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A Study on the Behaviour of Double Layer Steel Braced Barrel Vaults

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Abstract –The computer analysis of Double Layer steel braced barrel vault is presented. In this work four types of geometries of double layer braced barrel vault trusses are modeled and their behavior is studied. Axial force and deflection for top layer are compared and best geometry is suggested. Modeling and analysis is done using finite element software STAAD-PRO.

Key Words: Modeling, Double layer grid geometries, behaviour, axial forces, deflection, STAAD-PRO.

1. INTRODUCTION

1.1 Introduction

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. Double-layer grids, or flat surface space frames, consist of two planar networks of members forming top and bottom-layers parallel to each other and interconnected by vertical and inclined web members. Double-layer grids are characterized by pinned joints with no moment or torsional resistance; therefore, all members can only resist tension or compression. Several types of double-layer grids can be formed by these basic elements. They are developed by varying the direction of the top and bottom-layers with respect to each other and also by the positioning of the top-layer nodal points with respect to the bottom- layer nodal points. Additional variations can be introduced by changing the size of the top-layer grid with respect to the bottom-layer grid. Thus, internal openings can be formed by omitting every second element in a normal configuration.

Fig 1 Double layer steel braced barrel vault structure

2. Study of behaviour of double layer barrel vaults.

The structural behavior of double layer grid steel braced barrel vaults depends on the various factors such as type of patterns used for the geometry formation, types of support, aspect ratio, type of connection used at the joint, Type of sections, material used, type of bracings etc

To study the behavior of double layer grid steel braced barrel vaults,4 different types of geometric patterns are modeled and analyzed in Staad pro software and results for maximum nodal deflection and axial forces in members for particular group of elements are compared.

2.1 Common types of geometries used in double layers

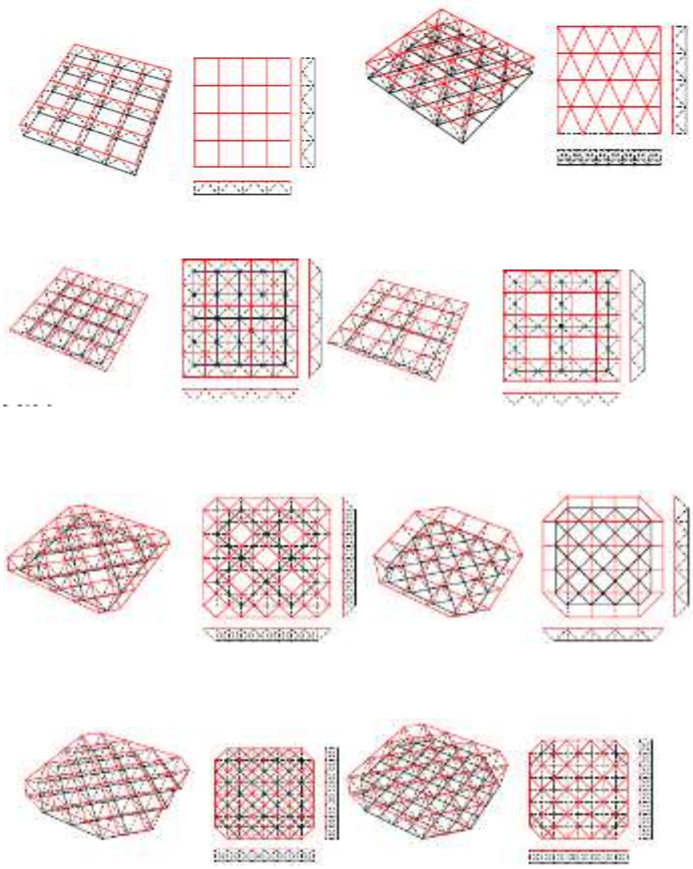


Fig. 2 Different types of geometries.

Also depending on their behavior they can be classified as long shells and short shells and it can be explained from L/R ratio where L is the distance between the supports in longitudinal direction and R is the radius of curvature of the transverse curve.

1) Beam action - . If the distance between the supports is long and usually edge beams are used in the longitudinal direction, the primary response will be beam action. For 1.67 < L/R< 5 , the barrel vaults are called long shells, which can be visualized as beams with curvilinear cross-sections. If L/R>3, beam theory with linear stress distribution can be applied for barrel vaults with uniform cross section and under uniform loading. . This class of barrel vault will have longitudinal compressive stresses near the crown of the vault, longitudinal tensile stresses towards the free edges, and shear stresses towards the supports.

2) Arch action - When distance between supports goes on decreasing i.e when 0 . 25< L/R >1.67 , then the primary response will be arch action in the transverse direction. Then the barrel vaults are called short shells. Their structural behavior is rather complex and dependent on their geometrical proportions. The force distribution in the longitudinal direction is no longer linear, but in a curvilinear manner, trusses or arches are usually used as the transverse supports.

3) Parallel arches – When L/R ratio becomes very small i.e., <25, the forces are carried directly in the transverse direction to the edge supports. Displacement in the radial direction is resisted by circumferential bending stiffness. Such type of barrel vault can be applied to buildings such as airplane hangars or gymnasia where the wall and roof are combined together

3. MODELLING AND ANALYSIS

3.1Geometric details of models

- Span - 30m
- Height - 15m
- Length – 30m
- Span to height ratio - 2
- No of divisions - 20
- Size of module – 2.355m

3.2 Data used for analysis

- Type of section – pipe
- Size of section – PIP483L-48.3mm-2.9mm
- Loading – 1)self weight (from software)

  2) DL – 4kN (Nodal load)

3.3 Types of geometries considered for study

- Square on square
- Lattice structure (Two way grid)
- Diagonal on diagonal
- Square on diagonal

3.4 Modelling and analysis of barrel vault structures in STAAD pro.

In this section the modelling and analysis of barrel vault structure in STAAD pro is explained in brief. The steps followed are also explained.

3.5Types of geometries created in STAAD Pro

1) Square on Square

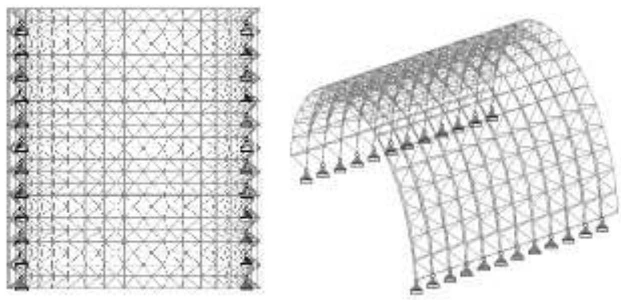


Fig. 3 Square on square geometry

2)Lattice structure (Two way grid)

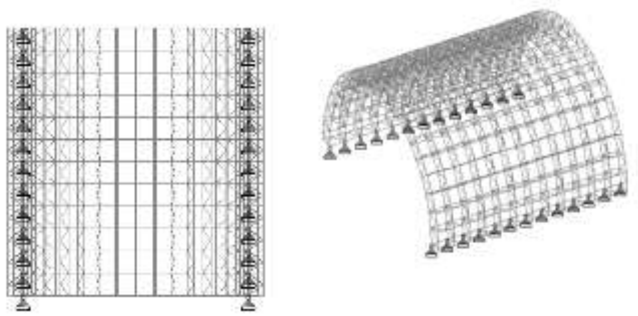


Fig. 4 Two way grid geometry

3) Diagonal on diagonal

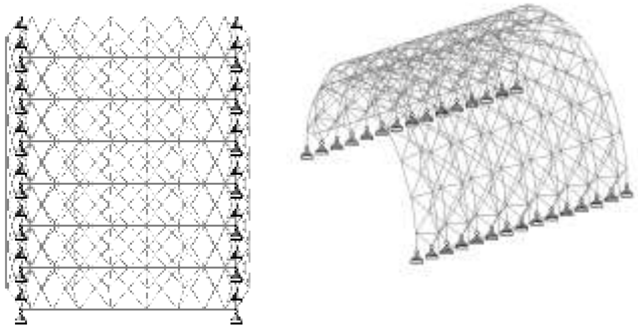


Fig. 5 Diagonal on Diagonal geometry

4) Square on diagonal

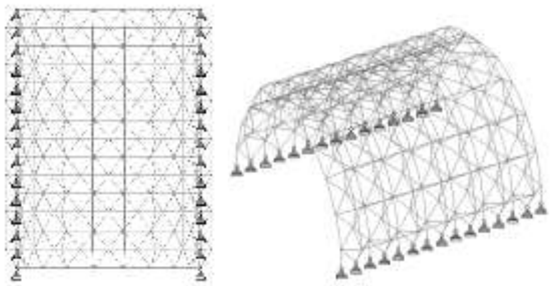


Fig. 6 Square on diagonal geometry

3.5.2 Material properties and section assignment

After modelling next part is creating and assigning material and section properties. Steel material having young's modulus 2x10^5 N/mm^2 and poisons ratio 0.3 is created and assigned. Then circular steel pipe section of Indian standard is assigned to whole structure.

3.5.3 Support conditions

Pinned support is created and assigned to the bottom nodes.

3.5.4 Loads definations and combinations

Here, only dead load case is considered so DL case is defined and self weight and nodal load of 4kN is assigned to the model.

3.5.5 Analysis

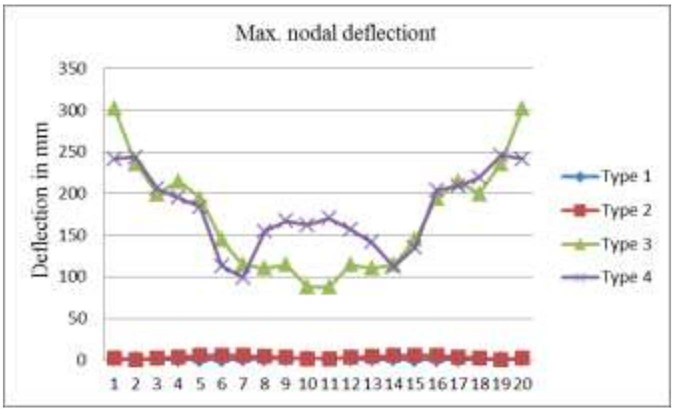
For analysis finite element software STAAD-PRO is used.

4. RESULTS AND DISCUSSION

4.1 Maximum nodal displacement

Table 1 Maximum nodal deflection in mm

Member No.	Type 1	Type 2	Type 3	Type 4
1	1.1176	2.3114	302.4124	241.3000
2	1.1938	0.7366	235.6866	243.3574
3	0.9144	2.0828	199.5678	205.5114
4	0.5588	4.0386	214.4268	194.8688
5	0.4318	5.2578	194.3862	183.3118
6	0.8636	5.6896	144.4498	113.0300
7	1.2700	5.4356	114.7064	98.7806
8	1.6256	4.5974	110.3630	154.7876
9	1.8542	3.2766	114.6302	167.1574
10	1.9558	1.6256	87.5538	162.1790
11	1.8796	1.6256	87.5538	170.2054
12	1.6764	3.2512	114.6556	156.9974
13	1.3462	4.5720	110.3884	141.4018
14	0.9398	5.4356	114.7318	112.014
15	0.5080	5.6896	144.4752	135.4328
16	0.5080	5.2578	194.3862	203.6064
17	0.8382	4.0386	214.4268	208.5848
18	1.1176	2.0828	199.5678	219.075
19	1.0668	0.7620	235.6866	245.7958
20	1.0000	2.4130	302.4124	241.3000



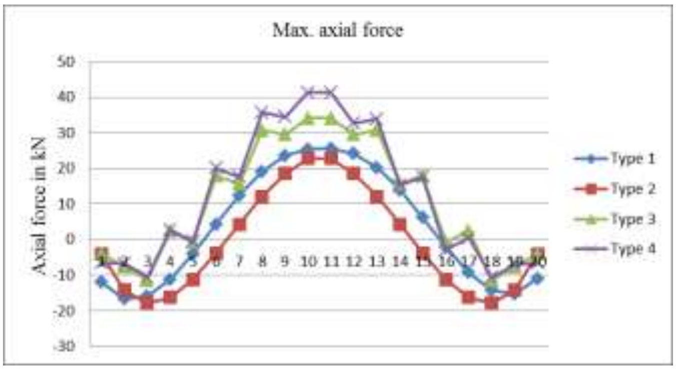
Graph 1 Maximum nodal deflection

Above graph shows that square on square (type 1) and latticed structure (type 2) geometry is stable having almost negligible nodal deflections. While, type 3 and type 4 geometries i.e., diagonal on diagonal and square on diagonal have large nodal deflections.

4.2 Maximum axial forces in members

Table 2 Maximum axial force in kN

Member No.	Type 1	Type 2	Type 3	Type 4
1	-11.859	-4.0645	-4.02946	-6.6002
2	-16.7115	-14.198	-7.5893	-6.6902
3	-15.9881	-17.8071	-11.4203	-10.518
4	-11.2538	-16.3102	2.49055	2.74696
5	-4.00375	-11.1746	-0.80748	-0.54851
6	4.32688	-3.84741	18.0204	20.0548
7	12.3935	4.31984	15.6291	17.6653
8	19.1006	12.1052	30.8225	35.7392
9	23.5980	18.5155	29.5624	34.4794
10	25.3465	22.8017	34.1503	41.3263
11	25.5832	22.8017	34.1503	41.3275
12	24.1528	18.5156	29.5626	32.6525
13	20.1700	12.1054	30.8227	33.9137
14	13.8974	4.3197	15.6292	15.2432
15	6.14695	-3.84753	18.0204	17.6329
16	-2.01009	-11.1753	-0.80798	-2.88158
17	-9.27413	-16.3103	2.49005	0.41250
18	-14.2011	-17.8057	-11.419	-10.6332
19	-15.2925	-14.1966	-7.58801	-6.80682
20	-11.0393	-4.07153	-4.02946	-6.60682



Graph 2 Maximum axial load

Chart 2: Maximum axial forces in members

Above graph clearly illustrates that, in barrel vault truss as we go from support to central peak axial forces goes on increasing. Here, square on square(type 1) and latticed truss(type 2) shows less axial force as compared to diagonal on diagonal(type 3) and square on diagonal(type 4).

5. CONCLUSIONS

From modeling and analysis of different types of double layer barrel vault truss the following conclusions are drawn.

1. The square on square and latticed truss geometries shows very less nodal deflections.
2. variation in axial forces in diagonal on diagonal and square on square geometries is nearly 63%
3. The square on square geometry (type 1) and latticed truss (type 2) has minimum deflection and axial forces. Hence they are optimun.

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