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Study of Barrel Vault

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Abstract: The aim of this paper is to the study Double Layer Barrel Vault (DLBV) of 3D Truss type and Slab type. Truss type double layer barrel vault is simple structural formation made up of network of longitudinal, transverse and braced member with curvature in one direction only. The slab type barrel vaults consist of concrete shell supported on longitudinal beam and having curvature in one direction.
Both types of barrel vault are analyzed and designed for Aspect Ratio (Rise/Span) with consideration of Loads like Live Load, Dead Load, Wind Load and Load combinations The truss type barrel vault is designed as per IS: 800-2007 and slab type is designed as per IS: 456-2009. This work leads to the comparison on span, maximum deflection, self-weight and cost criterions.
Keywords: Double layer barrel vault and Slab type barrel vault, wind load, STAAD Pro2007

I. Introduction

1.Space Frame Structure

The growing interest in space frame structure has witnessed worldwide over a last half century. It forms to accommodate large unobstructed area and satisfy the requirement for lightness economy and speedy construction. [1,2] New and imaginative application of space frame are being demonstrated in the total range of building types such as sport arenas , exhibition pavilions assembly halls transportation terminals, airplane hangars, workshops warehouse. They have been used not only on long span roofs but also on mid and short span enclosures as roofs, floors exterior wall and canopies.[2]

Some important factors that influence the rapid development of space frame are

1. Requirement of large indoor space for human activities
2. Sport tournament cultural performance, mass assemblies and exhibition can be held under one roof
3. Modern production and needs of grater operational efficiency.
4. Interior space can be used in variety of ways.

But the space frame highly statically indetermined and their analysis lead to extremely tedious computation if done by hand. The difficulty of complicated analyses as such system has contributed his limited use. But by using computer programs it possible to analyses vary complex space structure with greater accuracy and less time involved.[2]

Advantages of Space Frames [2]

1. One of the most important advantages of a space structure is its lightweight. This is mainly due to the fact that the material is distributed spatially in such a way that the load transfer mechanism is primarily axial i.e. tension or compression.
2. Space frames can be built from simple prefabricated units, which are often of standard size and shape. Such units can be easily transported and rapidly assembled on site by semi-skilled labor. Consequently, space frames can be built at a lower cost.
3. A space frame is usually sufficiently stiff in spite of its lightness. This is due to its three dimensional character and to the full participation of its constituent elements.
4. Space frames possess a versatility of shape and form and can utilize a standard module to generate various flat space grids, latticed shell, or even free-form shapes

2. Braced Double Layer Barrel Vaults

The braced double layer barrel vault is composed of member elements arranged on a cylindrical surface. The basic curve is a circular segment; occasionally, a parabola, ellipse or funicular line may also be used. Figure.1 shows the typical arrangement of a braced double layer barrel vault. Its structural behavior depends mainly on the type and location of supports, aspect ratio which can be expressed as R/S, where R is the rise of curvature and S is span of curvature.[1,2]

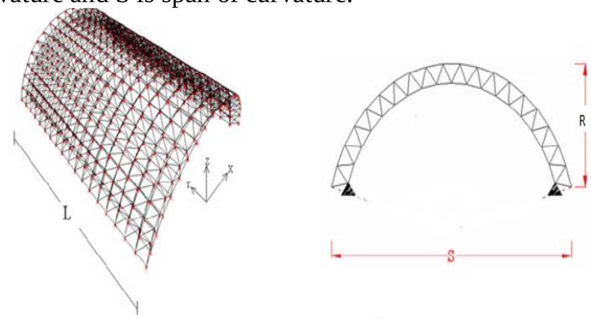


Fig. 1Truss Type DLBV[6]

A Components Of Braced Double layer barrel vault

a) Members
b) Member Connectors
c) Support member

a) Members

A space frame consists of axial members, which are preferably tubes, also known as circular hollow sections. In this analysis double layer barrel vault is provide with Tubular Member. **[1,2]**

b) Member Connectors

In this double layer barrel vault, MERO node connector was used to connect members. It is a threaded spherical ball of hot forged steel with as many as up to 18 tapped holes, at different angles, distributed evenly over its surface, to receive tubular members at different angles. The sphere has flat surfaces around the threaded holes to improve the seating of the spanner sleeve. The holes are precisely drilled so that the center lines of the tubes at a node meet at the center of the sphere. A bolt, which is inserted through a hole in the tubular member and passes through a cone welded to the end of the tube. The Mero connector has the advantage that the axes of all members pass through the center of the node, eliminating eccentricity loading at the joint. Thus, the joint is only under the axial forces. Then, tensile forces are carried along the longitudinal axis of the bolts and resisted by the tube members through the end cones[1,2]

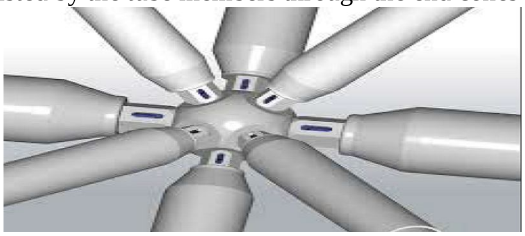


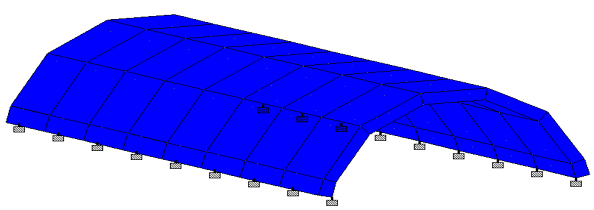
Fig. 2 Mero Connector

c) Support Members

Double layer barrel vault are rested on the column and it can be steel column section or a concrete column, here the vaults are rested on the steel column [1,2]

3. Slab Type Barrel Vault (Shell)

Slab type barrel vault is called as thin shell and also called as concrete shell. Concrete shell structure composed of a relatively thin shell of concrete usually with no interior columns or exterior Buttresses. Shell is curvature along in one direction.. A thin shell is small in thickness as compared to its other dimensions and which deformation is not large as compared to thickness. Membrane action in concrete shell primarily caused by in plane stresses, through there may be secondary forces resulting from flexural deformation. Shell is the analogous Concrete shell must be capable of developing tension and compression. Concrete shells have been widely used in the past as economical and suitable solutions for a number of structures such as roofs, silos, cooling towers and offshore platforms.[13]



II. Parametric study

The design parameters considered are Span S, grid aspect ratio and module size of DLBV. The configuration and model making of DLBV along with analysis and minimum weight designs is performed using analysis and design software [5]. The hollow circular steel sections (Pipe sections) are used as members of DLBVs and the design is carried out as per Indian Code IS: 800, 19843,4,7.[3]

Due to the practical demands, members are grouped. The grouping of problems is done based on module size and aspect ratio i.e. Rise/Span of DLG as given in Table1.

Table.1

Module Size	Span S	Aspect Ratio A.R= Rise/ Span
2.5m X 2.5m	S=(10m~30m)	0.20
	S=(10m~30m)	0.25
	S=(10m~30m)	0.30
	S=(10m~30m)	0.35
	S=(10m~30m)	0.40

Loads

The following loads are considered [1,5]

Dead load: The dead load includes self-weight of the structure and the weight of the roof covering materials. Galvanized Steel Sheets are used for roofing[1].

Live load: The live load depends upon rise/span ratio and it is calculated as per table-2 of IS-875 (Part-II). The dead and live load are applied as area load[1].

Wind load: Wind load is the most important of all and it often controls the design. The Wind load is calculated as per IS: 875–1987(Part-III). The wind load was applied as concentrated loads on the nodes of a barrel vault[1]. Determination of wind force on the curved surface of the barrel vault is complex task and hence in-house computer program is prepared to calculate wind force at each node of the structure. The nodal loads are determined by calculating the area surrounding each node, and multiplying this area by the
total factored load. The Excel sheet is used for the calculation of nodal load. This process was repeated for each configuration with a different (Rise/Span) ratio and boundary condition [5].

Load condition

Following loads and loading conditions is used for Analysis of Double Layer Barrel Vault

(1) Dead load (DL)
(2) Live load(LL)
(3) Wind load parallel to ridge (WL_{+x})
(4) Wind load parallel to ridge(WL_{-x})
(5) Wind load perpendicular to ridge (WL_{+z})
(6) Wind load perpendicular to ridge (WL_{-z})
(7)1.2 Dead load(DL) +1.2 Live load(LL)
(8)1.5 Dead load(DL) + 1.5Wind load parallel to ridge (WL_{+x})
(9)1.5 Dead load(DL) -1.5Wind load parallel to ridge (WL_{-x})
(10)1.5 Dead load(DL) + 1.5Wind load perpendicular to ridge (WL_{+z})
(11) 1.5Dead load(DL) - 1.5Wind load perpendicular to ridge (WL_{-z})
(12)1.2[Dead load(DL) + Live load (LL)+ Wind load parallel to ridge (WL_{+x})]
(13)1.2[Dead load(DL) + Live load(LL) - Wind load parallel to ridge (WL_{-x})]
(14) 1.2[Dead load(DL) + Live load(LL) + Wind load perpendicular to ridge(WL_{+z})]
(15)1.2[Dead load (DL)+ Live load(LL) - Wind load perpendicular to ridge(WL_{-z})]
(16) 0.9 Dead load (DL) + 1.2 Wind load parallel to ridge (WL_{+x})]
(17)) 0.9 Dead load (DL) + 1.2 Wind load parallel to ridge (WL_{-x})]
(18) 0.9 Dead load (DL) + 1.2 Wind load parallel to ridge (WL_{+z})]
(19)) 0.9 Dead load (DL) + 1.2 Wind load parallel to ridge (WL_{-z})]

III. Deflection Constraint

The deflection of the member shall not be such as to impair the strength or efficiency of the structure and lead to damage to finishing. The maximum vertical deflection should not exceed L/325 of the span as specified in Code of Practice for general construction in steel IS: 8007. But in present study, the

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maximum vertical deflection is restricted to L/400. It has been observed that for a constant length, few compression members of DLBV lead to failure due to slenderness for L/325 threshold and not for L/400. [3]

VI. Analysis

STADD.Pro2007 is an analysis and design software package for structural engineering, used in performing the analysis and design of wide variety types of structures. This implies that it addresses all aspect of structural include development, verification, analysis, design and review of results. [5]

After analysis in STADD.Pro2007 were found the maximu deflection shown in table.2for DLBV and Table3 for STBV below for different aspect ratio.

Table 2 DLBV

Input to the STADD					Output to the	
Identification Mark	Span	A.R	Rise	Member size(mm)	Deflection	Weight
DLBV-1	10	0.20	2	60x60x 6	3.552	51. 111
DLBV-2	20	0.20	4	80x80x 6	11.22	263
DLBV-3	30	0.20	6	100x100x 6	32.372	775 68
DLBV-4	10	0.25	2.5	60x60x 6	3.386	51. 567
DLBV-5	20	0.25	5	80x80x 6	14.77	287 38
DLBV-6	30	0.25	7.5	100x100x 6	23.848	785 46
DLBV-7	10	0.30	3	60x60x 6	2.537	52. 314
DLBV-8	20	0.30	6	80x80x 6	9.891	219 77
DLBV-9	30	0.30	9	100x100x 6	24.039	837 30
DLBV-10	10	0.35	3.5	80x80x 6	8.363	83. 542
DLBV-11	20	0.35	7	80x80x 6	9.611	317 80
DLBV-12	30	0.35	10.5	100x100x 6	32.286	891 56
DLBV-13	10	0.40	4	60x60x 6	3.573	61. 689
DLBV-14	20	0.40	8	220x220x 6	28.035	974 10
DLBV-15	30	0.40	12	100x100x 6	43.364	947 50

Table3 STBV

nput to the STADD				Output to the STADD	
Identification Mark	Span	A.R	Rise	Deflection	Weight
STBV-1	10	0.20	2	0.188	2624.567
STBV-2	20	0.20	4	1.846	10575.18
STBV-3	30	0.20	6	6.298	23866.26
STBV-4	10	0.25	2.5	0.176	2739.933
STBV-5	20	0.25	5	1.685	11142.39
STBV-6	30	0.25	7.5	6.842	25087.83
STBV-7	10	0.30	3	0.188	2912.981
STBV-8	20	0.30	6	2.155	11719.22
STBV-9	30	0.30	9	4.835	26490.83
STBV-10	10	0.35	3.5	0.17	3114.871
STBV-11	20	0.35	7	2.701	12536.4
STBV-12	30	0.35	10.5	8.616	28149.21
STBV-13	10	0.40	4	0.213	3335.989
STBV-14	20	0.40	8	2.998	13151.68
STBV-15	30	0.40	12	9.339	29793.17

V. Conclusion

In this Paper the Double Layer Barrel Vault and Slab Type Barrel Vault is studied, Analyses and design in Staad. Pro.2007 for span of 10m to 30m this varied from 0.2 to 0.4 Aspect ratios (Rise/Span). The paper concludes that Deflection of Double Layer Barrel Vault is increases or decreases at different member sizes for 0.2 to 0.4Aspect Ratio (Rise/Span) and in Slab Type barrel vault deflection is increases with different Aspect Ratio. The maximum vertical deflection should not exceed L/325 of the span as specified in Code of Practice for general construction in steel IS: 800. Moreover the choice of barrel vault is the major factor from economy and architecture point, we suggest using 3D truss type barrel vault will satisfy both the considerations.

Reference

i. *R.Surya"Instability Analysis and Design of Braced Double layer barrel vault" International Journal of Advanced ResearchinEduation Technology (IJARET), Vol. 1*

ii. *Tien T. Lan"Space frame structures", Handbook of Structural Engineering,Institute of Building Structures, Chinese Academy of Building Research, Beijing, China*

iii. *G. S. Deshmukh "Preliminary design of double layer grids sing ANN" Journal of Structural Engineering Vol. 40, No. 3,*

iv. *Ahmed El-Sheikh ,"Performance of Single-layer Double layer barrel vaults with Different Configurations", International Journal of Space Structures Vol.16 No.2*

v. *MULESH K. PATHAK, "Performance of Single Layer Steel Double layer barrel vault Under Buckling".*

vi. *Chilton J., "Space grid structures" (First Edition), Architectural press, 2000.7.*

vii. *Ramaswamy G.S. and M. Eekhout (1999) , "Analysis, Design and Construction of Steel Space Frame", Telford Publication, U.K.*

viii. *N.Subramanian (1999),"Principles of Space Structures", Wheeler Publishing, New Delhi.*

ix. *Ahmed El-Sheikh (2001), "Performance of Single-layer Double layer barrel vaults with Different Configurations", International Journalof Space Structures Vol.16 No.2*

x. *Ahmed El-Sheikh(2002)," Effect of Geometric Imperfections on Single-Layer Double layer barrel vaults" International Journal of Space Structures Vol.17 No.4*

xi. *Nooshin, H, Disney, P and Yamamoto, C (1993), "Formian: The Programming Language of Formex Algebra", University of Surrey Publication*

xii. *Makowski, Z S (1985), "Analysis, Design and Construction of Braced Double layer barrel vaults", Els1vier Applied Science Publishers,London.*

xiii. *Romano1 and E. Grande2 "MASONRY BARREL VAULTS: INFLUENCE OF THE PATTERN" The 14th World Conference on Earthquake Engineering*