1.9
30	-497	-438	-43	-37	75	81.8	-11	-1.15
40	-531	-510	-49	-45	0	6.6	-13	0.74

1. *Results indicate significant differences in the stress resultant Tx near the longitudinal edges. ASCE values are very high in the edge zone (0° -10°) and indicate large tension field (0° -20°) to prevail along the shell surface. FE results show a very small tension zone (0°-10°) to exist near the edges*

2. *In the zone (20°- 40°), Tx values obtained from both approaches are more or less similar both in nature and vary in magnitudes in a very close range.*

3. *ASCE manual and FE approach yield values for TØ and S to vary within a close range.*

4. *Some notable differences in values for MØ are observed between the two approaches.*

FE Model Data: for flexible support condition(175x175mm)

Span: 30m, Chord width: 10m, Thickness of shell: 80mm, Radius: 7.8m, Central rise: 1.8m, Diaphragm height: 1.8m, Thickness: 80mm, Column section: 300x300mm, Edge beam: 300mmx1800mm;Material property: young's modulus =22360Mpa, Poisons ratio =0.2;Pressure load on the shell:3.64 kN/m^2

Ø	**Tx(kN/m)**		**TØ(kN/m**		**S(kN/m)**		**MØ(kNm)**	
	ASCE	FE	ASCE	FE	ASCE	FE	ASCE	FE
0	1841	1834	0	-3.7	7	38	0	0.3
10	355	408	-10	-9.2	138	240	-2	2.29
20	-295	-257	-29	-31	134	185	-6	6
30	-497	-542	-43	-47	75	75	-11	12
40	-531	-732	-49	-58	0	1.6	-13	19.7

1. *With considerable reduction in beam stiffness, the nature and distribution of all the stress resultants except M_{Φ}, along the shell surface in longitudinal and circumferential direction are found to be similar from both the approaches.*

2. *Results obtained for the two cases with very different edge beam sizes (300x1800 mm and 175 x 175 mm), signify that the edge beam stiffness is an influencing parameter in the stress analysis of cylindrical shells.*

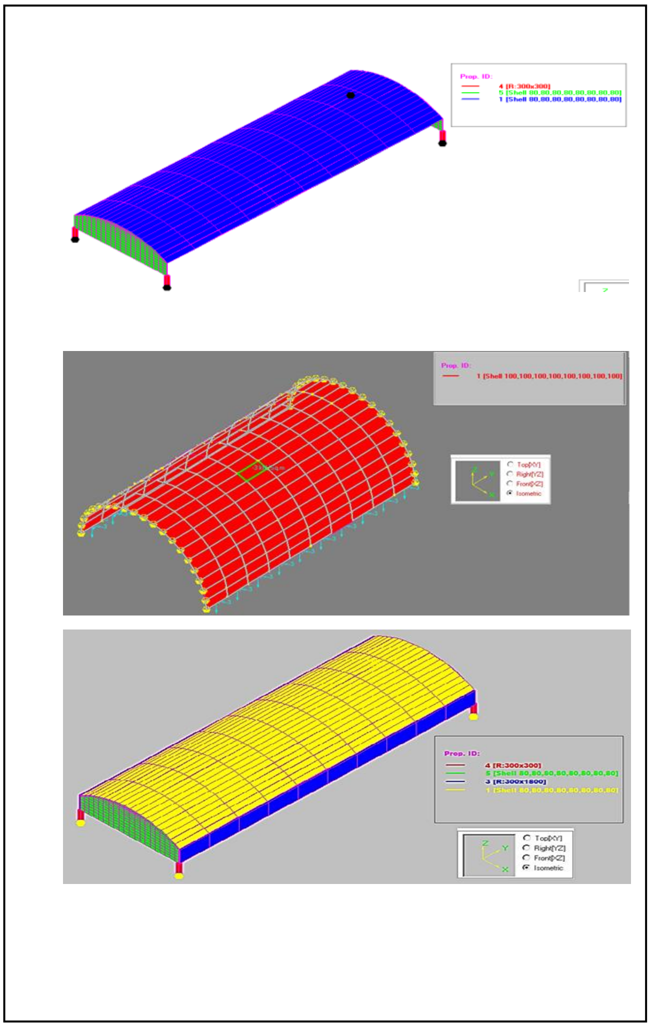


Fig 1: Realistic plot of FE models of single shells created using NISA Design Studio

Figure 1: The FE models for single shell of which longitudinal edges free, semicircular shell roof resting on the rigid support and circular cylindrical shell resting on flexible support are shown.

Results from the study signifies that with the considerable reduction in the beam stiffness, the nature and distribution of all the stress resultants along the shell surface in the longitudinal and circumferential direction are found to be similar from ASCE and FE approaches i.e found in rigid support and longitudinal edges free case. In the case of flexible support of 300x1800mm edge beam dimension, stress resultants obtained from FE results doesn't matches with ASCE manual procedure; this leads to a parametric study in which 175x175mm edge beam dimension is sufficient to take the loads which has been proved from the FE analysis. This shows that the edge beam stiffness is a factor impacting on the structural behavior of shells and also it is an influencing parameter in the stress analysis of cylindrical shell.

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REFERENCES

[1] Youssef BELMOUDEN*, Pierino LESTUZZI, Souad Sellami, Youssef BELMOUDEN, "A seismic analysis of a modular shell system," Proceedings of the 6th International Conference on Computation of Shell and Spatial Structures,IASS-IACM 2008:

[2] Ravindra Rai1 Dr. Umesh "Computer Aided Analysis of Multiple Cylindrical Shell Structure PendharkarInternational Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 3, May – 2012

[3] S. Kandasamy and A. V. Singh, "Free Vibration Analysis of Cylindrical Shells Supported on Parts of the Edges"

[4] K. Chandrashekhara, Kapania "Shell subjected to wind loading"

[5] P.C. varghese "Design of Reinforced concrete shells and folded plates"

[6] Shadi OSTOVARI DAILAMANI*, James G. A. CROLL, "Earthquake analysis of cylindrical roof shells," Proceedings of the 6th International Conference on Computation of Shell and Spatial Structures,IASS-IACM 2008

[7] J.L.Meriam , L.G.Kraige "Engineering Dynamics"–volume2