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Analysis of Open Circular Reinforced Concrete Shell Roof with Curved Edge Simply Supported

Abhishek Adhikari [a], Hikmat Raj Joshi [b]

[a] *Structural Engineer*
[b] *Department of Civil Engineering, Pulchowk Campus, IOE, TU, Nepal*
Corresponding Email: [a] 072mss101@ioe.edu.np, [b] hjoshi@ioe.edu.np,

Abstract
This paper deals with the analysis of open circular reinforced concrete shell roof with curved edge simply supported. The MATLAB coding is performed using classical theory and Scordelis-Lo-barrel roof problem is used to validate the classical problem. This roof is also modeled in finite element software SAP2000 and the comparison is done between classical and numerical method. Then boundary condition is changed and edge beam is provided along straight edge. The structure is analyzed using Chandrasekhara theory and using Scholar theory, the effect of using membrane solution as particular solution is analyzed. This roof is also modeled in SAP2000 and the comparison is done between classical and numerical method again.Further, Schorer theory, where membrane force are used as particular integral for solution of eighth order system of differential equations and difference between the results obtained by using membrane forces as particular integral has been found to be within permissible limit.Next, the effect of considering Poisson's ratio in analyzing the structure is considered. This effect is considered in both Scordelis-Lo-barrel roof and the one with edge beam along free edges. It is observed that Poisson's ratio have considerable effect on longitudinal moments.

Keywords
Circular Cylindrical Shells – Edge beam – Classical theory – SAP2000 – MATLAB

1. Introduction

The primary objective of engineer is to reduce the weight of structure as far as possible. Being covering structure, the open circular cylindrical shell has self-weight as dominating load and live load neglegible. As the self-weight of reinforced concrete material is very high, the use of thin walled shells with minimum thickness in the range of few centimeters reduce the weight of structure significantly. Due to small mass of the structure, they have high resistance to dynamic loadings like earthquake. This is more important in Nepal which lies in high seismic activity region. Thus, in Nepal for covering large spans without placement of interior columns, the structure is important. The single curvature essentially decrease bending moments and shear force as the function of structure is independent of thickness but depends on geometry. The open circular cylindrical shell completely satisfy these requirements, the study of the structures is needed.

The effect of neglecting Poisson's ratio is seldom being studied although many researchers has demonstrated behavior of open circular cylindrical structure as result. This paper aims to consider the effect of considering the Poisson's ratio. Moreover, this effect is considered in two boundary condition one with free edge and another with edge beam, which is analyzed by both analytical and numerical solution.

The use of finite element software is favored and well known method of performing analysis which gives information on how the structure behaves, but do not explain the reason of such behavior. So, results of such calculations cannot be used for other structures and in any other case new analysis should be carried out. On other hand, analytical methods by classical theory are more universal and visual but use of analytical solutions has become less relevant and known among young

engineers these days. This trend has consequence of eliminating the advantages associated with knowledge and understanding of analytical method. Since structural behavior of shells is not easy to predict, having knowledge and understanding of analytical solution can provide basis for verification and structural behavior of shell. This paper aims to find the degree of accuracy of using finite element software by comparing the results so that finite element software can be suggested for future design purpose.

Analytical solution are introduced in the form of eighth order differential equation. In Schorer theory, membrane forces is used as particular integral instead of exact forces so the differences in result due to the consideration need to be analyzed. Although the procedure for obtaining exact solutions are obtained in literature, numerical results are not available in sufficient detail to allow critical comparison with results from approximate Schorer method.

2. Related Work

(Sravana Jyothi, 2015) analyzed and designed short and long shell using D-K-J theory and Schorer theory. He has provided reinforcement details based on calculations of resultant at different sections of the shell.[1]

(Aswini and Ramakrishna, 2017) developed MATLAB coded program for analysis of a simply supported reinforced concrete cylindrical roof structure with and without edge beam using classical theory. The analysis of cylindrical shells with varying parameters of span and semi-central angle were provided.[2]

(Angalekar and Kaulkarni, 2011) conducted parametric studies on the linear elastic behavior of concrete cylindrical shell roofs using finite element analysis, wherein, 4-noded flat plate elements with increment load technique had been used. Here, also the parameter considered was t, R and L.[3]

(Rai and Pendharkar, 2012) compared analysis of multiple cylindrical shells with varying parameters of radius and thickness. The linear static analysis was adopted for analysis using SAP2000 due to static load only.[4]

(Lende and Talikoti, 2015) investigated the variation of stresses, forces and moment in multiple cylindrical shell using SAP2000 under variation of radius and thickness.[5]

(Jose, S, and Ramanujan, 2013) has conducted the Parametric study on the structural forces and the moments of cylindrical shell roof using ANSYS, wherein, influence of various parameter on the structural forces and moment developed on the surface of the cylindrical roof has been studied. The parameters considered in their study were t, R and L.[6]

3. Research objective

The main objective of this paper is to analyze the effect of neglecting Poisson's ratio in simply supported circular barrel shell. Further this research aims to investigate the results from analytical method and compare the results from SAP2000. Thus, this research work has following objectives:

- To compare the result of analysis of open circular cylindrical shell obtained through MATLAB using classical theories with the one obtained through finite element software SAP2000.
- To estimate the effect of Poisson's ratio in the open circular cylindrical simply supported barrel
- To evaluate the effect of using membrane force as particular solution (Schorer theory)

4. Method of Analysis

There are two major method of analysis :

1. Classical Theory
   - Method 1:K Chandrasekhara Theory
   - Method 2:Schorer Theory

   Procedure of classical theory
   - Determination of force, moment and displacement function in terms of constants B1 to B4 by using Table mentioned for both complementary and particular solution.
   - Application of boundary condition to obtain 4 equation with 4 unknowns B1 to B4.
   - Solution of those 4 equation to obtain 4 unknowns

- Substitution of those 4 unknowns to the expression for force, moment and displacement.

2. Finite Element Theory
   - SAP2000

     SAP2000(Version 19) is used in analysis of open circular cylindrical shell.

5. Detail of Model

Based on classical theory developed in previous chapter, a program has been developed in MATLAB environment. Using the developed code, some problem have been solved and results are compared with those using SAP2000 finite element software. Further, the investigation of effect of Poisson's ratio has been carried out. In this research, the load considered is only dead load and analysis is linear static. The model of following dimension and geometric properties are considered;

- Model 1:Open circular cylindrical shell with curved edge simply supported and straight edge free:Scordelis Lo Roof.
- Model 2:Open circular cylindrical shell with curved edge simply supported and straight edge with edge beam.

Table 1: Detail of Model

Description	Model1	Model2
Length	15.24m	25m
Semicentral ang	40	35
Radius	7.62m	10m
Thickness	0.0762m	0.08m
Modulus of Elasticity	20668Mpa	25000Mpa
Unit Weight	25	25

6. Results

For proof of validation, the results compiled by using Method 1 in MATLAB platform are matched with those present in [7] associated with Model 1 . Moments along the support and along the central section . Further, the result are compared with the output obtained through finite element software SAP2000.

Figure (1-2)shows the comparison of displacements and moments in Model 1: Scordelis Lo roof. Figure (3-4)shows how much the Poisson's ratio can affect the moments and displacements in Scordelis Lo roof.

Figure (5-6) shows the moments and displacements variation given by Method 1 and Method 2 in Model 2.Figure (7-8) shows the comparison forces given by Method 1 and Method 2 in Model 2 Figure (9-10) shows Moment and displacements variation given by Method 1 and SAP2000 in Model 2

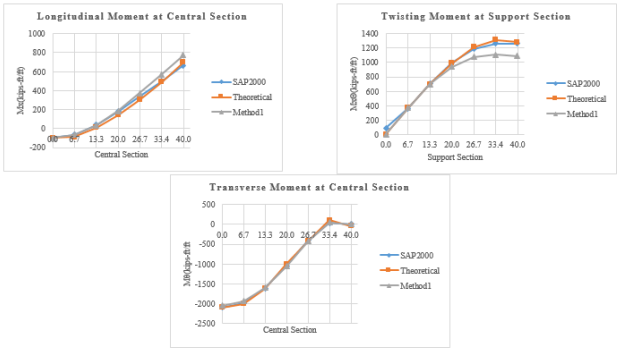

Figure 1: Moments in Scordelis lo roof

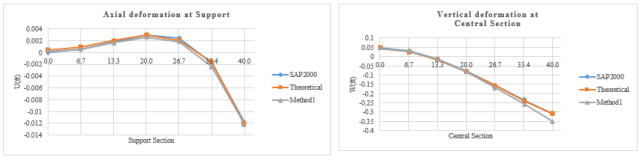

Figure 2: Displacement in Scordelis Lo roof

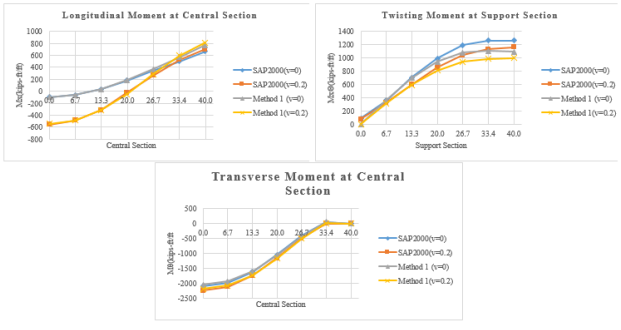

Figure 3: Moments in Scordelis lo roof with effect of Poisson's ratio

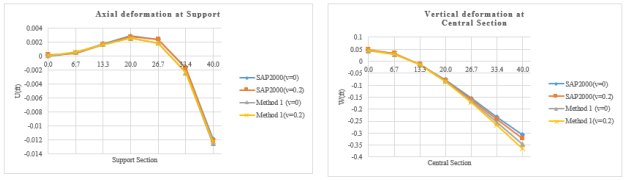

Figure 4: Displacement in Scordelis Lo roof with effect of Poisson's ratio

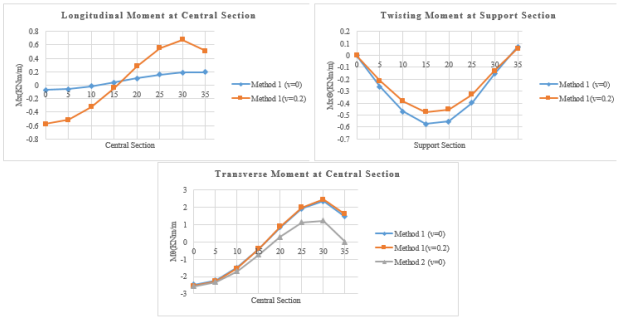

Figure 5: Moment given by Method 1 and Method 2 in Model 2

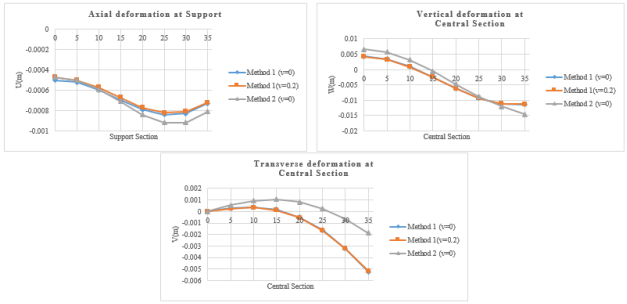

Figure 6: Displacement given by Method 1 and Method 2 in Model 2

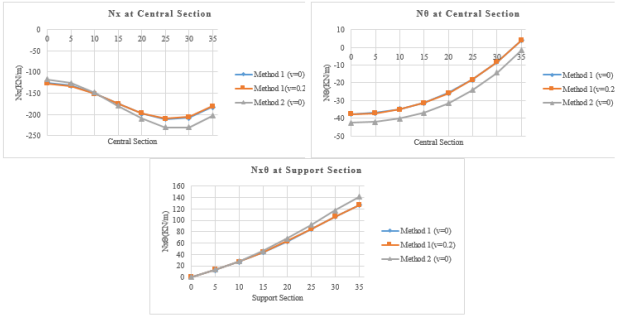

Figure 7: Normal and In Plane forces given by Method 1 and Method 2 in Model 2

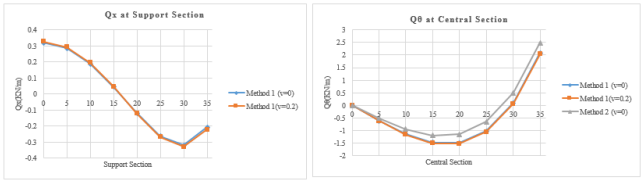

Figure 8: Transverse shear forces given by Method 1 and Method 2 in Model 2

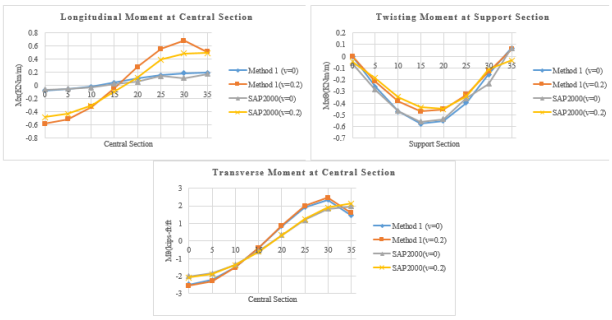

Figure 9: Moment given by Method 1 and SAP2000 in Model 2

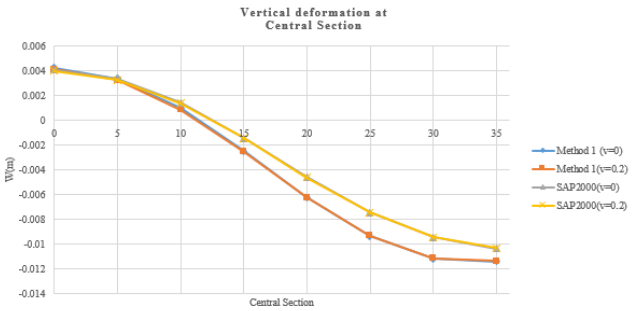

Figure 10: Displacement given by Method 1 and SAP2000 in Model 2

7. Discussion

A method has been presented to determine the forces, moments and displacements of an open circular reinforces concrete cylindrical shell using analytical approach. From the result obtained above, the following observation was made:

1. Open circular cylindrical shell with curved edge simply supported and straight edge free
    - Validation

Through comparison of moments and displacements obtained by [7] , the MATLAB code using analytical METHOD 1 was shown to give valid results. This method is valid for open circular cylindrical shell having curved edge simply supported, but arbitrary boundary condition can be imposed on straight edges. Figure (1-2) shows the proof of validation.

- Effect of Poisson's ratio
  The moments and displacements in Figure (3-4) indicates the Longitudinal moment at crown is significantly high with consideration of Poisson's effect in the shell with curved edge simply supported and straight edge free. While, the other moments and displacements are almost unaffected with the consideration of Poisson's ratio effect.
- Analytical and Numerical Method
  As shown in Figure (3-4), the moments and displacements obtained by using classical theory and finite element software SAP2000 are in acceptable comparison in both cases with and without consideration of Poisson's effect.

2. Open circular cylindrical shell with curved edge simply supported and straight edge with edge beam

   - Comparison of Analytical Approaches
     Figure (5-8) indicates that the two approaches Schorer theory and Chandrasekhara theory are in good approximation in case of forces. As longitudinal moment and twisting moment are assumed zero in Schorer theory, this theory doesn't give results for moments. Displacements from Schorer theory are lower from those from Chandrasekhara theory yet they are within acceptable range.
   - Effect of Poisson's ratio
     The effect of Poisson's ratio in moments and displacement are highlighted in Figure (9-10).With consideration of Poisson's ratio, the longitudinal moment is significantly high at central section both at crown and along edge beam. While other moments and displacements are within acceptable range.
   - Analytical and Numerical Method
     Figure (9-10) indicates that the analytical method using Chandrasekhra theory and numerical method using finite element software SAP2000 are in close approximation.

8. Conclusion

A finite element analysis using SAP2000 is used to analyze the forces of open circular cylindrical shells with curved edge simply supported. The level of correspondence between numerical model and classical approach verified the developed model was correct.The results from analytical and numerical methods were acceptable within permissible limits.

Schorer theory is an approximate method that is often practiced to avoid the more rigorous Chandrasekhara approach of shells. By no longer neglecting moments and Poisson's ratio, Chandrasekhara theory perform the elaborate derivation involving eighth order differential equation. It can be concluded that, in case of Schorer theory is most suitable for in plane normal forces and displacement are obtained if compared to Chandrasekhara theory and is not applicable to obtain the moments.

Both the classical theories utilized eighth order linear differential equation through simplification specific to circular cylindrical shells. Solving the homogenous and particular solution for the arbitrary constants allow the development of accurate solution. Once the equations are available they can be developed into code like in this research from which accurate and desirable result can be obtained in short interval if time.

After neglecting Poisson's ratio, the problem becomes simpler than that with consideration of Poisson's ratio. Because of simplicity, the theories with neglecting Poisson's ratio is often used as reasonable basis for design and analysis of open circular cylindrical shell. But to get more realistic picture of force and displacement especially longitudinal moment, cylindrical shell structure have to be analyzed with consideration of Poisson's ratio.

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