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Research Article

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Study on Behaviour of a Composite Space Truss Analytically

V Vanathi[1]* and T Mohanapriya[2]

Abstract

A three dimensional (3D) space truss structural member is used to transfer the force in 3D manner. The space truss is unstable and brittle in nature. Due to over loading, the buckling of one member may cause the subsequent failure in other members. This may even leads to collapse the entire structure. The slab will reduce the buckling in the chord member and to increase the stiffness. In this study a composite space truss model was created in Hyper Mesh FEM software using P ROD and P SHELL elements and its deflection values were obtained. Various design parameters such as grade of concrete, slab thickness, steel module sizes for truss members were incorporated in the software and the deflection values were found. Finally the optimum slab thickness for different grades of concrete and module size of steel truss by weight optimization and deflection criteria was found.

Keywords: Three dimensional; P ROD; P SHELL

Introduction

Trusses are triangular frame works in which the members are subjected to axial forces due to externally applied load. Steel members are generally more effective than members in flexure since the cross section is nearly uniformly stressed. Trusses are essentially axially loaded members and are very efficient in resisting external loads. They are extensively used for larger spans. Steel trusses can be efficiently used along with concrete slabs in buildings and bridges by mobilizing composite action between structural steel and concrete there by improving their behavior [1].

To reduce deflection in space truss many attempts were taken like over strengthening of top chord members, use of different types of node connectors, use of concrete slab to act compositely with the top chord members and use of force limiting devices [2].

El-Sheikh et al. [3] has studied the behavior of composite space truss experimentally by strengthening the top chord member in a space truss. The composite action can introduce some ductility into the overall structural behavior, but this approach may be successful in providing adequate warning of a sudden collapse. There was no serious damage to the composite space truss.

Sangeetha et al. [4] has studied the composite space truss with a slab thickness of 50 mm using ABAQUS with a size of 4 m × 4 m (5 module) Deflection was reduced in the space truss compared with the previous experimental results. It was concluded that the deck slab without decking sheet at the top in space truss decreases the overall deflection of the structure. While comparing the experimental results with the analytical results the deflection decreases upto 17%.

El-Sheikh et al. [5] developed a new space truss system called Catrus. The main features of Catrus are its continuous chord members, simple jointing system and ability to work compositely with concrete slabs with the diagonals without node connectors. Experimental work involved five complete models. The results obtained indicated a significant ability to distribute forces away from affected areas and a good joint stability.

Materials and Methods

The space truss of 6 m × 6 m with 3 different module arrangement as shown in Figure 1 where analyzed. The module arrangements are truss A with 7 modules each of size 0.8571, Truss B with 6 module each of size 1 m, and Truss C with 5 module each of size 1.2 m [6].

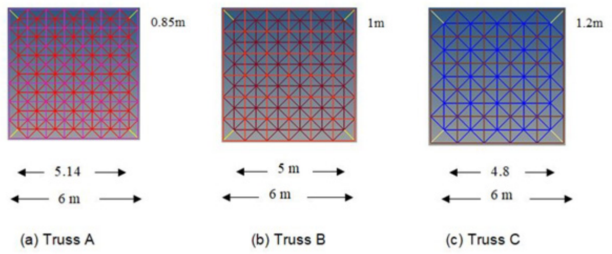

Figure 1: Modules with effective length.

Analytical work

The composite truss was analysed using finite-element analysis using hyper mesh for three Trusses A, B and C. Truss element was modeled as one dimensional using PROD, the slab were modeled as two dimensional using shell element (PSHELL). All the inner nodes of the top chord members were subjected to an allowable roof live load of 1.5 kN/m2 and a superimposed dead load of 3 kN/m2. In case of bottom chord members the four corner nodes were simply supported. Figure 2 shows the loading and boundary conditions [7-8].

Input values in hyper mesh

Parts created:

a. Truss (P ROD)

b. Slab (P SHELL)

Material properties:

Steel:

Density=7850 kg/m3

Young's Modulus E=200 GPa

*Corresponding author: Vanathi V, Assistant Professor, Department of Civil Engineering, PSG College of Technology, Coimbatore, India, E-mail: vna.civil@psgtech.ac.in

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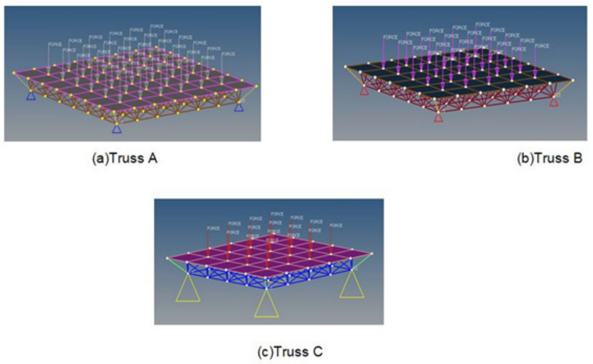

Figure 2: Different module arrangements of Truss A, B and C with loading and boundary conditions.

Poisson ratio μ= 0.288

Concrete:

Density ρ=2446.48 kg/m3

Young's Modulus E=5000(fck)1/2

Poisson ratio μ=0.2

Young's Modulus values for various grades of concrete:

E=25 GPa (for M25)

E=27.386 GPa (for M30)

E=29.580 GPa (for M35)

Steel sections used for the truss members are shown in the Table 1

Table 1: Details of Truss Members.

Types of member	Shape of the section	Size of the section (mm)
Top chord members	Channel section	40 × 24 × 1.6
Bottom chord and diagonal members	Tubes	28.58 × 1.63
Corner diagonal members	Tubes	60.3 × 3.2

The Trusses A, B and C were analysed by varying

a) Grade of concrete of the slab as M25, M30 and M35

b) Slab thickness as 50 mm, 80 mm, 100 mm and 125 mm

c) Module size as 0.8571 m, 1 m and 1.2 m

Interpretation of Results

Truss A-0.8571 m Module Size

The overall central deflection of the composite space trusses A, B and C was determined. The values are tabulated in the Tables 2-4. The deflection profiles of the composite space trusses are shown in the Figures 3-6, Figures 7-10, and Figures 11-14. Charts have been drawn showing the deflection reduction for slab thicknesses from 50 mm to 125 mm.

Table 2: Maximum central deflection for Truss A.

Grade of concrete	Slab thickness (mm)	Maximum central deflection (mm)
M25	50	6.906
	80	6.25
	100	5.693
	125	4.962
M30	50	6.868
	80	6.178
	100	5.598
	125	4.848
M35	50	6.835
	80	6.116
	100	5.516
	125	4.751

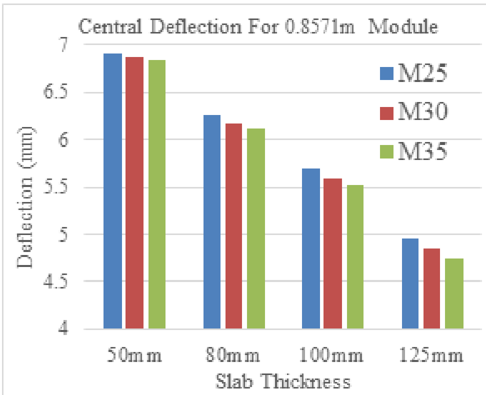

Figure 3: Graph showing slab thickness vs. deflection for Truss A.

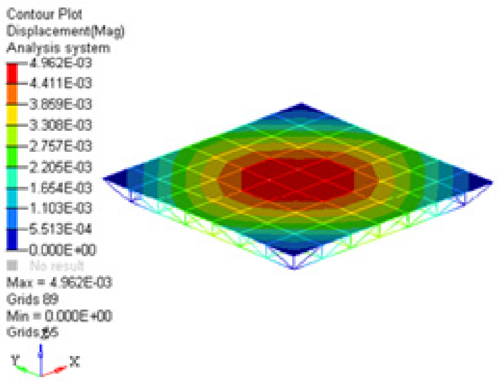

Figure 4: Deflection of Truss A for 125 mm slab thickness and M25 grade.

Table 3: Maximum central deflection for Truss B.

Grade of concrete	Slab thickness(mm)	Maximum central deflection(mm)
M25	50	7.816
	80	6.98
	100	6.284
	125	5.407

M30	50	7.772
	80	6.892
	100	6.17
	125	5.275
M35	50	7.734
	80	6.815
	100	6.071
	125	5.162

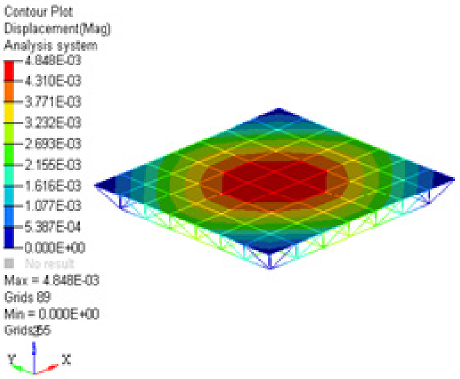

Figure 5: Deflection of Truss A for 125 mm slab thickness and M30 grade.

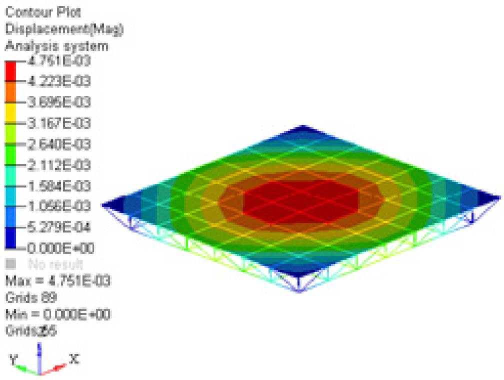

Figure 6: Deflection of Truss A for 125 mm slab thickness and M35 grade.

Truss B-1 m module

The maximum central deflection of truss B with various grade of concrete and varying slab thickness is tabulated in Table 4

Table 4: Maximum central deflection for Truss C.

Grade of Concrete	Slab thickness(mm)	Maximum central deflection (mm)
M25	50	8.3
	80	7.284
	100	6.496
	125	5.555
M30	50	8.248
	80	7.183
	100	6.371
	125	5.418
M35	50	8.203
	80	7.095
	100	6.264
	125	5.301

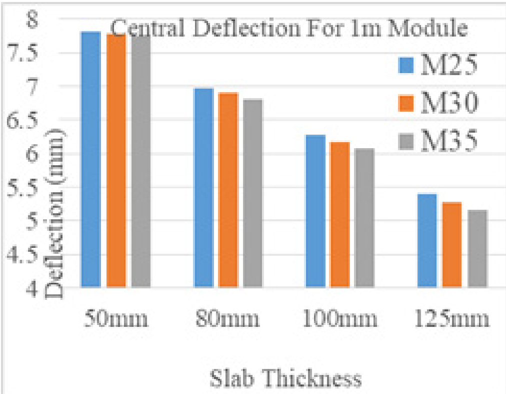

Figure 7: Graph showing slab thickness vs. deflection for Truss B.

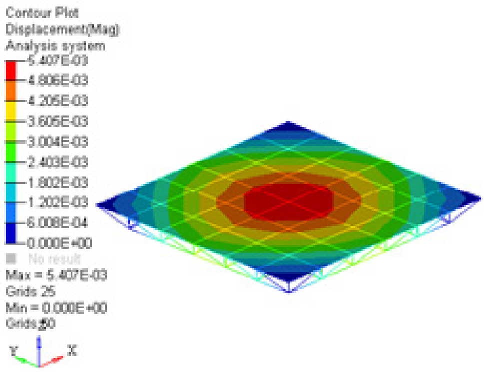

Figure 8: Deflection of Truss B for 125 mm slab thickness and M25grade.

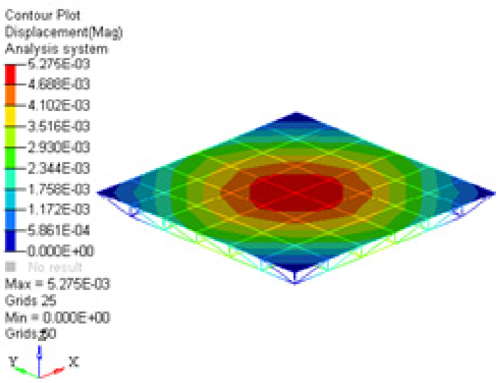

Figure 9: Deflection of Truss B for 125 mm slab thickness and M30 grade.

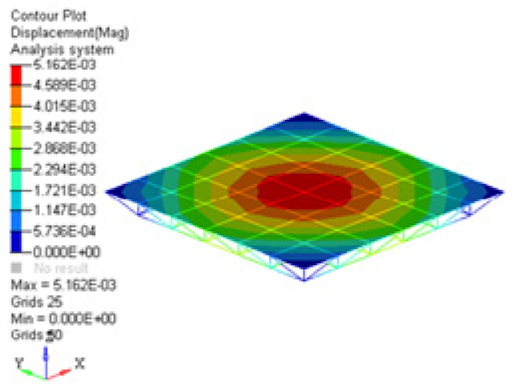

Figure 10: Deflection of Truss B for 125 mm slab thickness and M35 grade.

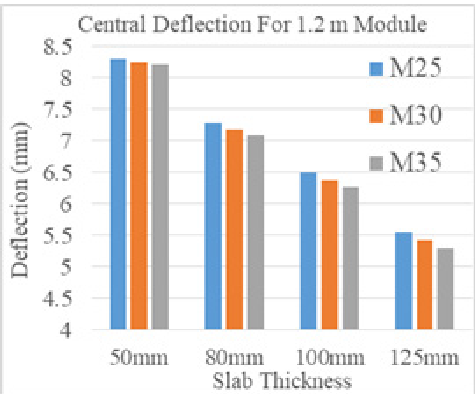

Figure 11: Graph showing slab thickness vs. deflection for Truss C.

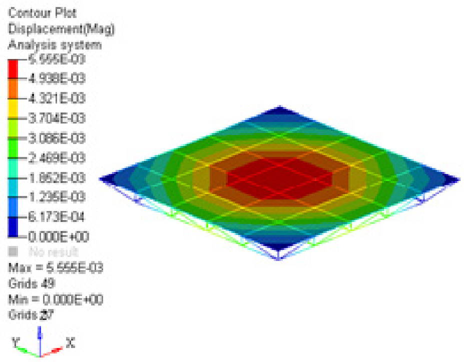

Figure 12: Deflection of Truss C for 125 mm slab thickness and M25 grade.

Check for deflection

a) Effective span for Truss A=5.1429 m

Permissible deflection=Eff.span/360

=5142.9/360

=14.285 mm

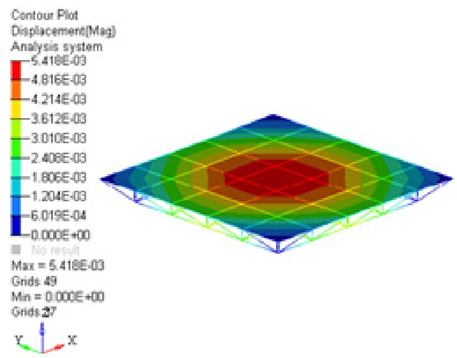

Figure 13: Deflection of Truss C for 125 mm slab thickness and M30 grade.

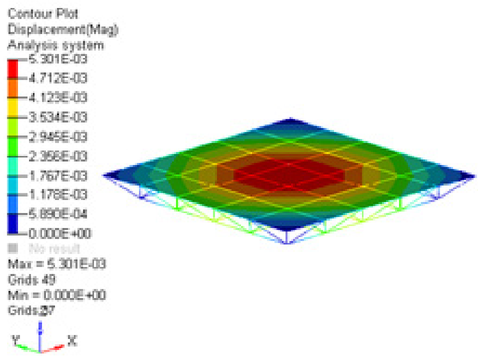

Figure 14: Deflection of Truss C for 125 mm slab thickness and M35 grade.

Maximum deflection obtained=6.905<14.285

Hence safe.

b) Effective span for Truss B=5 m

Permissible deflecion= Eff.span/360

=5000/360

=13.888 mm

Maximum deflection obtained=7.815<13.888

Hence safe.

c) Effective span for Truss C=4.8 m

Permissible deflection= Eff.span/360

=4800/360

=13.333 mm

Maximum Deflection obtained=8.300<13.333

Hence safe.

Results and Discussion

Effect of module size

Three different module sizes were adopted for analysis.

1. 0.8571 m

2. 1 m

3. 1.2 m

The percentage decrease in the central deflection of the composite space truss with the slab thickness 50 to 125 mm for various module sizes given in the Table 5

Table 5: Percentage reduction in deflection for different module sizes.

Module Size	Percentage decrease in central deflection
0.8571 m	28% to 33%
1 m	29% to 34%
1.2 m	30% to 35%

Effect of concrete strength

Three different grades of concrete were adopted for analysis.

1. M25

2. M30

3. M35

For the composite space Truss A the percentage decrease in the central deflection with respect to the concrete strength is 28.13% to 30.5%. For Truss B the percentage of deflection reduction is 30.82% to 33.25%. And for Truss C it is 33.13% to 35.37%.

Effect of slab thickness

Four different slab thicknesses were adopted.

1. 50 mm

2. 80 mm

3. 100 mm

4. 125 mm

The percentage of decrease in central deflection for various slab thickness are given in the Table 6

Table 6: Percentage reduction in deflection for change in slab thickness.

Change in slab thickness	Percentage decrease in central deflection
50 mm to 80 mm	9.5% to 13.5%,
80 mm to 100 mm	8.9% to 11.7%
100 mm to 125 mm	12.8% to 15.3%

Optimum design parameters

• From the deflection results it is inferred that the composite truss having 0.8571 m module size has least deflection. From Table 7 it is observed that 1.2 m module size requires lesser quantity of steel (31.24%) and also satisfies the deflection criteria.

Table 7: Weight of steel required for various module sizes.

Module size (m)	Number of modules	Length of steel(m)	Total weight of steel (kN)
0.8571	7	331.73	3.604
1	6	275.24	3.019
1.2	5	222.5	2.478

• From the results it is observed that M35 grade of Concrete shows less deflection compared to other concrete strengths.

• The deflection of composite truss having 125 mm thick slab is 35.37% lower than the truss having 50 mm thick slab.

From the observations it is inferred that the optimum design parameters for the composite space truss are

• 1.2 m Module size

• M35 Grade of concrete

• 125 mm slab thickness

Conclusion

• Composite space truss was modelled using FEM Solver Hyper Mesh and analysed for the deflection values. The deflected profile is shown in the figures and the values are tabulated and the deflection check has been done.

• It is observed that the deflection decreases with increase in grade of concrete, increase in slab thickness and decrease in the module size.

• It is found that composite truss having 1.2 m module size with M35 grade of concrete and 125 mm slab thickness reduces the cost when weight of steel is considered.

• For composite truss having 0.8571 m module size with M35 grade of concrete and 125 mm thick slab performs well when deflection criteria are considered.

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Author Affiliations Top

[1]*Department of Civil Engineering, PSG College of Technology, Coimbatore, India*

[2]*Departmebt of Structural Engineering, PSG College of Technology, Coimbatore, India*