11. SPACE FRAMES CONSTRUCTION

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Lecture Objectives

Upon completion of this lecture, the student will be able to:

1. Explain the concept of space frames.
2. Discuss the advantages of space frames.
3. Classify the types of space frames.
4. Estimate the dimensions of a space frame.
5. List & describe the erection methods of space frames.
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## Introduction

In architecture and structural engineering, a space frame or space structure is a truss-like, lightweight rigid structure constructed from interlocking struts in a geometric pattern. Space frames can be used to span large areas with few interior supports. Like the truss, a space frame is strong because of the inherent rigidity of the triangle; flexing loads (bending moments) are transmitted as tension and compression loads along the length of each strut.
Introduction

The simplest form of space frame is a horizontal slab of interlocking square pyramids and tetrahedra built from aluminium or tubular steel struts. In many ways this looks like the horizontal object of a tower crane repeated many times to make it wider. A stronger form is composed of interlocking tetrahedra in which all the struts have unit length. More technically this is referred to as an isotropic vector matrix or in a single unit width an octet truss. More complex variations change the lengths of the struts to curve the overall structure or may incorporate other geometrical shapes.

Historical Background

Space frames were independently developed by Alexander Graham Bell around 1900 and Buckminster Fuller in the 1950s. Bell’s interest was primarily in using them to make rigid frames for nautical and aeronautical engineering, with the tetrahedral truss being one of his inventions, however few of his designs were realized, while, Fuller’s focus was architectural structures and his work had greater influence.
Applications of Space Frames

we can use a space frame truss for a platform or overhead structure that spans large distances without need for internal load bearing support.

Dammam municipality building, KSA.        Al Andalus Mega Mall, Jeddah, KSA.

In the past few decades, the spread of space frame was mainly due to its great structural potential and visual beauty. New and imaginative applications of space frames are being demonstrated in the total range of building types, such as sports arenas, exhibition pavilions, assembly halls, transportation terminals, airplane hangars, workshops, and warehouses. They have been used not only on long-span roofs, but also on mid- and short-span enclosures as roofs, floors, and exterior walls. Many interesting projects have been designed and constructed all over the world using a variety of configurations.

Advantages of Space Frames

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<th>Factor</th>
<th>Description</th>
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<td>1. Lightweight</td>
<td>This is mainly due to the fact that material is distributed spatially in such a way that the load transfer mechanism is primarily axial; tension or compression. Consequently, all material in any given element is utilized to its full extent. Furthermore, most space frames are now constructed with aluminum, which decreases considerably their self-weight.</td>
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<td>2. Mass Productivity</td>
<td>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.</td>
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<td>3. Stiffness</td>
<td>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.</td>
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<td>4. Versatility</td>
<td>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. Architects appreciate the visual beauty and the impressive simplicity of lines in space frames.</td>
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**Structural Background**

A space frame is a long-spanning three-dimensional plate structure based on the rigidity of the triangle and composed of linear elements subject only to axial tension or compression, even in the case of connection by comparatively rigid joints, the influence of bending or torsional moment is insignificant.

Visualizing compression and tension from deformed shape, loads applied only at joints.

The depth and module size of double-layer grids are usually determined by practical experience. In some of the papers and handbooks, figures on these parameters are recommended, and one may find that the difference is quite large. For example, the span–depth ratio varies from 12.5 to 25, or even more. It is usually considered that the depth of space frame can be relatively small when compared with more conventional structures.

**Types of Space Frames**

**According to curvature**

<table>
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<th>1- Flat covers</th>
<th>2- Barrel vaults</th>
<th>3- Spherical domes</th>
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<td>These structures are composed of planar substructures. The plane are channeled through the horizontal bars and the shear forces are supported by the diagonals.</td>
<td>This type of vault has a cross section of a simple arch. Usually this type of space frame does not need to use tetrahedral modules or pyramids as a part of its backing.</td>
<td>These domes usually require the use of tetrahedral modules or pyramids and additional support from a skin.</td>
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Types of Space Frames

According to the number of grid layers

1- Single-Layer
All elements are located on the surface to be approximated.

2- Double-Layer
The elements are organized in two parallel layers with each other at a certain distance apart. The diagonal bars connecting the nodes of both layers in different directions in space.

3- Triple-Layer
Elements are placed in three parallel layers, linked by the diagonals. They are almost always flat. This solution is to decrease the diagonal members length.

Space Frames Components

1- Members
In common, members are axial elements with circular or rectangular sections, all members can only resist tension or compression. The space grid is built of relatively long tension members and short compression members.
A trend is very noticeable in which the structural members are left exposed as a part of the architectural expression.

2- Joints
In a space frame, connecting joints play an important role, both functional and esthetic, which derives from their rationality during construction and after completion. Since joints have a decisive effect on the strength and stiffness of the structure and compose around 20 to 30 percent of the total weight, joint design is critical to space frame economy and safety.
Types of Space Frame Connections

1- Welded Connection
2- Bolted Connection
3- Threaded Connection

Mero Space Frame System

The Mero connector, introduced in 1948 by Dr. Mongeringhausen, proved to be extremely popular and has been used for numerous temporary and permanent buildings. Its joint consists of a node that is a spherical hot-pressed steel forging with flat facets and tapped holes. Members are circular hollow sections with cone-shaped steel forgings welded at the ends, which accommodate connecting bolts.

The Mero connector was originally developed for double-layer grids. Due to the increasing use of non-planar roof forms, it is required to construct the load-bearing space frame integrated with the cladding element. A new type of jointing system called Mero Plus System was developed so that a variety of curved and folded structures are possible.
Design Considerations for Double-layer flat Space frames

- Glazing may occur within the panels of the space frame or be attached to the space frame.
- Wind speed at eave: 50 mph (23 m/s).
- Eaves or cantilever frame for drainage, minimum of 1/4 per foot (650) recommended.
- Depth range: span/2 to span/20.
- Roof and secondary connections are made at panel points.

Space Frame Methods of Erection

The method chosen for erection of a space frame depends on its behavior of load transmission and constructional details, so that it will meet the overall requirements of quality, safety, speed of construction, and economy. The scale of the structure being built, the method of jointing the individual elements, and the strength and rigidity of the space frame until its form is closed must all be considered.
Space Frame Methods of Erection

1- Scaffold Method

Individual Elements are Assembled in Place at Actual Elevations, members and joints or prefabricated subassembly elements are assembled directly on their final position. Full scaffoldings are usually required for this type of erection. Sometimes only partial scaffoldings are used if cantilever erection of space frame can be executed. The elements are fabricated at the shop and transported to the construction site, and no heavy lifting equipment is required.

Space Frame Methods of Erection

2. Block Assembly Method

The space frame is divided on its plan into individual strips or blocks. These units are fabricated on the ground level, then hoisted up into its final position and assembled on the temporary supports. With more work being done on the ground, the amount of assembling work at high elevation is reduced. This method is suitable for those double-layer grids where the stiffness and load-resisting behavior will not change considerably after dividing into strips or blocks, such as two-way orthogonal latticed grids, orthogonal square pyramid space grids, and the those with openings. The size of each unit will depend on the hoisting capacity available.
Space Frame Methods of Erection

3. Lift-up Method

The whole space frame is assembled at ground level so that most of the work can be done before hoisting. This will result in increased efficiency and better quality. For short and medium spans, the space frame can be hoisted up by several cranes. For long-span space frame, temporary posts are used as the support and electric winches as the lifting power. The whole space frame can be translated or rotated in the air and then seated on its final position. This method can be employed to all types of double-layer grids.

Summary

- A space frame or space structure is a truss-like, lightweight rigid structure constructed from interlocking struts in a geometric pattern.
- Space frame truss can be used for a platform or overhead structure that spans large distances without need for internal load bearing support.
- Space frames are advantageous compared to other common structures by their; light weight, mass production, stiffness, and versatility.
- Space frames are classified into three types according to the number of grid layers as follows; single, double, or triple layer.
- Space frame connections can be made by; welding, bolting, or threading.
- Space frame construction utilize three main methods of erection; 1- scaffold method, 2. block assembly Method, 3. lift-up method.
References

- Mehta, Madan et. al. (2013) “Building Construction”, Pearson, USA.
- http://youtube.com

Lecture Activity

Each student is required to prepare a brief but informative internet-based research about one of the topics related to this lecture (Space Frames Construction); i.e., new developments, successive and local case studies or important details. The research should be presented in only one A4 sheet.