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"Statistical Analysis of Light Tensile Shell Slab Element"

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Abstract – *Parabolic, Hyperbolic or Cylindrical members are often said to act as tension restraints hence called tensile members. For achieving the optimized load capability and flexural strength of such an element in form of roof shell is checked in for M30 grade concrete. The profile and aspect of structure used are unlike for loading conditions and geographical locations differs as such as horizontal, sloping or curved member such as dome and shell member.*

From the research work the tensile shell is designed in the form of beam and as grid shell slab element, then after load has been assigned for analysis via software tool i.e. STAAD. The types of load assigned are wind and seismic along with dead and live loads. The Design code specifications are provided for curved shell member in IS: 2210 – 1994, the load case criteria is to be as per IS: 875(2)– 2000 and RCC design specifications as per IS: 456 – 2000.

Keywords: *Tensile shell, Shell, STAAD, Flexural.*

1. INTRODUCTION

Curved shape members like shell structures generally known as Tensile member are naturally able to reduce the effect of acting stresses by dilution of the load on the surface of structures from a point on it. A shell structure is a thin curved membrane or slab usually of reinforced concrete that functions both as structure and covering.

The term "shell" is used to represent and describe the structures provided with durability, strength and rigidity due to its low height i.e. low thickness, There are various examples of curved mass shell structures adopted by nature in various forms of living and non –living things such as tortoise back, snails cover, human skull bone, filament bulb and caves top upper part.

Tensile shell members are structural edifice that caries only tension and without buckling or bending. Tensile structures are the most common type of thin-shell structures used worldwide from past.

On account of multiplicity of the types of reinforced concrete shell and folded plate structures used in present day building large column-free area, practice for a variety of applications demanding roofing of buildings, only possible due to light weight anti-compression assembly.

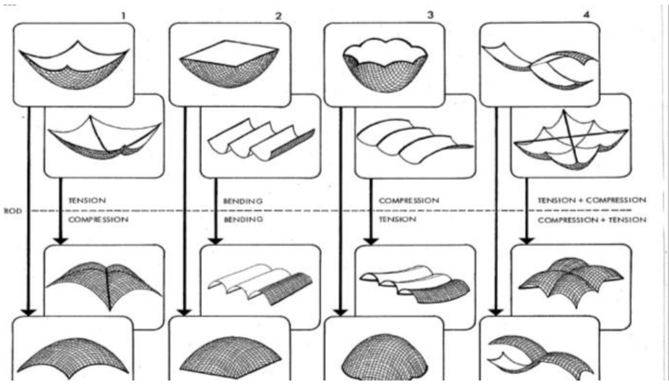


Fig. – 1: Classification of Shell Members.

1.1 Classification of shells as per Indian codes?

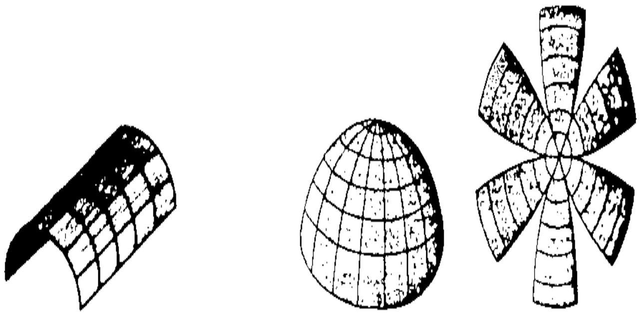
As per IS 2210: 1988 in General - Shells may be broadly classified as 'singly-curved' and 'doubly-curved'. This is based on Gauss curvature. The gauss curvature of singly curved shells is zero because one of their principal curvatures is zero. They are, therefore, developable. Doubly-curved shells are non-developable and are classified as synclastic or anticlastic according as their Gauss curvature is positive or negative.

The governing equations of membrane theory of singly curved shells are parabolic. It is elliptic for synclastic shells and hyperbolic for anticlastic shells. If z = f (x, y) is the equation to the surface of a shell, the surface will be synclastic, Developable or anticlastic according as s2- rf < 0 where t, s and t are as defined in clause 3.1. There are other special types of doubly curved shells, such as, funicular shells, which are synclastic and anticlastic in parts and corrugated shells which are alternately synclastic and anticlastic.

The gauss curvature for such shells is positive where they are synclastic and negative where they are anticlastic. Single curvature shell: Are curved on one linear axis and are a part of a cylinder or cone in the form of barrel vaults and conchoids shell.

Double curvature shell: Are either part of a sphere, or a hyperboloid of revolution. Surfaces with double curvature cannot be developed, while those with single curvature can be developed.

Thickness of shells shall not normally be less than 50mm if singly curved and 40mm if doubly-curved. This requirement does not, however, apply to small precast concrete shell units in which the thickness may be less than that specified above but it shall in no case be less than 25mm. The span should preferably be less than 30m. Shells longer than 30m will involve special design considerations, such as the application of pre-stressing techniques



Developed Non- Developed

Fig. 2: Forms of Curvature used as Tensile Members in shell structures.

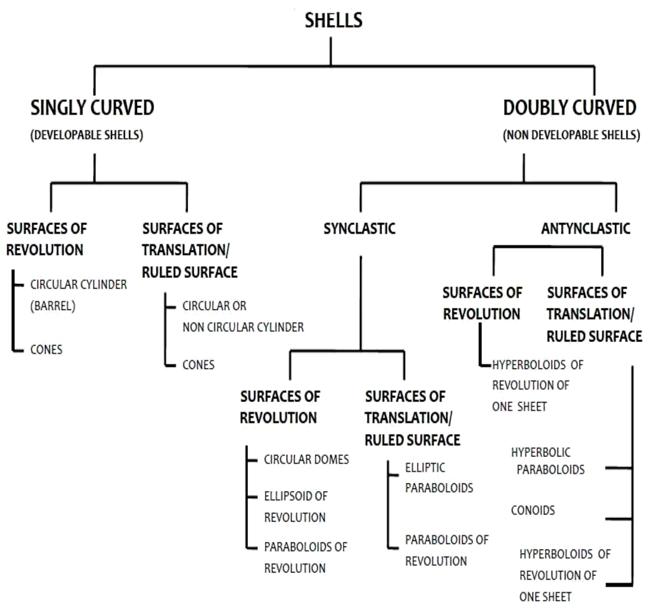


Fig. 3: Block diagram of Shell structure form based on curvature.

1.2 Which materials are most suited for construction of shell?

The material most suited for construction of shell structure is concrete because it is a highly plastic material when first mixed with water that can take up any shape on centering or inside formwork. Small sections of reinforcing bars can readily be bent to follow the curvature of shells. Once the cement has set and the concrete has hardened the RCC membrane or slab acts as a strong, rigid shell which serves as both structure and covering to the building.

Controlled concrete mix shall be used for all shell and folded plate structures. The concrete to be used is of minimum grade as M20 for RCC work. The quality of materials used in concrete, the methods of proportioning and mixing the concrete shall be done in accordance with the relevant provisions of IS: 456-2000.

2. LITERATURE REVIEW

A comprehensive literature review was performed in order to gain a better insight into the key issues relevant to shell design and analysis of reinforced concrete shell structure. The roof tensile shell absorbs more pressure due to curved surface where as the plate surface comparatively fails to do so due to horizontal alignment. Based on this review, it was concluded that shell is curved slab beam like member exposed to direct stresses due to loading, and may buckle infinitely.

a. **Economy point of view:** This criterion is not always useful, because it is difficult to define the best building, especially if there are intangibles that cannot be evaluated in terms of investment. It also provides benefits of early removing of form works due to light and self stabilizing elastic property of the shell dimensional structures.

b. **Construction joints:** Small to medium size shells may be placed at one time and construction joints may not be a problem. On the other hand, a shell may be so large, that is not possible to place all of the concrete at one operation, and construction joints become necessary. The change in temperature causes the expansion and contraction in structures, which causes then it to deform or collapse. To limit this continuous expansion joints are formed at the interval of about 30m, along the span and across the width of the multi-bay and multi-span barrel vault roofs.

i. **Smitha Gopinath**, et. Al. "Nonlinear analysis of RC shell structures using multilevel modeling techniques", integrates critical methodologies used for behaviour modelling of concrete and reinforcement with the physical interaction among them. The study is unique by considering interaction of tensile cracking and bond-slip which are the main contributors to nonlinearity in the nonlinear response of RC shell structures.

ii. **V. Kushwaha**, et. Al. "A Comprehensive Study for Economic and Sustainable Design of Thin Shell Structure for Different Loading Conditions" The design of curved member is sophisticated in comparison to horizontal and sloping roofs due to non-linear stresses and bending moments. Shell is a thin, light weight and curved structure may be used as side as well as top covering - roof member which bears upcoming loads, due to its curved shape and low flexural rigidity.

iii. **Koga**, et. Al. Presents asymptotic solutions for the eigen value problems of buckling under uniform external pressure of a circular cylindrical shell having an arbitrary combination of the boundary conditions for the simply supported, clamped, and free ends. A simple formula for the buckling pressure is derived, which is shown to be accurate enough for engineering purposes by comparison with available results

iv. **Dr. Mrs. Mrudula S. Kulkarni,** et. Al. presented a model of Analysis of tensile fabric structure using thin concrete doubly curved shell. On basis of FEM models of varying complexity and precision shows that the simplest model, which represents the shell with uniform thickness and no edge beams, yields conservative stress results. Yet these results indicate that the stresses are well within the strength limits.

3. METHODOLOGY

Modelling of Shell structure is done here in two ways; First type by assuming it as Beam structure acting as shell slab modelled by using curved beam provided in software and in second type it is assumed and made with panelled grid system or as finite element. Also the shell structure is designed as single as well as for multiple or continuous shell structure. It is solemnly tried to keep basic specification of the structure detail same for result for various loads, which is likely to occur.

Technical reference as per Staad.pro Plate and Shell Element: The Plate/Shell finite element is based on the hybrid element formulation. The element can be 3-noded (triangular) or 4-noded (quadrilateral). If all the four nodes of a quadrilateral element do not lie on one plane, it is advisable to model them as triangular elements. The thickness of the element may be different from one node to another.

"Surface structures" such as walls, slabs, plates and shells may be modeled using finite elements. For convenience in generation of a finer mesh of plate/shell elements within a large area, a MESH GENERATION facility is available.

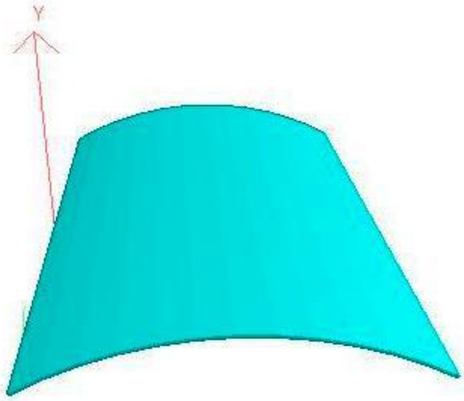


Fig. 4: Shell structure in form as curved beam.

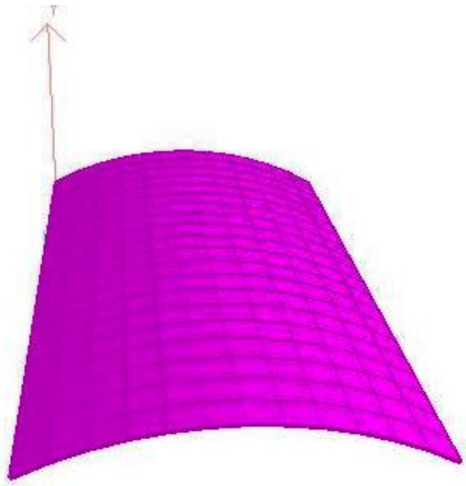


Fig. 5: Grid shell tensile structure formed as curved slab.

The figure 4 and 5 shows the curved beam used as single shell and continuous grid shell with following design element details,

a. Radius of curvature (in x direction) = 12
b. Gamma angle = 0° or 360°
c. Span of shell(in z direction) = 20 m
d. Width of shell or length of chord = 12 m
e. Thickness of shell = 0.10 m
f. Depth of shell = 1.615 m
g. Depth of shell = 1.615 m
h. Dead Load(factor) = -1
i. Live load (imposed) = 0.4 kN/m
j. Seismic Load = as per IS: 1989 – 2000
k. Wind Load = -1 KN/m

3.1 Thickness of Shells - Thickness of shells shall not normally be less than 50 mm if singly curved and 40 mm if doubly-curved, it shall in no case be less than 25 mm (IS: 6332-1984).

0.384R.d and 0.761/rd, where R and d are the radius and the thickness, respectively. The thickening of shell at straight edges shall depend on the transverse bending moment. For doubly-curved shells, this distance will depend upon the geometry of the shell and the boundary conditions as the extent of bending penetration is governed by these factors. In such shells, if P exceeds 10 and **K** exceeds 0.15, the effect at any point on the shell of the disturbances emanating from the farther edge may be ignored, where

$$\rho = \sqrt{\frac{12\,\pi\,R^6}{L-d^2}} \text{ and } K = \frac{\pi R^2}{L^2\,\rho^2}$$

4. RESULTS & DISCUSSIONS

BEAM NO. 1 DESIGN RESULTS

M30 Fe415 (Main) Fe415 (Sec.)

LENGTH: 12566.4 mm SIZE: 20 mm X 80.0 mm COVER: 15.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	3141.6 mm	6283.2 mm	9424.8 mm	12566.4 mm
TOP REINF.	2705.34 (Sq. mm)	1228.92 (Sq. mm)	5375.74 (Sq. mm)	12192.67 (Sq. mm)	2705.35 (Sq. mm)
BOTTOM REINF.	2705.34 (Sq. mm)	1228.92 (Sq. mm)	5375.74 (Sq. mm)	12192.67 (Sq. mm)	2705.35 (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

SECTION	0.0 mm	3141.6 mm	6283.2 mm	9424.8 mm	12566.4 mm
TOP REINF.	64-10í 1 layer(s)	64-10í 1 layer(s)	69-10í 1 layer(s)	69-10í 1 layer(s)	64-10í 1 layer(s)
BOTTOM REINF.	64-10í 1 layer(s)	64-10í 1 layer(s)	69-10í 1 layer(s)	69-10í 1 layer(s)	64-10í 1 layer(s)
SHEAR REINF.	2 legged 8í @ 8 mm c/c	2 legged 8í @ 8 mm c/c	2 legged 8í @ 8 mm c/c	2 legged 8í @ 8 mm c/c	2 legged 8í @ 8 mm c/c

Fig. 6: RCC Design details for tensile shell as per Software analysis in form of curved beam structure.

ELEMENT DESIGN SUMMARY

ELEMENT		LONG. REINF (SQ.MM/ME)	MOM-X /LOAD (KN-M/M)	TRANS. REINF (SQ.MM/ME)	MOM-Y /LOAD (KN-M/M)
1	TOP :	72.	0.97 / 9	72.	0.09 / 9
	BOTT:	72.	-0.81 / 8	72.	-0.17 / 8
2	TOP :	72.	0.09 / 3	72.	0.01 / 3
	BOTT:	72.	-0.32 / 9	72.	-0.15 / 9

Fig. 7: RCC Design details for tensile shell as per Software analysis in form of curved slab element structure.

Following are the items included in the ELEMENT STRESS output.

i. SQX, SQY Shear stresses (Force/ unit len./ thk.)
ii. SX, SY, SXY Membrane stresses (Force/unit len./ thk)
iii. MX, MY, MXY Moments per unit width (Force x Length/length) (For Mx, the unit width is a unit distance parallel to the local Y axis. For My, the unit width is a unit distance parallel to the local X axis. Mx and My cause bending, while Mxy causes the element to twist out-of-plane.)
iv. SMAX, SMIN Principal stresses in the plane of the element (Force/unit area). The 3rd principal stress is 0.0.
v. TMAX Maximum 2D shear stress in the plane of the element (Force/unit area)
vi. ANGLE Orientation of the 2D principal plane (Degrees)
vii. VONT, VONB 3D Von Mises stress, where

Table – 1: Beam Max Force details for tensile shell as per Software analysis in form of curved beam structure.

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	1	4 GENERATE	2	**251.833**	-0.000	-264.870	-0.000	-592.543	-0.000
Min Fx	1	3 LOAD CAS	1	**0.000**	13.823	0.000	0.434	0.000	30.245
Max Fy	1	9 GENERATE	2	251.833	**20.735**	-264.870	0.650	-592.543	-45.368
Min Fy	1	8 GENERATE	2	251.833	**-20.735**	-264.870	-0.650	-592.543	45.368
Max Fz	1	4 GENERATE	1	251.833	0.000	**264.870**	0.000	-592.543	0.000
Min Fz	1	4 GENERATE	2	251.833	-0.000	**-264.870**	-0.000	-592.543	-0.000
Max Mx	1	8 GENERATE	1	251.833	20.735	264.870	**0.650**	-592.543	45.368
Min Mx	1	9 GENERATE	1	251.833	-20.735	264.870	**-0.650**	-592.543	-45.368
Max My	1	3 LOAD CAS	1	0.000	13.823	0.000	0.434	**0.000**	30.245
Min My	1	4 GENERATE	1	251.833	0.000	264.870	0.000	**-592.543**	0.000
Max Mz	1	8 GENERATE	2	251.833	-20.735	-264.870	-0.650	-592.543	**45.368**
Min Mz	1	9 GENERATE	2	251.833	20.735	-264.870	0.650	-592.543	**-45.368**

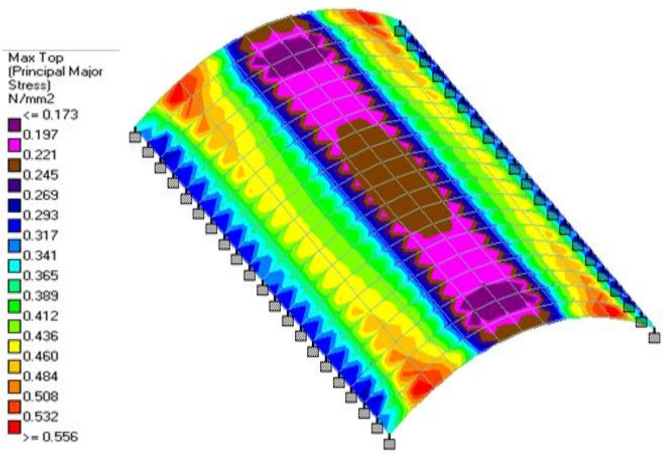


Fig. 8: Max Absolute forces contour details for tensile shell in form of curved slab element structure.

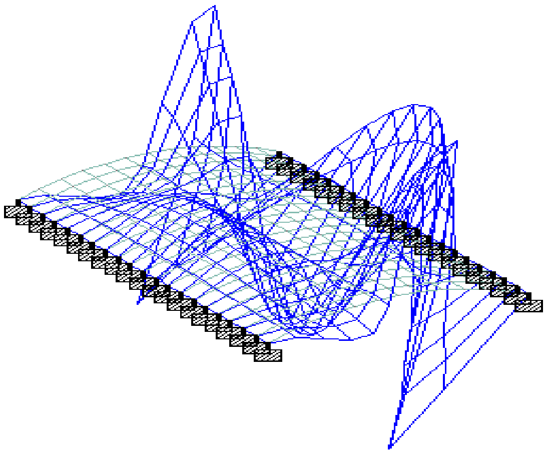


Fig. 9: Buckling details for tensile shell in form of curved slab element structure under buckling mode shape factor..

Mode	Buckling Factor
1	466.362
2	741.882
3	921.781
4	1051.060

Table – 2: Comparison of result data on basis of material required.

S.No	Structure type	Concrete – Quantity m³	Steel Quantity Newton
1	Single Beam Based designed Shell	25.13	436349.19
2	Single Grid panel Based designed Shell	24.66	437642.19

5. CONCLUSIONS

For the applied specification the structural analysis shows that shell structure analysed on basis of beam structure is less better on base of material requirements as it quantity is lower than that of shell analysed on basis grid panelled.

The result data of forces, stress and reaction of beam along with stresses of plate member shows that there is slight variation in design result components single shell with respect to double or in continuous shell structure.

The amount of concrete and steel used in continuous shell is simply multiple of value of single shell requirements where as the comparison between beam type and grid type shows that there is economy in designing the shell by later method.

6. REFERENCES

[1] Johannes, Silberkuhl Wilhelm, Uwe, Kastl Ernst, Haeussler, "Shell structure for concrete roofs and the like", 1966, United States.

[2] Timoshenko, s. and woinowsky-krieger, s. (1990). Theory of plates and shells, vol. 2, mcgraw-hill new york.

[3] Haeusler, E, "Precast pre-stressed hyperboloids of revolution", I.A.S.S. Bulletin No.6, A-7, Madrid, 1959.

[4] V. Kushwaha, R. S. Mishra, S. Kumar "A Comprehensive Study for Economic and Sustainable Design of Thin Shell Structure for Different Loading Conditions." International Research Journal of Engineering and Technology (IRJET) Volume -3, Issue: 01 | Jan-2016, pp: 107-114.

[5] J.F Abel and J.G Oliva, Cylindrical Thin Concrete Shells Structural Analysis of the Frontón Recoletos roof by Jose Antonio Lozan Galant , volume 1,No, pp: 7-18.

[6] Richard G. Weingardt, P.E.: Anton Tedesko` Great Achievements Notable Structural Engineer, Father of Thin-Shell Concrete Construction in America. `Structure Magezine April 2007,pp: 69-77.

[7] Parme, A.L, Elementary Analysis of Hyperbolic Paraboloid Shells, Bulletin 4, the International Association for Shell Structures, Madrid, 1960.

[8] Dr. Mrs. Mrudula S. Kulkarni1,Lakdawala Aliasgher2, analysis of tensile fabric structure using thin concrete doubly curved shell International Journal of Research in Advent Technology, Vol.2, No.3, March 2014.

[9] Cost Analysis of Anticlastic Shell Roofs by Rakul Bharatwaj.R, Jayashree. S.M, Dr. Helen Santhi. M3International Journal of Engineering Inventions e-ISSN: 2278-7461, p-ISBN: 2319-6491 Volume 2, Issue 3.

[10] Smitha Gopinath, Nagesh Iyer, J. Rajasankar, Sandra D'Souza, (2012) "Nonlinear analysis of RC shell structures using multilevel modelling techniques", Engineering Computations, Vol. 29, Issue: 2, pp.104 – 124

[11] Koga, Tatsuzo (Univ of Tsukuba, Tsukuba, Jpn); Morimatsu, Shigeyuki. AIAA J v 27 n 2 Feb 1989 pp - 242-248.IS: 2210-1988 "Criteria for Design of Reinforced Concrete Shell Structures and Folded Plates", Bureau of Indian Standards, New Delhi.

[12] IS: 456-2000 "Code of Practice for Plain and Reinforced concrete", Bureau of Indian Standards. New Delhi.

[13] Help full References available at websites like Google search engines.

BIOGRAPHIES

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