Structures for Sports Centre

G. Immanuel and K. Kharthi
School of Architecture, Bharath University, 173, Agharam Road, Selaiyur, Chennai-600073, Tamilnadu, India

1. Structural Elements

• Chamber – to correct deflection tendencies and to assist in roof falls for drainage.
• Castellated roof beams in a lightweight of steel can be more economical.
• Lattice beams are used as roof principal with a steel weight. The longer the span the more economic the lattice arrangement become square – ended square – ended lattice is provided by tapering the top member which reduces its weight by shortening a number of bracing in the beam.
• Space frames are an effective means of roofing sports halls. A square on diagonal layout is indicated but several permutations are available square mansard or cornice edge details can be incorporated as required. The spacing of principal roof members is determined by the support requirements of the roof cladding material.
• Weight of steel member in purloins and main beams influenced the spacing. The spacing of columns must coincide with the roof principal excessive spacing of columns leads to either thicker walls of additional secondary steelwork, both of which increase cost.

2. Long Span Structure

A vast study of all these aspects is essential for an architect to design swine all stadium need long span structure raging from loom to loom. Curved long span roofs give the greatest possible lure arm to the resistance moment but it produces thrusts, which is transmitted to the ground. Domes solve both the problems. New structure such as suspension roofs, space frames and members supported by air pressure, are low hallowing the supreme achy for long spans.

3. Structural System

The structural frames are broadly divided into

• Traditional structures
• Surface structure
• Cable structure
• Space structure
• Tent structure
• Pneumatic structures

4. Traditional Structures

The type of structure is considered as the oldest system and it is divided into three-sub division.

4.1 Bulk Active Structure System

This is represented in its simplest form, in pillars upon which free or fixed beams are based and that are in a shape of grid beams and stab system distributing load in two direction.

4.2 From Active System

This is represented by arches

The characteristic at arch system are

• Carry only direct stresses
• Material like brick, stone concrete which are good in compression can be used to chair fall strength
• Dead weight / span ration decreases with the increase of span
• Being stiff, it is has resistances to wind lead
• Pre stressing is an effective means of increasing span with increasing dead weight
• Resistance to asymmetrical point loads is less.

*Author for correspondence
5. Comparision

To balance increasing in external moment, the lever arm ‘a’ and hence the beam depth has to be increased. As the span increases, the member gets deeper and heavier and a-stage is thus reached, where a beam can no longer supports its own weight, whatever its depth. In case of arch, the lever arm is the rise; hence greater economy can be achieved using arch system for larger spans.

The vector active system, which is represented with flat trusses

6. Plane Truss System

A stable composition of compressive and tensile member in triangle assemblage but together in a system with hinged joints. When suitable supported this system services asymmetrical and changing leads and transfer them to the ends. It spans long distance without intermediate supports. By arranging the member in singly or doubly curved planes, the advantage of form active redirection of force is integrated. Plane truss system is composed of short, solid, straight – line elements and because of their length, can be transmit loads only in the direction of their length

The aim designers over time has been to improve this type of structure, either by cancelling some movement or by adopting structure system in the forces are less than other factor, or by attempting to reduce the structure weight, know as “dead load” with the aim of adding the difference to the “live loads” by increasing the efficiency of the tradition method used, such as the use of pre stressed concrete or the substitution of a lighter material such as laminated wood or by using a material with a better capability of bearing stress, such as iron.

However, in these structures it is difficult to cross-large widths with structure without some financial sacrifices, due to their heavy weight in most cases.

7. Surface Structure System

Thesis is included within the category of surface-active structure systems. They are geometric surface defining the span, both internally and externally. These system have good characteristics as they can bear loads classifying the forces affecting them into compression, tension and sheer force. These structure have in most cases, a thin surface of reinforced concrete, which is formed in a way giving this surface dimension moments, either in a folded shape, a pyramidal folded shape, a single curved shell, rotational shell shaped etc.

Surface active structure system is considered one of the best concreted fixed permanent structure systems, because of their lightweight, and expression of the structure both internal and external. The load is carried by membrane stresses and for enormous spans; we need only a short section thickness of the shell. Shell structure also includes folded plates.

8. Shells of Revolution

These are shells, which are obtained when a plan curve is rotated about the axis of symmetry (e.g.) segmental domes, cones, parabolic of revolution, Hyperbolic or revolution.

9. Hyperboloids of Revolution

When the generatrix is a straight line, connected to two rings on top and bottom and these rings are twisted in the opposite direction or if a hyperbola is rotated about some axis a hyperbolic of revolution is generated.

10. Conodial Shells

A conidial is a ruled surface formed by one of a line sliding on a vertical curved while the other end slides on a horizontal line.

11. Hyperbolic Parabolids

Hyperbolic parabolic are anticlastic ruled surface. Curvatures in opposite direction generated by movies a plane curve parallel to itself along another plane curve (directive x) that usually is in a plane at right angles to the plane of the generative x.

Double country – curvature surface of these shells have every stress balanced with maximum economy. A property reinforced shell can adsorb tension and compression at any point and in any direction tangential to its curved surface.

These shells are most economical in terms of material consumption and their shutting is easy because of their surface being ruled.
R.C.C is also ideal material for hyperbolic parabolic shells cause of their ability to take both compression and tension. Another useful material is timber with an advantage of bring light weighted.

In simply supported shells, the stresses get concentrated near the support for simply supported shells. The ridge point also acts like a supports and stress concentration takes place there. Due to frictional resistance of support or due to introduction of ring beam (provided for non vertical tangential reaction) at the lower edge, binding deflection are produced between lower edge of the shell and ring beam is caused by opposite direction of ring forces but this deflection is prevented due to reversal in deflective direction in ring beam through pre stressing.

If the edge of shell of revolution do not follow a parallel of latitude and is terminated in other form such as, straight or titled arch other interesting form are develop. The doubly curved surfaces are naturally stiff so the edge need not be heavily reinforced in these cases. However, the concentration of load at the point of support leads to the development of forces and corresponding stresses in the shell. Thus the sharp comers of the shell have to be thickened, so the spherical form is lost.

### 12. Cylindrical Shells

These are shell generated by a curve moving on a straight line or vice versa. Cylindrical shells have 3 fold bearing action.

- **Arch action**
- **Plate action**
- **Slab action**

Cylindrical shells behave like a folded planted composed of numerous narrow strips. The loads area at first transferred to the folds and then resolved into components strips. The loads are at first transferred to the folds and then resolved into components tangential to the adjacent strips.

The bearing mechanism of cylindrical shells depends on its ability to resist shear. Since these shells are supposed to resist, tension compression and shear, R.C.C is the idea material for them, through steel framed cylindrical shells are also being built. This shell is a beam with a thin curved web.

Pre stressing is an effective means to stiffen the edges of cylindrical shells thereby increasing its spanning capacity.

Cylindrical shell when viewed as a close system has a clear analogy with the action of beam. The reinforced pattern in simple beam resembles the stress pattern of cylindrical shells.

### 13. Structures with Tension

**Skewers / Cable Structure**

These include form active structure system which is used to cover a space by means of non-metallic structure made of an elastic material which is formed according to desired shape and which is fixed from its corneas inorder to bear the weight only. These structures, in their simplest shape are formed by means of suspending pulling skewers transferring loads to pillars which transfer in turn these loads to their bases, so as to make the structure subject to tension and compressing stresses only to function as a ceiling in a way with which it is possible to shape the building in accordance with the shape of the stresses existing on the building and according to the stress lines direction.

These are also known as cable structures and their characteristics include

- Only direct stress no bending,
- Maximum utilization of high tensile strength of steel
- Capacity to span large spans without intermediate supports
- Dead weight / span ratio is very low
- Susceptible to (i) wind (ii) vibrations (iii) asymmetrical and moving loads
- Pre stressing can be used to effectively increase the span

The formation of such structures is subject to the positions of tension points and support points. One of the most important disadvantages of these structures is the difficulty of front closing under the tents due to this elasticity as well as the difficulty of proving such a structure with air conditioning facilities because of the smallness of the thickness of the cover of the structure.

Cable changes its shape with each new loading condition. This is because of its incapability to resist bending due to its small cross section area in relation to its length. A cable is a linear supportive system (end dimensional) large in one direction and small in the other two. When a cable transmits tensile forces, it becomes a straight line. A
cable suspended between two points is uniformly loaded and forms a catenary.

The idea of building with cables gave us the suspension bridge. This new form of the construction is chiefly characterized not by “suspension” but by the stressing of orthogonal families of cable into surface curved in mutually opposed direction so us to produce system with three dimensional stability.

We distinguish the cable structure into the following groups

1. Simple curved roofs the stability of which is derived entirely from their own weight or from stiffeners.
2. Doubly curved cable system, the stability of which is derived from pre stressing
3. System in which cables for various load conditions.
4. Tents geometry of cable for various load condition.

In the process of carrying the load and transmitting the load to both sides, cables span the spaces, its form following direction of stresses. A cable roof can be defined as one in which a cable or a system of cables is used as a head-carrying elements.

In accordance with the manner in which cable are used, they can be classified as
- Cable suspends roof’s
- Cable supported roof’s
- Cable cum air supported roof’s

13.1 Cable Suspended Roofs
In cable suspended roof’s, the system of cable carries the roof load directly and as such has a primary structure function. The cables system is also serves as the false work for the execution of the cladding.

13.2 Cable Supported Roofs
In a cable supported roofs, developed some what on the same lines as cables supported bridges, the cables have only the ancillary function of providing additional supports for elements which are otherwise sufficiently strong to carry a major portion of the loading.

13.3 Cable cum Air Supported Roofs
Another class of cable roofs which is comparatively recent development and has now gained consideration popularity, is the cable cum air supported roof. These roof are mostly tent or balloon type structure, which are supported by a combination of cables and air inflation. The use of air suspended roofs in now extensive.

14. Space Structures
These are included under the vector active structure system and are composed of straight short hand units which are collected together in an articulate manner, which are formed by their assembly facilitating the transference of loads to their ends inside the above mentioned units exposing these units to compression and tension only, thus resembling structure with tension skewers and differing from them in the use of a hand surface and an elastic one.

15. Curved Truss System
It has three fold bearing action
- Beam action
- Truss action
- Arch action
- Walls and roof of the building’s can be transformed into one continuos structure with a curved truss system
- Transverse stiffness is required to take edge stresses.
- Various geometric roof forms are possible with curved truss system, for eg vault, cylinder, dome, cross, vault, hyperbolic parboiled shell and most important geodesic dime.
- Steel being good in tension and acceptable in compression is ideal material for this system. A combination of steel and concrete is more suitable.

Pre stressing can be used effectively for enhancing the span capacity of this system. Transverse bearing action as separates’ trusses

16. Tent Structures
These are included under form active structure system. These structures are elastic and flexible and consists of a cover and a similar to a great extend to the structures with tension skewers, in that they are center tension and are based on support points in the case of compression.
The tension of the cover is by means of tension skewers in most cases.

17. Pneumatic System

These structure come under from action system which are called air structure and of which bearing material is the air itself. It is shaped in accordance with comes shape made by air pressure fastening to the interior space of building to high air pressure the interior space of the building is filled with air. The space existing between the two cover is filled with air in way that give the inner atmosphere of the building normal air pressure the formation of such structures in subject to the formation of the cover itself of to its tension to the ground. The internal air pressure and the membrane envelope are the two important constituents.

- Resistance against deflection is provided by the air tight enclosure and the tensile strength of membrane
- The ability of pneumatic structure to resist external forces depend on the
  - The volume air contained
  - The internal air of the structure
  - The structural form adopted
  - The characteristics of the membrane material
  - Any shape can be achieved with a soap film is suitable for pneumatic constructions.

The criteria given by frei otto are

- It is possible to form a shape pneumatically it a body of revolution can be in scribed unit.
- Logically the simplest solution is to inscribe spheres plane surfaces are impossible
- The surface tension are need not be equal in all directions as long as any shape in which spheres arranged in straight or curved lives can be inscribed leaving no excess volume
- Membrane material for pneumatic structure should have good tensile strength, tear resistance, higher volume of elasticity modules. It should be light in weight permeable to air, flexible in nature.

18. Presently Crossed Materials

- plastic films
- coated fabric
- woven metallic fabric
- metallic foils

The shortcomings are structure collapsing or tears in the cover. Therefore it is essential to protect the users of such buildings by high bars to prevent the total collapse of the ceiling in case of any defect. These bars do not prove costly considering the overall reduction of costs due to the structure. A study of soap bubbles helps the understanding of pneumatic structures. In each soap bubble the membrane stress are equal at each point in each direction.

19. Air Supported Structure

These universal shelters consist of a structural membrane anchored to the ground to form as air tight joint and supported in its design shape by the internal air pressure, maintained by a few blowing air into structure access is obtained through an air tight door in the membrane. Established uses of air supported structures include military, commercial and social, while for sports use they offer short life and low cost cover.

20. Structure and Technology

As soon as the overall shape of the structure is defined, it is necessary to choose the structural systems.

A wide variety of structural systems is available, which can fulfil the geometrical requirements of the design.

The sizing of the cross section of members is a task of the designer, where as the producer of the structural systems must guarantee that the node-member combination should be able to give a joint of full strength type only by means or appropriate qualification procedures can this guarantee be realized.

21. Qualification Procedure

The qualification procedure should demonstrate that the system for the space structure is based on a basic node-member joint that is full strength type. The demonstration can be done by calculation and by tests.

The qualification procedure should be based on laboratory tests, the results validating the calculations. A suggested procedure could be based on the following phases:

- Mono axial tests on the member to node connection
- Bending and shear on full scale structural units
• Bending tests, monotonic and cyclic, in the elastic range (including temperature effects) up to collapse on the full scale prototypes.

22. Cable and Tension Structures

These structural systems play an interesting role in modern construction and are examined in detail below.

23. General

High-strength steel cables have been used extensively over the past twenty-five years for roof structures.

There are two different possibilities when using steel cables in roof structures, which can be either conventional, e.g., beams, cantilever etc., or a space frame. In this case, the main roof structure, instead of being supported, is actually suspended from cables above the roof, which transmit the tensile forces to appropriate anchorages. These are cable-stayed roofs. This maximizes the bending moment in the tower.

In the parallel system of stays, each stay is parallel and thus connects to the tower at a different height. This creates large bending moment in the tower because the force from the cables have larger horizontal components.

24. Construction Characteristics

The construction surface usually acts as a simple beam, most commonly in the form of a truss or box beam. The box beam is advantageous because it resists tensile forces well; however, it provides a greater surface area subject to the lateral force of the winds.

The towers are the first portions of the structure being constructed. The section of the horizontal pieces are connected until the horizontal surface supported by the first stay is built next. In a similar form, the remaining pieces are connected until the horizontal surface is completed and supported.

25. Typical Materials

A steel beam is most common however a concrete beam, despite the considerable increase in weight, can be used for some shorter spans. The towers may be of any material, historically stones too.