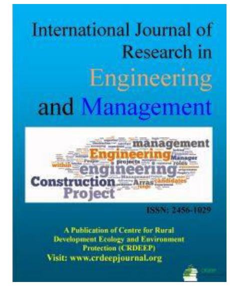
Vol. 4. No. 3. 2021

Contents available at:

www.crdeepjournal.org

International Journal of Research in Engineering & Management (ISSN: 2456-1029)(SJIF: 2.228)



Full Length Research Paper

Forces Distribution in Space Truss Grid Structures

Reham Milad[1], Ahmed Ebid[2], Mohamed Korashy[3], Said Youssef Abo El Haggag[4]

1,3,4Department of Structural Engineering, Ain Shams University, Egypt.
2Department of Structural Engineering and Construction Management, Future University, Egypt.

ARTICLE INFORMATION

Corresponding Author:
Reham Milad

Article history:
Received: 04-02-2021
Accepted: 06-02-2021
Published: 08-02-2021

Key words:
Space truss; long span Structure; Jointing systems

ABSTRACT

Space frames are highly statically indeterminate, and their analysis leads to extremely tedious computation if performed manually. The difficulty of the complicated analysis of such systems contributed to their limited use. The introduction of electronic computers has radically changed the whole approach to the analysis of space frames. By using computer programs, it is possible to analyze very complex space structures with great accuracy and less time. Space frames also have the problem of connecting many members (sometimes up to 20) in space through different angles at a single point. The emergence of several connecting methods of proprietary systems has made great improvement in the construction of the space frame, which offered simple and efficient means for making connection of members. The objective of this paper is to present the concept of space frame grid systems, applications of these systems and parameters that affect the structural behavior of the space frame structure. This paper focuses on and presents the distribution of forces in space trusses under loads considering different parameters regarding the geometry of the space truss. Finite element modeling software SAP2000 V20 was used for analysis of double layer grid space trusses. The results show that the forces developed in top layer member's increase from supports to central region. It was investigated that the maximum axial forces develop in the bottom layer members, which are connected directly to the supports due to the load combination.

Introduction and Background

Space trusses are a type of most used a space structures in the world. They are used to cover large clear spans where there is a need to avoid columns. Because the triangulated arrangement of their discrete members, the forces included in space trusses under loads are principally axial. The axial action leads to a more efficient use of materials, and results in reliable lightweight structures. The term 'space truss' is used to donate the structural system in which small linear members are arranged in three dimensions, and in which the loads are also transferred in three dimensions. There are also other names for the space truss such as reticulated shell, latticed shell, or braced shell. An individual space truss is called a "barrel vault", a "dome" or a "hypar" according to the formation of the curved structure. Alexander Graham Bell showed the possibility of applying the space trusses in structures. The concept of applying industrialized methods to structures was utilized earlier in the construction of the Crystal Palace in London. In the nineteenth century many other examples can be mentioned: bridges, towers, large span buildings, etc. Architectural concepts of aesthetics are changing all the time, leading to the introduction of new structural systems. Designers agree that for large span structures conventional beam and truss systems prove to be uneconomical. Engineers always took the rigidity of 3D structures in consideration and their ability to cover large spans with minimum weight. However, the difficulty of the complicated stress analysis of such systems originally contributed to their limited use. The introduction of electronic computers and their widespread use changed this picture. Architects started to experiment with new shapes [1]. Some years ago, reinforced concrete shells entered the market. The visual beauty of these shells appealed to architects. The possibility of being molded into any shape gave to the architects and engineers new freedom in their search for new forms. However, there is no ideal structural material or form; all of them have their advantages and disadvantages. The construction time in reinforced concrete is lengthy and requires elaborate scaffolding and framework which are not used in the completer structures. Further, concrete is heavy and the accuracy with which it can be built is inherently limited. Soon progressive designers realized these limitations and turned their attention to three-dimensional skeleton frameworks. The development of metal space truss systems induced by the search for economical industrialized construction methods [2]. Advances in computerization have resulted in major changes in space structure design, and in the analysis of their stability and plastic behavior. Now space structures are universally accepted as economical and aesthetically pleasing. In recent years space trusses have been widely used for covering large spans without intermediate supports, with a very small weight of structural material per unit area covered. The development in space structure design, especially light-weight construction is accelerating rapidly.

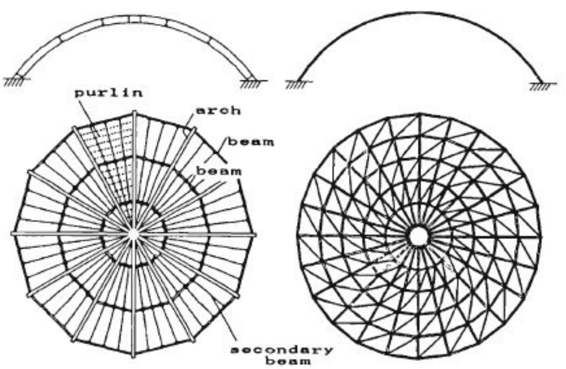
The main objective of this paper is to present the force distribution in space truss members subjected to static loads, this paper focuses on the double layer grid structures.

Methodology

Finite element modeling software SAP2000 V20 [4] was used for analysis of double layer grid space trusses to determine the forces in the space truss members. The obtained data from SAP2000 [4] space truss models were taken and sorted according to each element type of the structure members for each joint.

Characteristics of space trusses

The principal characteristic of a space truss system (as compared to a planar frame system) is three-dimensional nature both in the assembly and in load carrying behavior. This characteristic is illustrated by the examples given by Kawaguchi [3].



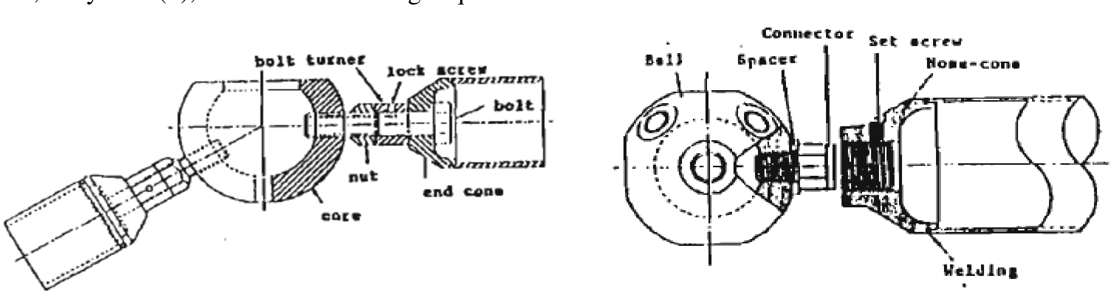
(a) Plane Frame Dome (b) Space Truss Dome

Fig 1 Domes formed from different structural systems

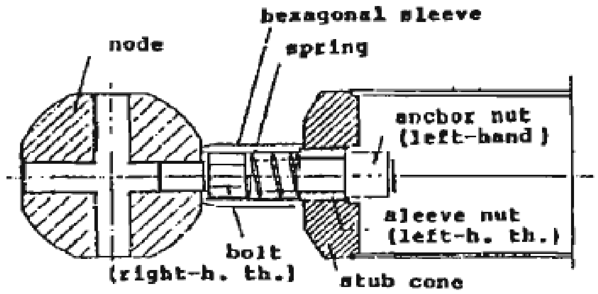
Plane frame and Space truss are different in the sequence of load transfer. In system (a), the transferring sequence of the loads applied to the roof is in such a way that the forces are transferred successively through the purloins, secondary and primary beams to the archest to the ground. In each case, members of the frame system transfer loads from the lighter members to the heavier members. As the sequence progresses, the magnitude of the loads to be transferred increases. Consequently, distinct ranks are produced among the elements, in terms of the size of their cross sections, according to the importance of the tasks assigned to them. In contrast, in system (b), the load transferring sequence is not set from the beginning, and all elements contribute to the task of supporting the applied loads in accordance with the three-dimensional geometry of the whole structure. For this reason, the ranks of the constituent members do not necessarily exist. Therefore, a space truss can be characterized as a spatially framed structure without appreciable rank among its constituent elements.

Structural constituents of space trusses

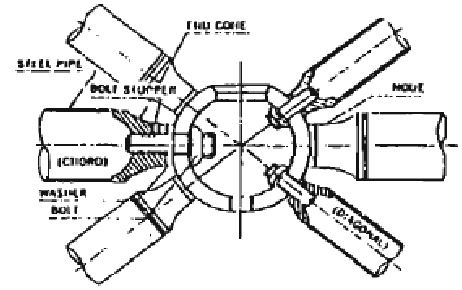
The essential components of space truss systems are the linear members and joints. The members firmly connected by joints result in a single, integrated structural entity. The following description of characteristics of the members and joints in space trusses need to be considered. In space truss structures, linear straight members have been used, where curvilinear members used in other cases. Mild steel is the most popularly material for the members, however aluminum space trusses are encountered yet. Although not common, timber is also used for linear members from time to time. Tubes are the most common section used for linear members, because of their structural efficiency in compression. However, hollow section such as angles, channels, and I or H sections are also utilized when the efficiency of transferring flexural loads is a significant requirement. The most essential component of a space truss structure is the joints. Joints are an essential factor in reducing the overall cost of a space truss, although other factors such as own weight, assembly and erection also affect the overall cost. However, the joints are essential in structural systems other than space trusses, their role in the space trusses is necessary. Because more members are connected to them, the joints in a space truss are much more complicated than the joints in other structures. Furthermore, because the members are in a three-dimensional space truss, the force transferring mechanism is much more sophisticated than in other systems. The main point of consideration for designers was on the problems of the jointing systems in space trusses. The joint's efficacy affects the economical aesthetic result of the entire construction. Figure 2 shows the joints in some common space systems. The most prevalently used materials of space truss joints are steel and aluminum. Joints of cast or forged steel, pressed steel plates (sometimes partially welded), and aluminum found among the popular commercial systems. Joints are usually carefully machined for more accuracy. Typically, the ends of the linear members are manufactured to fit the space truss joints exactly with their lengths and angles. Space trusses have concentric joints and some of them have eccentric joints which causes local bending of the joints and members that results in heavier structures. The continuity of linear members can compensate the disadvantages of eccentricity and it can be used only in a few types of space trusses.



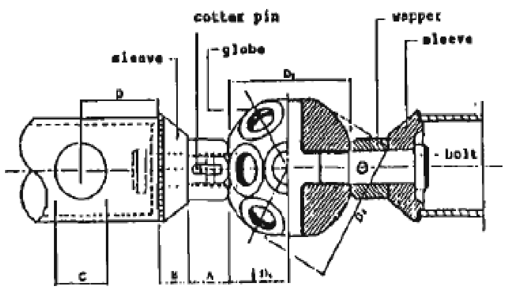
(a) SS truss (b) Uni truss



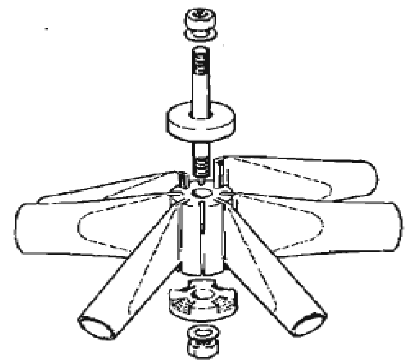
(c) KT truss



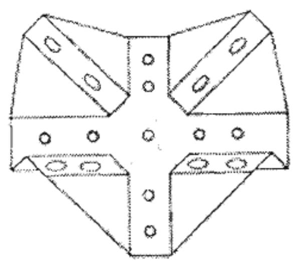
(d) NS truss



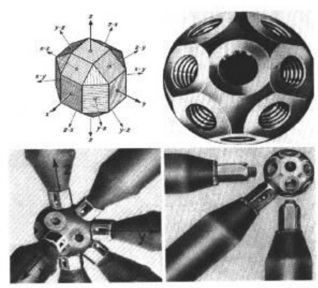
(e) TM truss



(f) Triodetic system



(e) Unistrut system



(f) MERO system

Fig 2 Joints in some common space systems

Force distribution in Space Truss

Nine space truss models were created in SAP2000 software with certain parameters to know the distribution of loads in space truss members. First parameter considered for this study was the short span to its depth ratio, its values were maintained between (8 to 12). Second parameter considered was the location of critical nodes to achieve the maximum forces in space truss members. Table 1 shows details of the parameters considered for each space truss model. All models were loaded by vertical concentrated loads at the top members of space trusses at each of their nodes. Own weight of space trusses was calculated by the software itself, and live load of50 kg/m² respectively.

Table 1. Parameters and geometry of space truss models

Model number	Dimensions (Ls8Ll) (m)	Height (H) (m)	Module (M) (m)
1	8*8	0.65	1
2	8*12	0.65	1
3	8*16	0.65	1
4	8*8	0.8	1
5	8*12	0.8	1
6	8*16	0.8	1
7	8*8	1	1
8	8*12	1	1
9	8*16	1	1

Space Truss Model No.4:

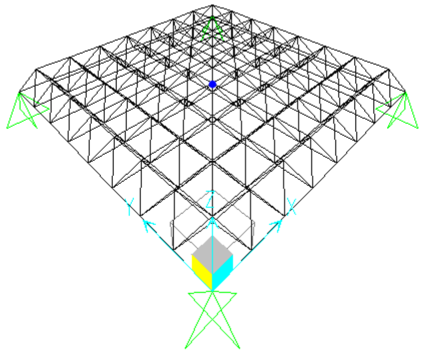


Fig 3 Space Truss Model 4

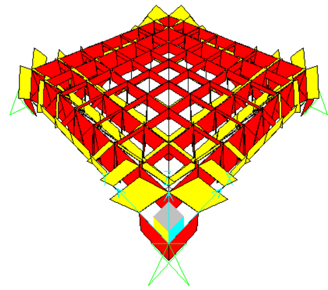
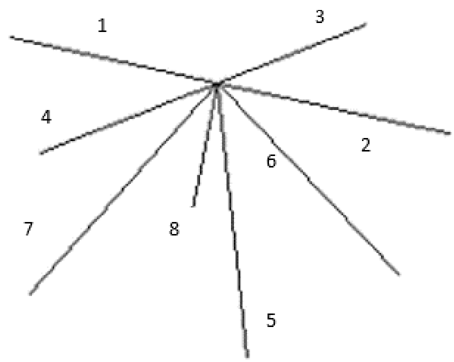


Fig 4 Axial forces diagram of members of Space truss Model 4

Table 2 shows the loads distribution in space truss Model 4



Node 1	Upper joint	Model 4	Members	Axial forces
			1	1.00
			2	1.00
			3	1.00
			4	1.00
			5	0.00
			6	0.08
			7	0.08
			8	0.21

Space Truss Model No.9:

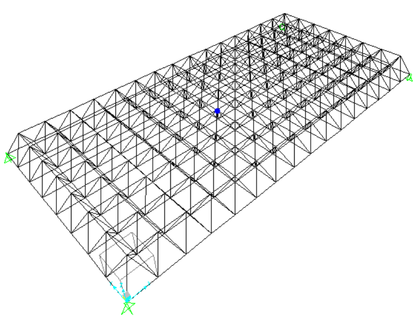


Fig 5 Space Truss Model 9

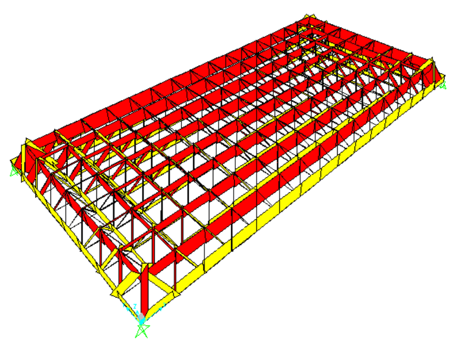
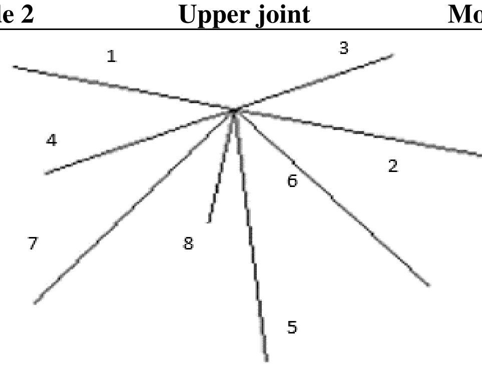


Fig 6 Axial forces diagram of members of Space truss Model 9

Table 3 shows the loads distribution in space truss 9



Node 2	Upper joint	Model 9	Members	Axial forces
			1	0.98
			2	0.40
			3	1.00
			4	0.40
			5	0.90
			6	0.20
			7	0.20
			8	0.50

Space Truss Model No.7:

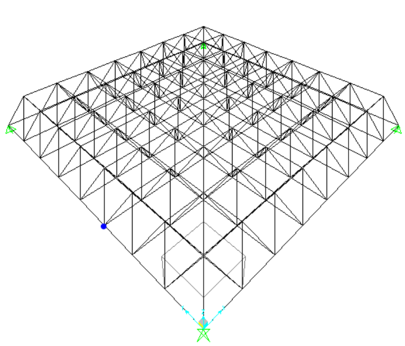


Fig 7 Space Truss Model 7

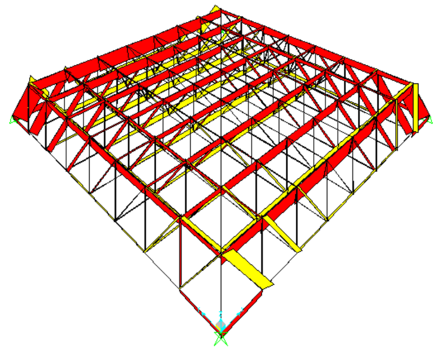
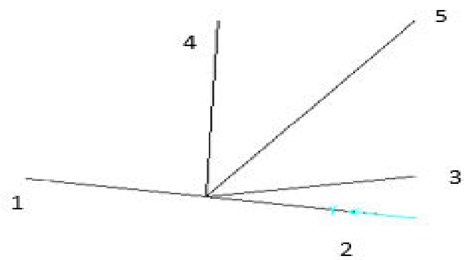


Fig 8 Axial forces diagram of members of Space truss Model 7

Table 4 shows the loads distribution in space truss 7

Node 3	Lower joint	Model 7	Members	Axial forces
			1	1.00
			2	1.00
			3	0.28
			4	0.28
			5	0.28

Space Truss Model No.5:

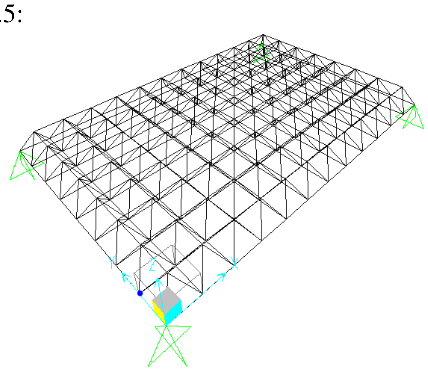


Fig 9 Space Truss Model 5

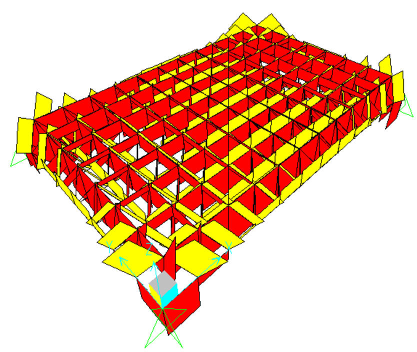
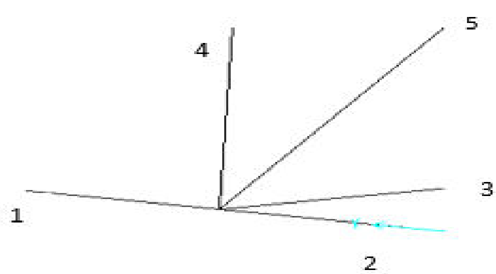


Fig 10 Axial forces diagram of members of Space truss Model 5

Table 5 shows the loads distribution in space truss 5

Node 4	Lower joint	Model 5	Members	Axial forces
			1	1.00
			2	0.06
			3	0.01
			4	0.99
			5	0.99

Conclusion

This paper was presented to study the distribution of loads in the members of space trusses using the analysis of SAP2000 [4] FE software of 9space truss models and was obtained the following:

- The maximum forces in trusses are in the chord members in general, which are in midspan for trusses.
- In space truss model 5, maximum axial forces develop in the bottom layer members, which are connected directly to the supports due to the load combination.

- it has been investigated that forces developed in top layer member's increase from supports to central region.

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