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# Parametric study on the stiffness and energy absorption capacity of composite space truss

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ABSTRACT

Space truss is a three dimensional assembly of linear elements in which load get transferred in three dimensional manners. It is used to cover large area as roof system. The space truss with concrete slab can act a floor system with proper shear connector. This paper details with analytical behaviour of the composite space truss against the published experimental results. The parameters varied in the study are slab thickness, concrete strength and module size of the space truss. The stiffness, energy absorption capacity and ductility factor for the composite space truss was found and compared.



## 1. Introduction

Space truss is a three dimensional structure used to cover large area with or without intermediate support. The major problem of the space truss was the failure of the top chord members, which can be overcome by placing concrete slab along with shear connector over the space truss that act as composite space truss. The composite space truss can be used as floor system in the multi-storey and industrial building for rapid construction.

Mezzina et al. (1975) have presented two methods of analysis for prediction of the theoretical behaviour of the space truss. The method explains the step by step approach of the tension members to study it's the elastic and plastic behaviour. The yield line approach was also adopted to study the behaviour of the tension members. Both the theoretical analysis gives the collapse loads.

Elsheikh and McConnel (1993) have done experimental study on the space truss with over strengthened top chord member and concrete slab over the space truss to overcome the buckling of the critical top chord member and concluded that composite space truss performed better than the over strengthened top chord member.

Elsheikh (1998) has designed and optimized the double layer space truss and fitted the force limiting devices in the critical compression member and observed that the ductility and load carrying capacity were improved. The force limiting devices were more costly, so it was limited to use in the one or few members of the space structures. Lakshmikandhan et al. (2010) have carried out a parametric study on the behaviour of composite space structures using ANSYS and concluded that top concrete slab enhanced the strength of the top chord members and also increased the strength and stiffness of the system. Sangeetha and Senthil (2017) discussed the study on the ultimate load carrying capacity on the composite space truss with proper shear connector and concluded that the composite space truss with steel flat and bolts as shear connectors enhances the composite action. This paper emphasise the parametric study on the energy absorption, stiffness and ductility factor for varying slab thickness, module size and concrete strength of composite space truss analysed using ABAQUS.

## 2. Analysis of composite space truss

The composite space truss of 4 m × 4 m and 9 m × 9 m space truss were taken from the published experimental results were analysed. The parameters varied in their model to analysis using ABAQUS are slab thicknesses (50 mm, 80 mm, 100 mm and 125 mm), grade of the concrete (M25, M30 and M35) and the size of the space truss module (800 mm × 800 mm, 1000 mm × 1000 mm and 1333.3 mm × 1333.3 mm). The steel space truss was modelled using Truss Element (T3D2) and concrete slab using Solid Element (C3D8) from element library of ABAQUS. The details of the elements are shown in Fig. 1 and the layouts of the space truss are shown in Fig. 2. Table 1 gives material property of steel and concrete used as input in analysis.

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**Table 1:** Material properties of steel and concrete

| Sl. No | Material Property | Steel | Concrete |
|---|---|---|---|
| 1 | Young's modulus N/mm$^2$ | $2 \times 10^5$ | $5000\sqrt{f_{ck}}$ |
| 2 | Poisson's ratio | 0.3 | 0.15 |
| 3 | Density kg/m$^3$ | 7850 | 2500 |

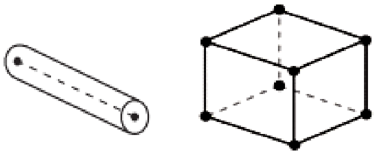


**Fig. 1:** Truss and solid element

The non-linear analysis of the composite space truss was done using ABAQUS. Figs. 3 and 4 show the mesh model and deformed shape of the composite space truss of size 4 m × 4 m and 9 m × 9 m.

The composite space truss model was restrained at four corner node of the bottom layer and subjected to the concentrated load at all intermediate node of top layer(4 m × 4 m ) and at intermediate node of the top layer (9 m × 9 m).

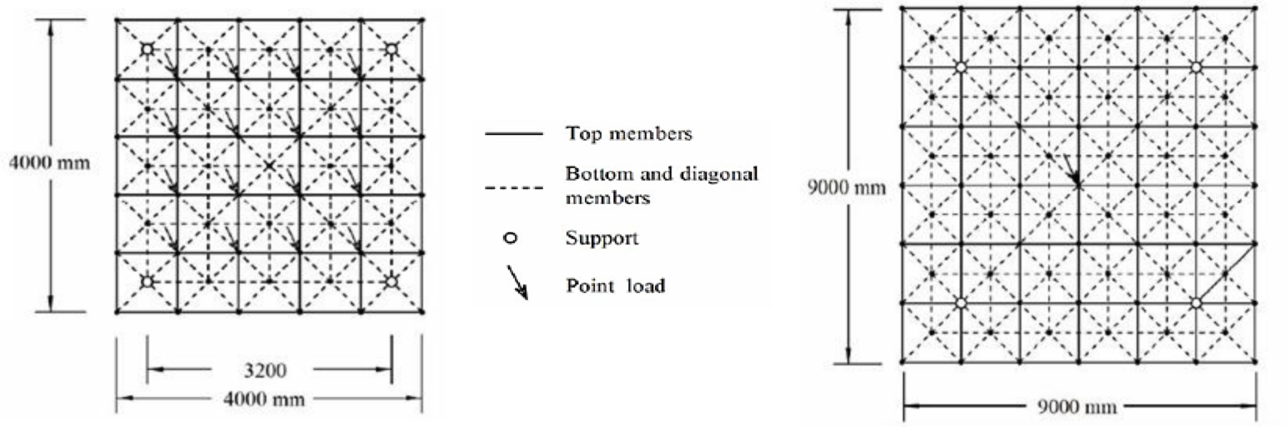



**Fig. 2:** Layout of the space truss

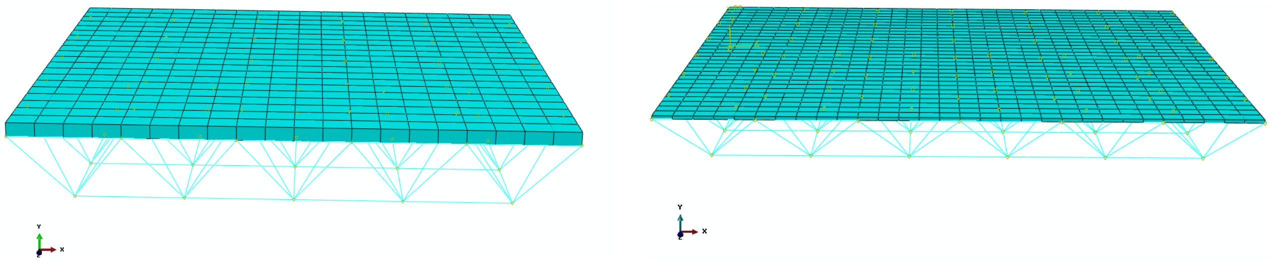
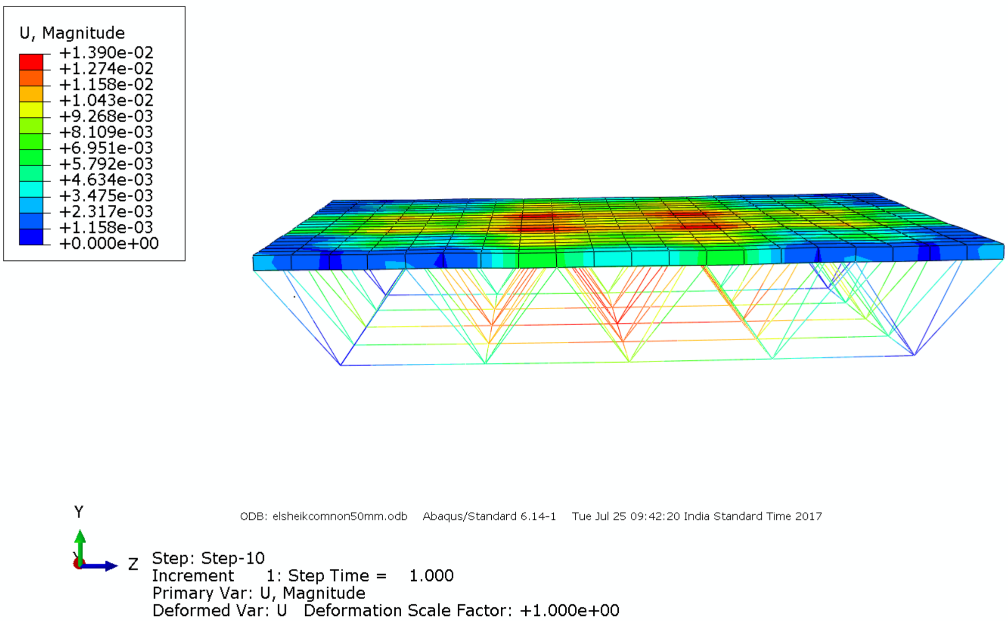


**Fig. 3:** Mesh model of 4 m x 4 m and 9 m x 9 m space truss



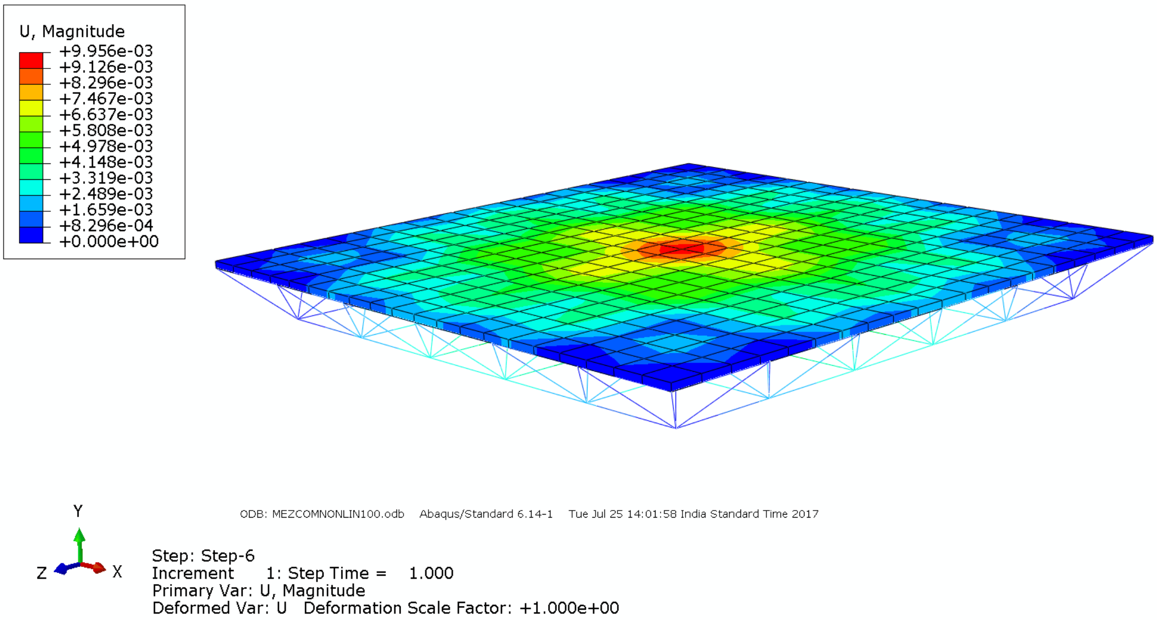



**Fig. 4:** Deformed shapes of 4 m x 4 m and 9 m x 9 m space truss

## 3. Result and discussion

Ductility and energy absorption capacity are more important for structures located in seismic areas. Ductility is defined as the ability of structure to deform plastically under load without any failure. The ductility factor of the space truss is defined as the ratio of the deflection at failure load to the deflection at the yield load of the extreme fibre in the compression region.

The yield deflection from the load – deflection plots are obtained by taking offset from the value of 0.2% as proof strain. Table 2 shows the calculated analytical values of energy absorption of the composite space truss having different module sizes. The ductility factor of the two different composite space truss are tabulated in Tables 3 and 4, indicates that composite space truss of 4 m × 4 m exhibited greater values than 9 m × 9 m truss.

The energy absorption is the work done by the external load up to the failure of the specimen. The area under the load-deflection diagram provides details of the energy absorption by the structure under loading. Tables 3 and 4 show the calculated analytical values of energy absorption of the composite space truss. The results show energy absorption capacity as the highest for the composite space truss with the lower thickness of the concrete slab. The mean energy absorption of 4 m × 4 m is more than double that of 9 m × 9 m. A comparison of the energy absorption capacity of all types of composite space truss is shown in Fig. 5. This clearly shows the energy absorption capacity of 50 mm slab thickness as considerably greater than the 125 mm.

**Table 2:** Analytical results of the composite space truss for varying module size

| Truss Name | Size of the Composite Space Truss (m) | Module Size (mm) | No. of Module | Max Load $P_u$ (kN) | Max Deflection $\Delta_u$ (mm) | Yield Deflection $\Delta_y$ (mm) | Ductility Factor $\mu = \Delta_u / \Delta_y$ | Energy Absorption (Nm) |
|---|---|---|---|---|---|---|---|---|
| Truss A | 4 × 4 × 0.575 (Elsheikh (1998) Model) | 800×800 | 5 | 350 | 7.8 | 2.00 | 3.90 | 1820 |
| Truss B | | 1000×1000 | 4 | 350 | 8.2 | 2.40 | 3.42 | 1913 |
| Truss C | | 1333×1333 | 3 | 350 | 8.5 | 4.20 | 2.02 | 1983 |

**Table 3:** Analytical results of composite space truss (4 m × 4 m)

| Size of the Composite Space Truss (m) | Thickness of the Concrete Slab (mm) | Grade of Concrete | Maximum Load $P_u$ (kN) | Maximum Deflection $\Delta_u$ (mm) | Yield Deflection $\Delta_y$ (mm) | Ductility Factor $\mu = \Delta_u / \Delta_y$ | Energy Absorption (Nm) |
|---|---|---|---|---|---|---|---|
| 4 × 4 × 0.575 | 50 | M25 | 350 | 8.90 | 3.32 | 2.68 | 2077 |
| | 80 | | 350 | 6.41 | 2.50 | 2.56 | 1496 |
| | 100 | | 350 | 5.81 | 2.40 | 2.42 | 1356 |
| | 125 | | 350 | 5.21 | 2.30 | 2.27 | 1216 |
| | 50 | M30 | 350 | 7.80 | 2.94 | 2.65 | 1820 |
| | 80 | | 350 | 5.80 | 2.40 | 2.52 | 1353 |
| | 100 | | 350 | 5.51 | 2.30 | 2.40 | 1286 |
| | 125 | | 350 | 5.00 | 2.20 | 2.27 | 1167 |
| | 50 | M35 | 350 | 7.36 | 2.81 | 2.62 | 1717 |
| | 80 | | 350 | 5.52 | 2.20 | 2.51 | 1288 |
| | 100 | | 350 | 5.23 | 2.10 | 2.49 | 1220 |
| | 125 | | 350 | 4.46 | 2.00 | 2.23 | 1041 |

**Table 4:** Analytical results of composite space truss (9 m × 9 m)

| Size of the Composite Space Truss (m) | Thickness of the Concrete Slab (mm) | Grade of Concrete | Maximum Load $P_u$ (kN) | Maximum Deflection $\Delta_u$ (mm) | Yield Deflection $\Delta_y$ (mm) | Ductility Factor $\mu = \Delta_u / \Delta_y$ | Energy Absorption (Nm) |
|---|---|---|---|---|---|---|---|
| | 50 | | 180 | 9.90 | 9.79 | 1.011 | 891 |
| | 80 | M25 | 180 | 8.72 | 8.65 | 1.008 | 785 |
| | 100 | | 180 | 8.52 | 8.46 | 1.007 | 767 |
| | 125 | | 180 | 4.29 | 4.26 | 1.006 | 386 |
| | 50 | | 180 | 9.22 | 9.09 | 1.014 | 830 |
| 9 × 9 × 0.75 | 80 | M30 | 180 | 8.56 | 8.48 | 1.009 | 770 |
| | 100 | | 180 | 8.30 | 8.24 | 1.007 | 747 |
| | 125 | | 180 | 4.17 | 4.15 | 1.004 | 375 |
| | 50 | | 180 | 9.12 | 9.00 | 1.013 | 821 |
| | 80 | M35 | 180 | 8.45 | 8.35 | 1.012 | 761 |
| | 100 | | 180 | 8.21 | 8.12 | 1.011 | 740 |
| | 125 | | 180 | 4.01 | 3.98 | 1.008 | 361 |

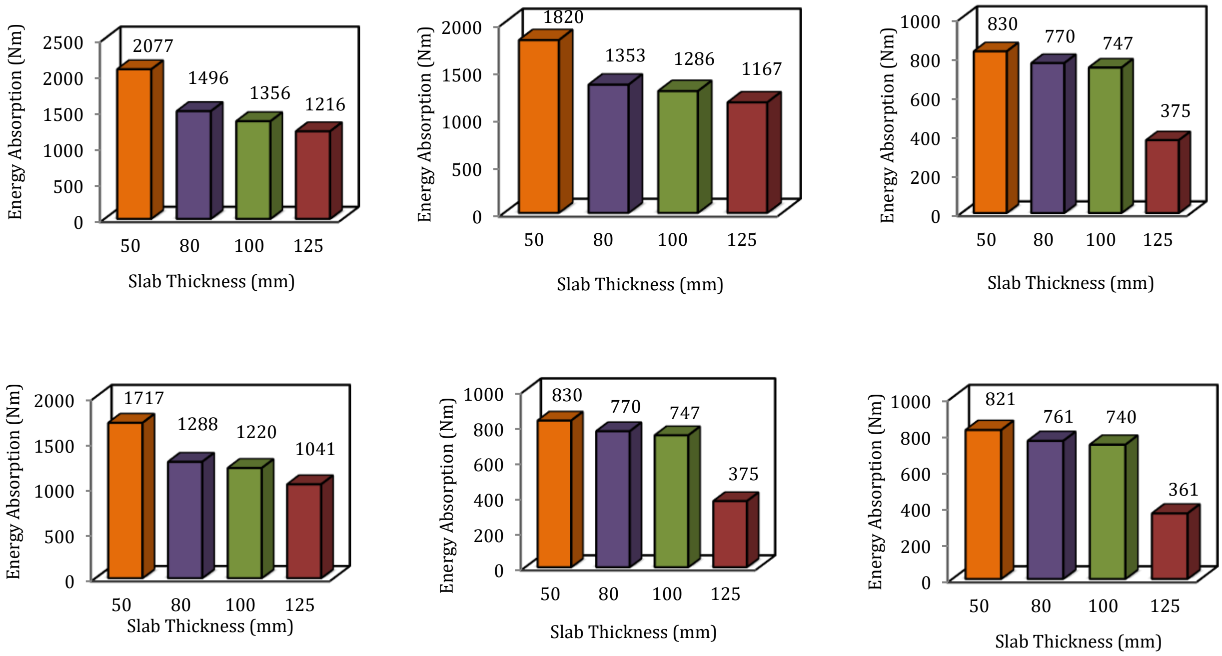



**Fig. 5:** Comparison of energy absorption capacity of composite space truss (M25, M30 and M35)

Stiffness is defined as the ability to resists deflection. Stiffness value is calculated as the ratio of the load increment to the corresponding deflection at the centre of the composite space truss. The variations in the stiffness of two truss 4 m × 4 m and 9 m × 9 m with the slab thickness of 50 mm, 80 mm, 100 mm and 125mm are shown in Figs. 6 and 7. Decrease in the stiffness with the increase in the load is observed and the rate of decrease is more in the initial load range. Behaviour of composite space truss with 125 mm slab thickness which behaved in a stiff manner over the load range is shown in Figs. 6 and 7. In general, the stiffness of the composite space truss is much higher than that of non-composite space truss.

## 4. Conclusion

The study on the analytical behaviour using ABAQUS was carried out employing published experimental results of Elsheikh (1998) model of size 4 m x 4m and Mezzina et al. (1975) model of size 9 m x 9 m for composite space truss.

The influence of various parameters like thickness of slab, module size and concrete strength were also studied. From the analytical study following conclusion were arrived. The increase in the thickness of concrete slab over the space truss is having relatively high stiffness. The slab of 125 mm is five times stiffer than the 50 mm slab. The increase in the slab thickness of the composite space truss enhances energy absorption capacity. The ductility factor does not significantly change when the size, slab thickness and grade of concrete is changed.

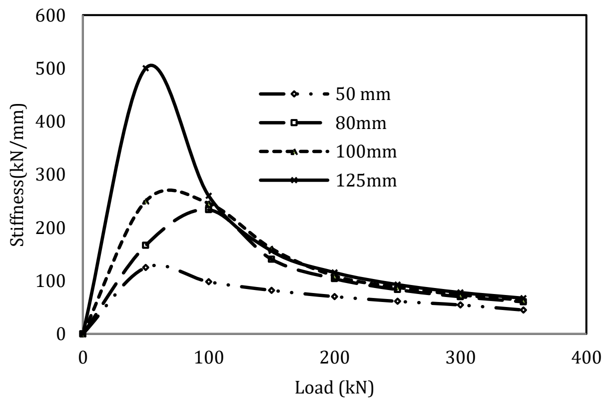



**Fig. 6:** Load - Stiffness behaviour of composite space truss (4 m × 4 m)

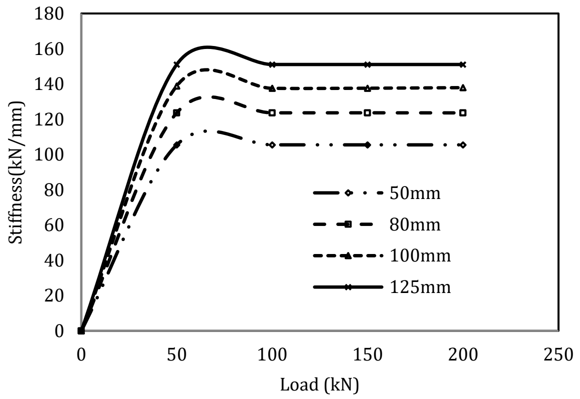



**Fig. 7:** Load - Stiffness behaviour of composite space truss (9 m × 9 m)

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