Structural systems for Large span Sports Complex structures

C.V.Subramanian 1, Lydia Clemmie 2
1 Associate Professor, Department of Architecture, Periyar Maniammai University, Tamil Nadu
2 U.G. Student, Department of Architecture, Periyar Maniammai University, Tamil Nadu, India

Abstract—The roof structures exceeding 12m in length are called long span roofs. They create internal space which are barrier free and flexible. The sufficiently advanced stage of cast iron structures provided us with long span enclosures. There are many types of structures which can be used according to their spans, material, and aesthetics. By far, steel is the most commonly used material. Advancement in technology is providing us with large options of materials. Sports buildings these days have been given importance and the long span structures are being widely used in the sports field. Various types of large span structures and their efficacy are analysed to arrive out design recommendations.

Keywords—Long span structures; Space frames; Cable structures; Tent; Pneumatic; Sports complex

I. INTRODUCTION
Nowadays long span structures are widely used in various fields such as sports, commercial, industrial, social and other activities. From the previous experiences it was evident that long span structures are best capable in solving many problems that cannot be faced with the help of traditional building types. Also these days’ technical aspects by adopting modern technology in execution operation with the use of computers to solve constructional problems are followed.

II. STRUCTURAL SYSTEM
Structure systems vary in their frames as well as in their resistance methods of force. They form:

1. Active structure systems
2. Bulk-Active structure systems
3. Vector active structure systems
4. Surface active systems

Again broadly classified as
- Traditional structures
- Surface structures
- Space structures
- Tent structures
- Cable structures
- Pneumatic structures

2.1 Traditional Structures
These are the methods being followed from a very ancient period of time. These structures can be subdivided into the  Bulk active structures, Form active structures and Vector active systems.

2.1.1 Bulk Active structures
It is represented by horizontal elements i.e beams - free or fixed places on vertical elements i.e pillars. The principle is distribution of load into two directions.
2.1.2 Form Active Structure
Form active structures are represented by arches that carry only direct stress and no bending take place. These types of structure are wind resistant. In case of increase in span increase in dead weight takes place.

2.1.3 Vector Active System
These systems are represented by flat truss. It comprises of compressive and tensile members in assembly put together with hinged joints. It receives asymmetrical and changing loads. It can support large spans without intermediate support. Le parc Desprince stadium in Paris is a good example.

2.2 Shell Structural System (Surface Systems)
This is also called as surface systems. In this system the span is defined both internally and externally by geometric system. Because of their light weight and expressive structural system both internally and externally they are considered as one of the best concrete fixed permanent structural system. Load here is carried for enormous span with short sections.

2.2.1 Shells of Revolution
These shells are obtained when a plane curve is rotated about the axis of symmetry. Examples are paraboloids of revolution, hyperboloid of revolution cones, segmental domes.

![Fig 1. Shells evolved by revolution](image1)

2.2.2 Hyperboloids of Revolution
It is generated when a straight line is connected to two rings above and below and both the rings twisted in opposite direction. It is used in cooling towers.

![Fig 2: Hyperboloids of revolution](image2)
2.2.3 Conoidal Shells
It is a ruled surface formed by one end of a lining sliding on a vertical curve while the other end slides on a horizontal line. Doubly curved surface generated from straight lines. It can span up to 12m length.

![Image of Conoidal Shells]

*Fig 3. Doubly curved surfaces generated from straight lines*

2.2.4 Hyperbolic Paraboloids
These are anti elastic ruled surfaces. A properly reinforced shell can absorb tension and compression at any point and in any direction tangential to its curved surface. These are most economical in terms of material consumption and their shuttering is easy.

![Image of Hyperbolic Paraboloids]

*Fig 4. Hyperbolic paraboloids*

2.2.5 Cylindrical Shell
It is generated by curve moving on a straight line or vice versa. Cylindrical shells behave like a folded plate composed of numerous narrow strips. Cylindrical shells have three fold bearing action:

- Arch action
- Plate action
- Slab action
2.3 Structures with Tension Skewers (Cable Structures)
In this type of active structures non-metallic structures made of elastic material of desired shape is used to cover a place. They are fixed in corners to bear weight only. They are also known as cable structures.

Due to its smaller cross section it can resist to bending when it is loaded. A cable roof can be defined as one in which a cable or a system of cables is used as a load carrying element.

2.4 Space Structures
These are vector active structure comprising units which are straight, short, hard in a articulated manner and are formed by assembling these and facilitating transfer of loads to their ends inside the above mentioned units. It differs from cable structures for having a hard surface and not a elastic one and differs from flat truss in that its functions in various direction.

2.5 Tent Structures
These structures are included under form active structures systems. They are elastic, flexible and consist of a cover .They are similar to a great extent to the structures with tension skewers in that they are under tension and are based on support points in the case of compression.
Fig 8. Typical tent structure

Tent structures constitute membranes stretched in frames rigid in bending or rings rigid in compression. The formation is subjected to the position of tension points. These points can take the shape of simple pillars, arches or other shapes. They are flexible and are difficult to close these structures in front thus finding it difficult to air condition the building.

2.6 Pneumatic Structures
These systems have air as the bearing systems thus they are called as Pneumatic structures (Air structures). This is done by filling a cover with air and fastening it to the ground exposing the cover to tension and thus it is shaped in accordance with the cover shape made by the air pressure.

Figure 9. Forces on a pneumatic structure

Membrane material for the pneumatic structure should have good tensile strength tear resistance higher value of elasticity modules. It should be light in weight, permeable to air and flexible in nature. Presently used materials are:

- Plastic films
- Coated fabric
- Woven metallic fabric
- Metallic foils.
3.0 APPLICATION OF LONG SPAN STRUCTURES IN SPORTS COMPLEX

The various types of structures suitable for sports facilities are analysed in the table 1

Table 1. Types of building structures and their properties

<table>
<thead>
<tr>
<th>STRUCTURAL SYSTEM</th>
<th>LIMITATIONS</th>
<th>FLEXIBILITY OF STRUCTURE</th>
<th>AESTHETICS</th>
<th>MATERIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRADITIONAL STRUCTURES</td>
<td>Not suitable for large spans</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A) Bulk active structures</td>
<td>Large span will lead to increase in height of the structure as the ratio of span: height is high.</td>
<td>Height can be varied by making arch segmental or semi-circular but not to a great extent else it will bend.</td>
<td>Monotonous structures results in skyline not broken /punctured much.</td>
<td>Brick ,stone and concrete materials are good in compression</td>
</tr>
<tr>
<td>B) Arches</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C) Plane Truss System</td>
<td>To achieve triangulation of forces span to height needs to be high. Large span are possible, but due to heavy weight of materials there is a limitation.</td>
<td>By arranging the members in singly or doubly curved planes, the advantages of form-active redirection of forces is integrated.</td>
<td>This essentially rigid vector active structure can be converted into a form active structures.</td>
<td>Pre-stressed concrete, laminated, wood, iron.</td>
</tr>
<tr>
<td>SHELL STRUCTURE SYSTEMS</td>
<td>Surface must be geometrically defined.</td>
<td>These structures must be defined curves which acts as a limitation but its possible to achieve forms that are not easily possible in other structural system.</td>
<td>New varying forms can be achieved using shells thus giving the structure a single unified character. Skyline cannot be controlled.</td>
<td>Concrete .As loads are carried as membrane stresses for large spans we need only short section.</td>
</tr>
<tr>
<td>CABLE STRUCTURES</td>
<td>These structures are susceptible to wind uplift, vibration and to asymmetrical and moving loads.</td>
<td>Highly flexible cables can be made to span more. By varying the profile of end members cables can be made to follow several varieties of curves</td>
<td>Infinite varieties of curves can be generated. Skyline can be controlled by creating strong point in space.</td>
<td>Steel cables, supporting concrete roof.</td>
</tr>
<tr>
<td>SPACE STRUCTURES</td>
<td>Have minimal limitations. High span to height ratio for geodesic domes.</td>
<td>Many roof forms are possible with curved truss system. For</td>
<td>With space grids interesting patterns can be developed for</td>
<td>A combination of steel and concrete is ideal for curved</td>
</tr>
</tbody>
</table>
example vault, cylinder or domes. given spans. space structures.

### TENT STRUCTURES
- Too flexible. It is difficult for the fronts to close under tents.
- The flexibility can result in large column-free spans, unlike conventional roofing systems that require rigid immediate support.
- As the materials are translucent, the spaces enclosed within remain bright LED backlighting can change the structure’s look at night.
- PVC (Poly Vinyl Chloride) coated polyester cloth and PTFE (Poly Tetra Fluro Ethlene) (Teflon) coated glass cloth.

### PNEUMATIC STRUCTURES
- The possibility of the structures collapsing as a result of mechanical failure in inflation equipment or as a result of tears in cover.
- Membrane can support both tension and compression and thus withstand bending moment.
- Provide fascination among observers and by standers.
- Cotton and PVC

In addition to the above some more reasons for application of long span structures in sports complex are:
- They give column free spaces.
- The structures are cost saving with guaranteed fixed overall project cost.
- They have a short production time and rapid installation properties.
- As these structures are demountable and therefore can be resold, reconfigured, extended or relocated.
- They have more life span.

### 4.0 CONCLUSION
The design of sports building has been given a great deal of care during the last few years. This is leading to new architectural aspects of design by searching for new concepts, good design and beautiful formation. Also the structural aspects integrated with architectural design create realistic expression of forces affecting the structures. The attempt to device new methods of construction leading to weight reduction and material development to increase the efficiency is continuously made.

The structural framework adopted in the construction of any building is essential as the structure is greatly similar to man’s skeleton defining many of its characteristics. When dealing with sports buildings we find the problem is deeper than those of other buildings. Hence several recommendations arrived based on materials, aesthetics, limitations and flexibility for different types of structures can be made use appropriately during the construction of sports facilities.

### REFERENCES