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Comparison between Smooth and Ring Beam Stiffened Cylindrical Shell Roof

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Abstract
In this paper smooth and ribbed spherical is taken for the analysis and the effect on the stresses for increase in span in both shell structure is investigated as it is a prominent factor in optimizing of the cylindrical design. The cylindrical shell roofs can be categorized as smooth cylindrical shell and ribbed stiffened shell roofs. The problem is to compare smooth cylindrical shell roof over ring beam cylindrical shell roof in term of their moment, stress and deflection by keeping volume of concrete constant. This paper perform optimisation study of ring stiffened cylindrical shell after getting conclusion from comparision. Performance of the ribbed cylindrical shell is higher than smooth cylindrical shell when span of the structure increase. In Spite of the construction difficulties and difficulties in the placement of formwork ribbed cylindrical shell might more efficient than smooth cylindrical shell for a higher span. Thus, the smooth and ribbed cylindrical shell with different rise and span keeping apex angle constant as 120° with different boundary condition has been studied. Further finite element analysis has been performed in SAP 2000 and the stresses are compared with that of the stresses obtained from the theoretical solution for verification.

Keywords
Smooth Circular Cylindrical Shell, Ring Stiffened Circular Cylindrical Shell[1, 2], Classical Theory- MATLAB, SAP2000

1. Introduction

Shell structure are plate structures having curvature in one direction or in both direction which can transmit applied forces by compressive, tensile, and shear stresses that act in the plane of the surface. Shell structures are also those type of structure which have three dimensional curved surfaces capable of spanning long spans without any intermediate supports i.e. columns. Shell structures, due to curvatures develops in plane stresses and also some bending stress due to flexure deformations whereas plate structures are flats which develop bending and shear stresses. Thus, shell structures are capable of resisting load through compression, tension as well as shear stress. So that shell structure perform best load carrying capacity having same dead load compare to other type of structures. Because of its structural configuration shell structure are widely used in long span structures i.e. large buildings, conference hall and in stadium. Construction of Shell structure begins from 1920 and are widely used after World War II. Besides that, the shell structures are also used in aesthetically appalling structures like Opera House in Sydney, Temple of Delhi etc. are shell structures.

The structural analysis of thin concrete shells can be performed numerically using finite element analysis and/or analytically by using classical theory of thin shells. While FEA analysis is becoming increasingly prominent way of performing structural analysis than the analytical solution procedure. Compared to structural elements such as beams, slab and walls, the structural behavior of shells in not easy to predict so that evaluating the accuracy of the results obtained from FEA of shell structures is a challenging task. Having the knowledge and understanding of the analytical solution method can provide the basis for this verification and at the same time give a much needed insight into the structural behavior of shells.

The cylindrical shell consists of different geometrical configuration. For a small span and length of structure it is better to design smooth cylindrical shell, and for large span and length ribbed cylindrical shell may require. In this paper, smooth and ribbed cylindrical shell are analyzed.

The specific objective of this paper is to find difference in the moment,stresses and in deflection between smooth cylindrical shell roof and ring stiffened cylindrical shell roof. Furthermore this thesis aims to compare the different method of analysis done using theoretical methods and finite element analysis. The other objectives are:

- To compare the results obtained from the analytical method with that of the finite element method.
- To compare the behavior of both the cylindrical shells on the basis of stresses and deformation.

2. Detail of Model

Their are two different model seleted for the analysis of cylindrical shell roof:

Model 1: This model is the solved example of Scordelis-Lo barrel roof [3]. This model has been used to validate the analytical method with finite element method.

The Scordelis-Lo barrel roof (or vault) is a singly curved shell structure shown in Figure 1, loaded by its own weight). This cylindrical shell is supported along the curved ends by rigid diaphragms (v=w=0) while the straight edges are free, meaning that translational d.o.f. parallel to the plane containing the curve are prohibited but translational d.o.f. normal to this plane and all rotational d.o.f. are unrestrained.

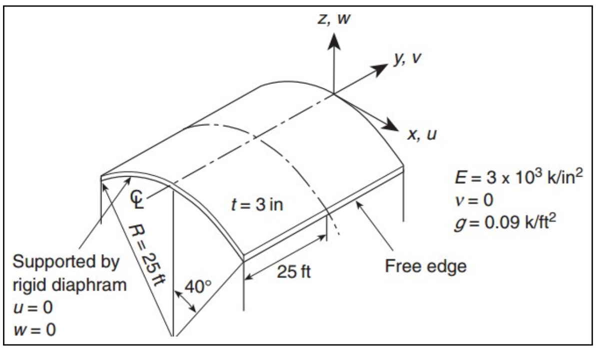

Figure 1: Scordelis-Lo-Barrel Roof geometry and properties

Geometric Properties

Length = 50 ft

Semi-circular angle = 40 Degree

Radius of shell = 25 ft

Thickness= 3 inch

Material Properties

Linear Elastic homogeneous Isotropic Material with

Young's modulus =432000000 lb/ft2

Poisson's ratio =0

Unit weight of concrete = 360 lb/ft3

Loading

Gravity load=90 lb/ft2 (Uniform load on surface area in –Z direction.)

Model 2: After validation of analytical and finite element method, this model has been executed as a real problem for this paper. Smooth cylindrical shell having following geometry has been selected for the further analysis from finite element analysis:

Geometric Properties

Length = 10 m

Semi-circular angle = 60 Degree

Radius of shell = 2.88 m

Thickness= 80 mm

Material Properties

Linear Elastic homogeneous Isotropic Material with

Young's modulus = 25000 N/mm2

Poisson's ratio =0.2

Unit weight of concrete = 25 KN/m3

Loading

Live Load= 1.5 KN/m² (as per IS code)

By keeping volume constant from model 2[3] , smooth cylindrical shell[4] convert into the ring beam cylindrical shell by changing thickness of shell. Number of ring for the above geometry has been varied by keeping depth to breadth ration of beam constant with 1.5. so that total 3 number of ring stiffen cylindrical shell having following geometrical parameters different than smooth cylindrical shell are analyzed:

Geometric Properties

Thickness= 50 mm

Size of Ribbed Beam:

Having 3 Number of Ribbed Beam

B= 0.258 m

D= 0.387 m

Having 5 Number of Ribbed Beam

B= 0.20 m

D= 0.30 m

Having 7 Number of Ribbed Beam

B= 0.17 m

D= 0.253 m

3. Analytical Method

Analytical method has been adopted for the solution of smooth cylindrical shell roof for the validation of the entire work. For the analysis of Smooth cylindrical shell following two theories has been adopted for the Analytical solution from MATLAB.

- **Schorer Theory**
- **K Chandrasekhara Theory[5]**

4. Finite Element Modeling

Analysis of the smooth and ring beam cylindrical shell are perform by using software packages from Computers and Structures, Inc. for structural analysis and design, SAP2000 (Version 21).It is a fully integrated system for modeling, analyzing, designing, and optimizing structures.

Boundary condition for finite element method: At curved edges, the shell body is simply supported. (Uy and Uz are restrained against translation in y and z direction) and at straight edges the shell body is free.

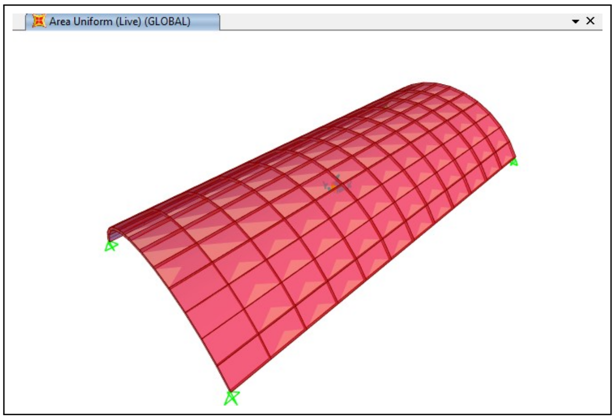

Figure 2: Finite Element Modeling of Smooth Cylindrical Shell

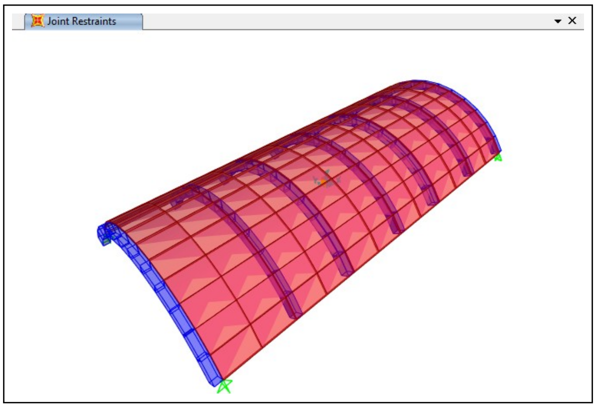

Figure 3: Finite Element Modeling of Ring Beam Cylindrical Shell

All total 144 mess are created as shown in figure 3 for finite element modeling both smooth and ribbed cylindrical shell roof. It is assumed that the shell thickness throughout the section are constant and is as per geometry.

Variable in ribbed beam cylindrical shell is number of beam, so that according to the number of beam size of beam are also changed and are modeled in finite element method. Rib network develop in the ribbed stiffened cylindrical shell are simple and aren't connected with each other.

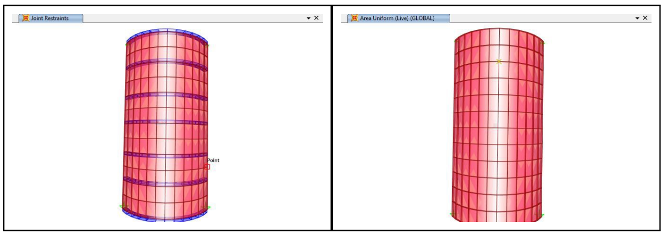

Figure 4: Mess created in finite element analysis for smooth and ribbed cylindrical shell

5. Result

Selected geometry from Model 1 has been modeled by Analytical method in Matlab and modeling also done from finite element method (SAP 2000) and result from both method has been compared with solution from The finite Element Method Fifth Edition Volume 2, Solid Mechanics: (Zienkiewicz and Taylor[6]).

Further Model 2 having smooth cylindrical shell and ring beam cylindrical shell roof has been modeled from finite element analysis in SAP 2000. Hence following results has observed:

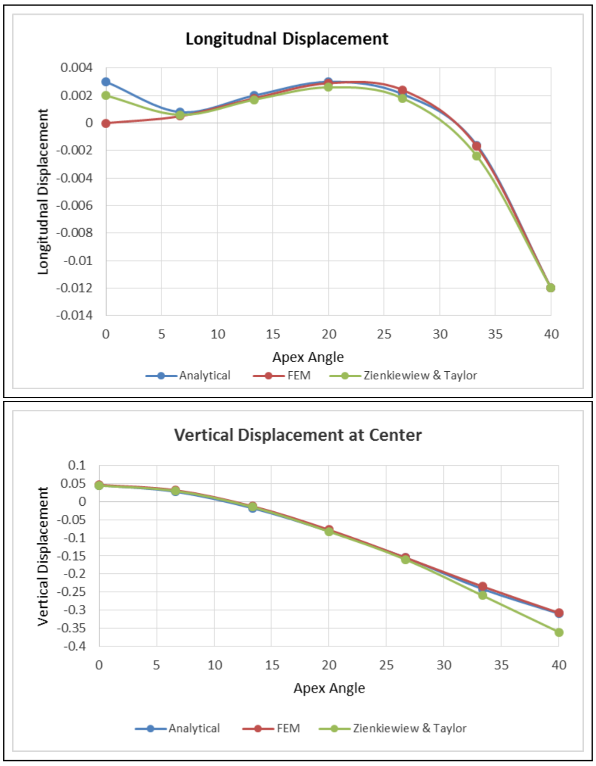

Figure 5: Comparison of Analytical method, FEM Method and Zeinkiewicz and Taylor

Above figure 5 is the graphical comparison between three solution made for only one problem. This graphical representation gives result for Model 1. First method adopted to solve Scordelis-Lo barrel roof is Analytical method, second is finite element and third is solve example from Zienkiewicz and Taylor[6]. First graph gives result for longitudinal displacement 'w' of support and second graph gives results for vertical displacement 'v' of center. By comparing three solution,we only find the discrepancies of less than 5 % so that this two graph illustrates the validity of methods we adopted and analysis process.

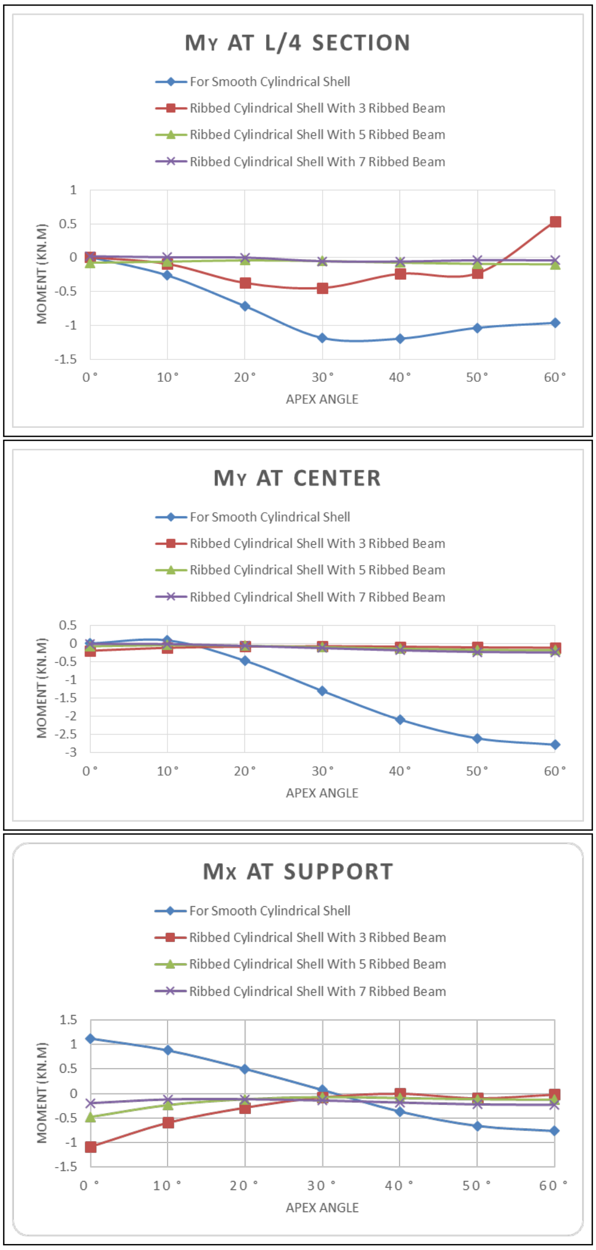

Figure 7: My at Support, at L/4 and Center Setion

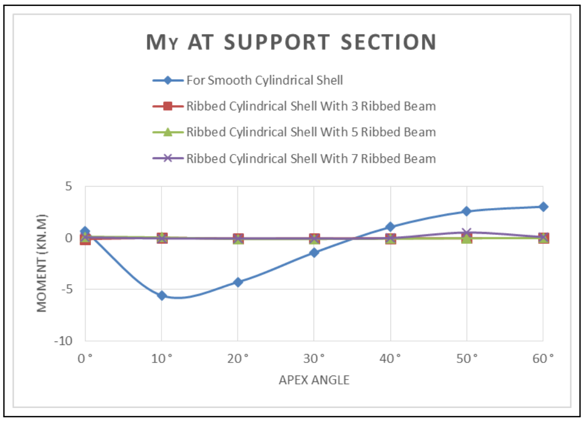

Figure 6: Mx at Support Section

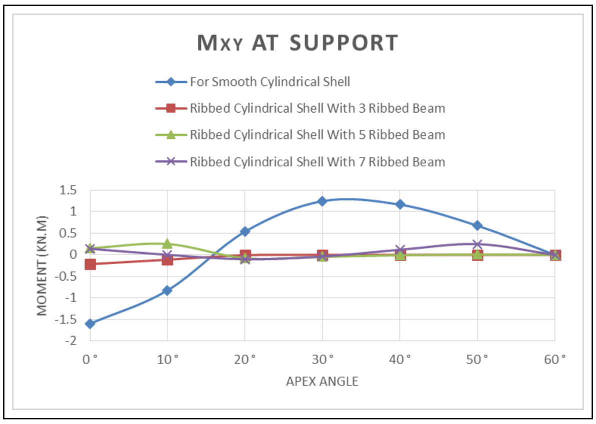

Figure 8: Mxy at Support Section

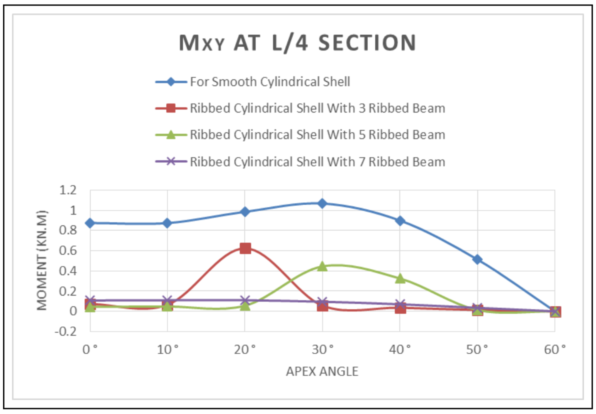

Figure 9: Mxy at L/4 Section

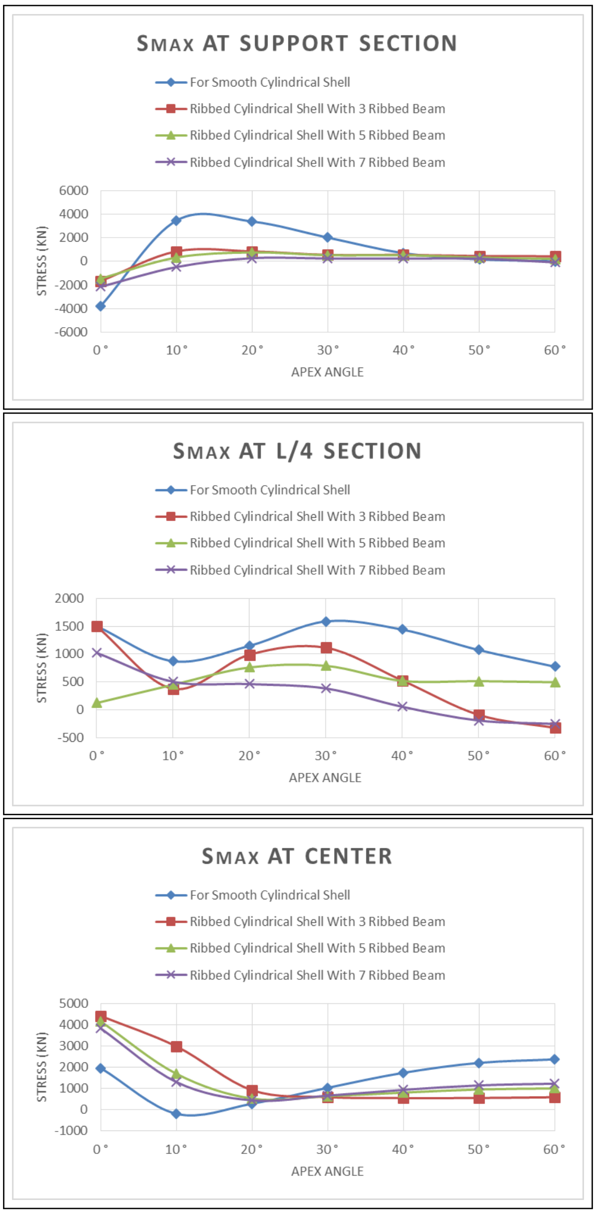

Figure 10: Maximum Stress at support,at L/4 and at center section

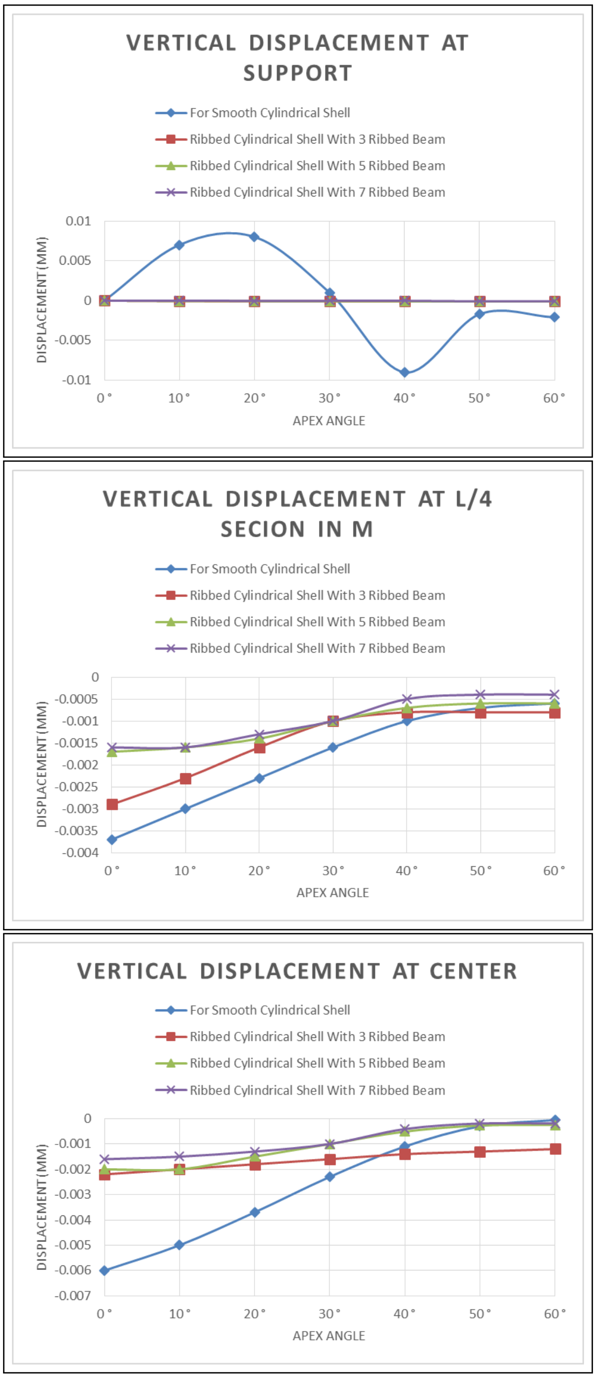

Figure 11: Vertical Displacement at support , L/4 and at center section

Figure 6 to figure 11 compares different output parameter between smooth cylindrical shell and rinned stiffened cylindrical shell having three, five and seven rib beam. Comparing Mx from figure 6 it seems that difference between smooth and ribbed beam cylindrical shell are noticeable. There is huge difference between smooth and seven ribbed beam in comparison with Mx. Similarly with compared to My, Mxy and Smax their is significant difference between smooth and ribbed cylindrical shell roof for same volume of concrete.

From figure 11, deflection of ribbed cylindrical shell are negligible in compare to smooth cylindrical shell at support section and L/4 section. Similarly at central section deflection of smooth cylindrical shell os about 3 times greater than ribbed cylindrical shell.

6. Conclusion and further scope

This paper gives a distinct figures for the selection of ribbed cylindrical shell over a smooth cylindrical in variation of span to length of the shell. And it also aims to find out the effect on increasing number of ribbed in the same ribbed shell. This might be concluded that the ribbed cylindrical shell is more stable and suitable because of its moment and stress resisting capacity. Furthermore because of the bulkling phenomenon in large cylindrical shell roof it would be better to design ribbed stiffen cylindrical shell rather than smooth cylindrical shell.This paper delivers further conclusions:

- Moment stresses Mxx and Myy for smooth cylindrical shell is higher than the ribbed cylindrical shell so that moment carrying capacity of ribbed cylindrical shell is higher than of smooth cylindrical shell hence percentage of reinforcement for ribbed cylindrical shell will be much lesser than smooth cylindrical shell.
- Maximum Plane normal stresses for smooth cylindrical shell is higher than the ribbed cylindrical shell .
- Vertical deflection for smooth cylindrical shell is much higher than ribbed cylindrical shell and it is about 3 times higher than ribbed cylindrical shell so that this may prevent pre and post bukling phenomenon on shell surfaces .

Furthermore optimisation of ringed stiffen cylindrical shell with the variation of span and number of circular ring will be perform in the continuation of this paper and optimisation on the ring beam will be carried on the basis of this paper

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