

Comparison of Barrel Vaults

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Abstract - This study compares the performance of barrel vaults made of reinforced concrete (RCC) and steel grid structures. Barrel vaults are commonly used in the construction of large span structures such as airports, sports arenas, and exhibition halls. RCC and steel grid structures are two of the most popular construction materials used for barrel vaults. This study examines the structural performance and cost-effectiveness of these two materials using statistical analysis. The analysis is based on data collected from case studies of several barrel vault structures constructed using RCC and steel grid materials. The results show that RCC barrel vaults have a lower cost per unit area than steel grid barrel vaults, but steel grid barrel vaults have a longer service life and require less maintenance.

Keywords: Barrel vault, RC barrel vault, Double Layer Grid, Slab type barrel vault, cost- effectiveness.

1. Introduction

Now a day the growth of construction is increased and required maximum space and large span. The barrel vault is the best for large span structures. The popularity of barrel vaults is partially due to the economy of these structures, At the same time, their cylindrical shape provides a great deal of volume under the roof, a distinct advantage for railway stations, or for large span warehouses, providing a welcome increase in their storage space. Barrel vaults are lightweight and cost-effective structures that are used to cover large areas such as exhibition halls, stadium and concert halls. These structures provide a completely unobstructed inner space, and they are economical in terms of materials compared to many other conventional forms of structures as explained by Makowski [11].

2. Space Frame

Space frame is a sophisticated structural system that combines elegance and efficiency to achieve large, uninterrupted spans. Its unique geometric configuration allows for both structural strength and aesthetic appeal, making it a popular choice for a variety of architectural applications. Space frames offer significant advantages over traditional structural systems, including lighter weight, reduced material consumption, and faster installation times. With its striking

visual impact and impressive engineering capabilities, space frame continues to push the boundaries of modern architecture.

- 1) Flat Lattice
- 2) Lattice Dome
- 3) Barrel vault

Flat Lattice

A space frame is a structure system assembled of linear elements so arranged that forces are transferred in a three-dimensional manner. In some cases, the constituent element may be two dimensional. Macroscopically a space frame often takes the form of a flat or curved surface. It should be noted that virtually the same structure defined as space frame here is referred to as latticed structures A latticed structure is a structure system in the form of a network of elements (as opposed to a continuous surface). Rolled, extruded or fabricated sections comprise the member elements. Another characteristic of latticed structural system is that their load-carrying mechanism is three dimensional in nature. Flat lattice is composed of planner unit which connected with unit beams pace plane covers. These spatial structures are composed of planar substructures. Their behavior is similar to that of a plate in which the deflections in the plane are channeled through the horizontal bars and the shear forces are supported by the diagonals. Flat lattices can have one, two, three or even multiple layers, but they are widely used in the form of two layers. Double-layer lattices consist of two parallel plates which are jointed together by elements.[1,2,12]

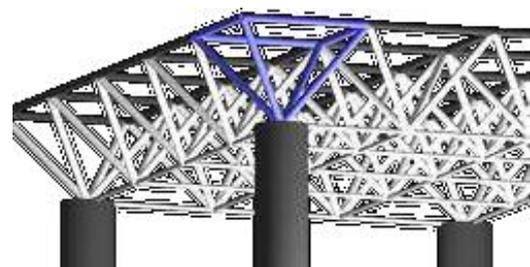


Figure 1: Double Layer Grid Flat Lattice

Lattice Dome

Dome is a lattice has curvature in two directions Domes are structures with high rigidity and are used for very large

spans. Domes are one of the oldest and well-established structural forms and have been used in architecture since the earliest times. They are of special interest to engineers as they enclose a maximum amount of space with a minimum surface and have proved to be very economical in terms of consumption of constructional materials. The stresses in a dome are generally membrane and compressive in the major part of the shell except circumferential tensile stresses near the edge and small bending moments at the junction of the shell and the ring beam. Most domes are surfaces of revolution. The curves used to form the synclastic shell are spherical, parabolic, or elliptical, covering circular or polygonal areas. Out of a large variety of possible types of braced domes, only four or five types proved to be frequently used in practice.[1]

Braced Barrel Vault

The barrel vault is a lattice which has curvature in a one direction. This structure is used widely for covering the rectangular corridor surfaces and sometimes is without columns. 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, which can be expressed as R/S , where R is the rise of curvature and S is span of curvature.[1,2]

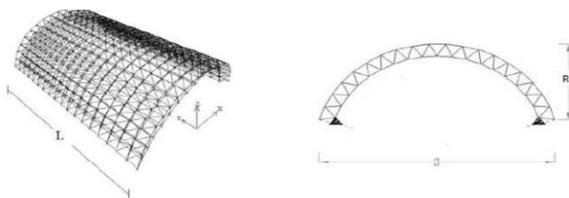


Figure 2: Double Layer Barrel Vault

3. Components of Braced Double layer barrel vault

A braced double layer barrel vault is a type of structural system commonly used for roofing large span buildings. It is composed of several components including the Members, Member Connectors, Support members, etc

I) 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]

II) 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]

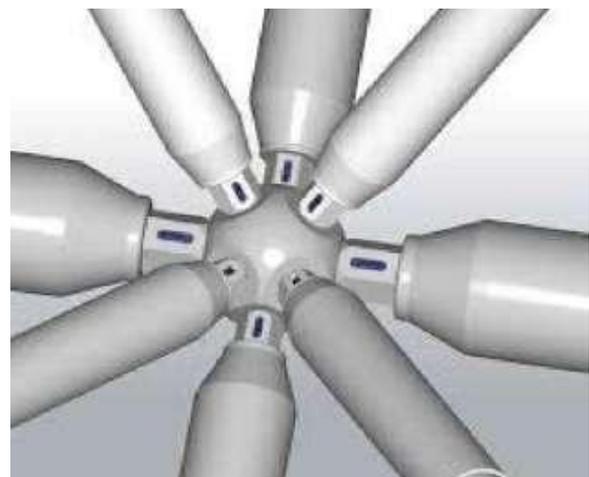


Figure 3: Mero Connector

III) Support Members

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

Slab Type Barrel Vault / Shell (STBV)

Slab type barrel vault is called as thin shell and 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 several structures such as roofs, silos, cooling towers and offshore platforms.[13]

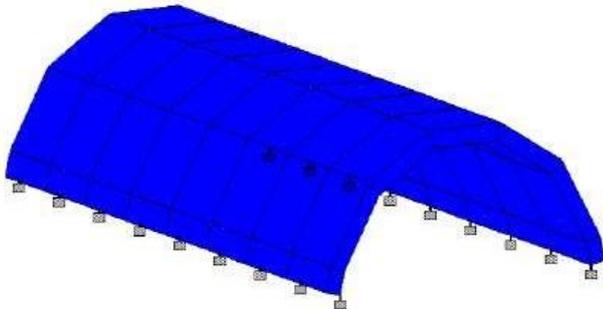


Figure 4: Slab Type Barrel Vault (Shell)

Double Layer Grids (DLG)

Double-layer grids, or curve 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. Even in the case of connection by comparatively. [1, 2, 3]

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. According to the form of basic elements, double-layer grids can be divided in two groups, latticed grids and space grids. The rigid joints, the influence of bending or torsional moment is insignificant. [1,2,3]

Double-layer grids are usually composed of basic elements such as

- 1) Planar latticed truss.
- 2) A pyramid with a square base that is essentially a part of an octahedron.
- 3) A pyramid with a triangular base (tetrahedron).

The basic elements used for various types of double-layer

Double layer grid consists of two plane grids forming the top and bottom layers, parallel to each other and interconnected by vertical and diagonal members as shown in Fig. DLGs may be lattice grids or true space grids. The grid pattern of the top

layer may be identical with that of the bottom layer, or it may differ. Some types of double layer grids are listed below.

- 1) Square on square offset (SOS)
- 2) Square on diagonal pattern (SOD)
- 3) Diagonal on square (DOS)
- 4) Diagonal on diagonal pattern (DOD)

In present work Square on Square offset (SOS) is considered for the analysis and design. The preliminary analysis and design is carried out using software STAAD Pro-2007 Top Member Bottom, Member Inclined, Members (a) (b) (c) (d) [2, 3]

In recent years, extensive and increasing use has been made of space trusses, especially in the form of double-layer barrel vault (DLBV). and Slab type barrel vault (STBV) have primarily been used in the construction of large span structures – sports stadiums, assembly halls, swimming pools, exhibition buildings, churches, shopping arcades, factory buildings. These are typical examples of structures where large unobstructed areas are essential and where minimum interference from internal support is required. These structures consist of a large number of elements, which combine into a light, but very rigid, three-dimensional structure. DLBV are typical examples of prefabricated space structures and one of the most popular forms which are frequently used nowadays, Makowski [11]. These structures have various geometrical configurations and proved to be very economical in terms of weight and ease in construction [11].

The support condition is the one of important parameter for any structure from stability point of view. In addition to that the support condition are also effect the performance of structure, in present work support condition decided in such way that. Thus three type of support conditions are considered that is the two longer side pin, two longer side fix and four side pin supports and is shown in figure 5 (a) for DLBV and figure 5 (b) for STBV.

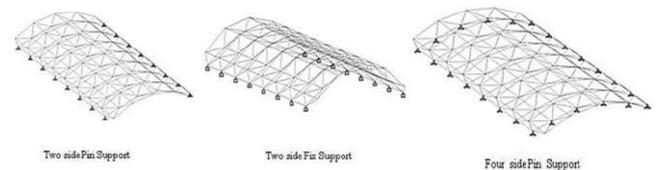


Figure 5 (a) Support Conditions for DLBV

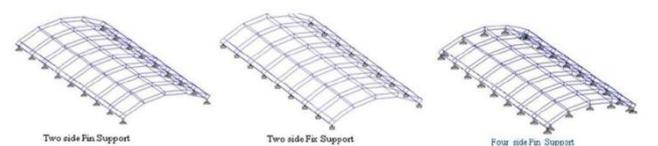


Figure 5 (b) Support Conditions for STBV

Grouping of Members

The description of the group of members is given below.

Table.4.3.1 Module size, Span Aspect Ratio

Module Size	Span S	Aspect Ratio A.R= Rise/ Span
S= (10m~30m)		0.20
TRUSS TYPE BARREL VAULT	S= (10m~30m)	0.25
2.5 × 2.5 m	S= (10m~30m)	0.30
S= (10m~30m)		0.35
S= (10m~30m)		0.40
S= (10m~30m)		0.20
SLAB TYPE BARREL VAULTS	S= (10m~30m)	0.25
2.5 × 2.5 m	S= (10m~30m)	0.30
S= (10m~30m)		0.35
S= (10m~30m)		0.40

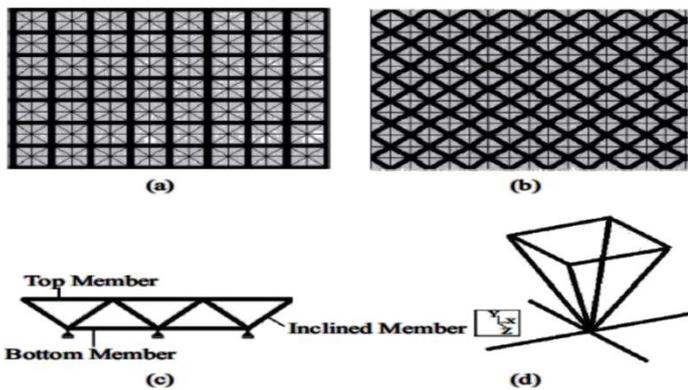


Figure 6: (a) SOS type DLG Top Members (b) SOS type DLG Web or Inclined Members (c) SOS type DLG in various members (d) SOS type DLG 2.5 × 2.5 m Mod

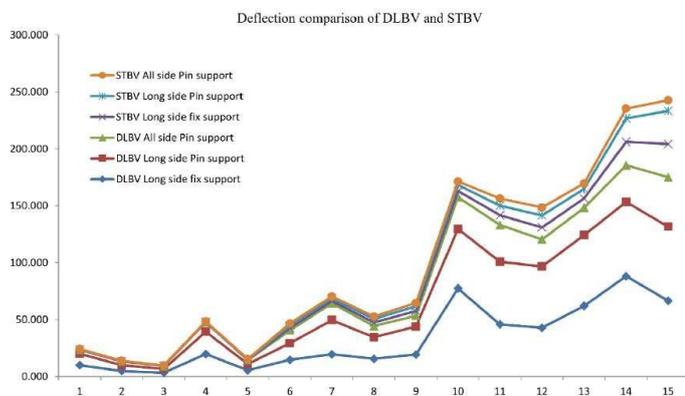


Figure 7: Deflection comparison of DLBV and STBV

Weight comparison of DLBV and STBV

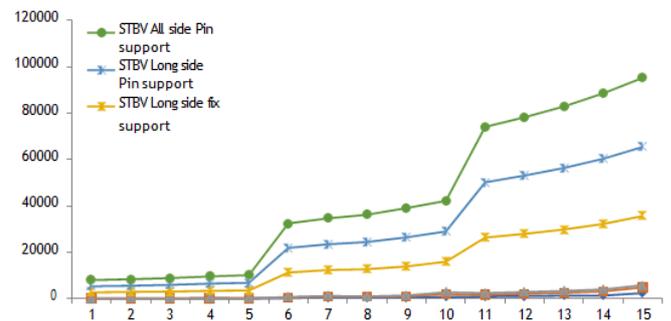


Figure 8: Weight comparison of DLBV and STBV

4. Conclusion

In present work the Double Layer Barrel vault (DLBV) is analyzed and designed based on the linear analysis performed using STAAD Pro. V8i. Present work is arrived at the following conclusions.

- 1) Deflection of Double Layer truss type Barrel Vault and Slab Type Barrel Vault increases with increasing in Aspect Ratio (Rise/Span) and span.
- 2) Though the deflection of truss type barrel vault is more as compared to slab type for same span, the weight for truss type barrel vault is much less.
- 3) When truss type barrel vault is supported on all sides, then it is observed that its deflection is nearly 1.5 times less than that of supported on longer sides.

- 4) Also, the truss type barrel vaults weight for all side supported barrel vault is 2.5 times lesser than that of supported on longer side.
- 5) For slab type barrel vault, the deflection of long side supported is seen to be 3 times more than all side support.
- 6) Slab type barrel vaults are providing very less deflection for large span also, hence when the selection is based on the deflection alone Slab type barrel vaults can be preferred for large spans.
- 7) The choice of barrel vault for long span governs the criteria of minimum deflection and minimum weight, so through in this study it is found that truss type barrel vaults with all sides pinned are suitable for covering large spans.

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