Buckling Characteristics Study of IsoTruss Structure for Different Bay Lengths

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Abstract

The present paper illustrates a buckling characteristics study on composite light weight lattice structure called as IsoTruss. Finite element modelling and simulation is carried out to observe the buckling characteristics of IsoTruss. Comparison of compressive buckling load carrying capacity is done for different bay lengths and different diameters of IsoTruss. The result from this study concludes that the IsoTruss with same diameter yields maximum critical buckling load when global and local buckling is observed simultaneously. For maximum critical buckling load bay length decreases with increase in diameter of isotruss.

Keywords

IsoTruss, Bay length, Helical members, Longitudinal members, Carbon fibre, Local buckling, and global buckling.

1. Introduction

As technology progresses in the field of structures the demand for light weight and high strength materials increasing rapidly and one of the solutions for it is a composite material. From two or more constituent materials a composite material is produced. Physical and chemical properties of composite material differ from the constituent materials. These properties also differ with the proportion of constituent materials.

IsoTruss is one of the light wight trusses. Its geometry is made up of longitudinal and helical composite material tows such as carbon fiber with epoxy coating. IsoTruss is a lattice structure which is manufactured by interweaving of different numbers of longitudinal and helical members. Bending and compressive loads are carried by longitudinal members, while helical members could be designed for torsion loads.

1.1 Geometry of IsoTruss

Longitudinal tows: These are the tows which are placed parallel to longitudinal axis of isotruss. Helical tows: From bottom end of each longitudinal tow, two helical elements start. One of these goes in clockwise direction and another goes in anticlockwise direction (Figure 1a, 1b, Figure 2). These helical elements forms tetrahedron geometry while crossing each other. Bay length: In longitudinal direction same geometry is repeated at fixed length of IsoTruss. The length between these points of IsoTruss is called as bay length. (i.e., the distance between two consecutive peaks of tetrahedrons in longitudinal direction is considered as bay length.)

Depending upon the number of longitudinal and helical tows to form the IsoTruss structure, it is named as 6 node IsoTruss, 8 node Isotruss etc. 6 Node geometry is the simplest form of IsoTruss, which comprises of double triangular cross-section geometry with six longitudinal tows and twelve helical tows. Eight node geometry is comprising of two squares placed at 45° to each other.

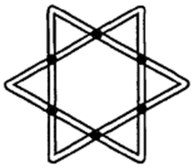

Figure 1a. Cross section of six node IsoTruss

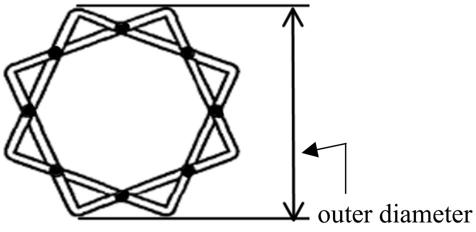

Figure 1 b. Cross section of eight node IsoTruss

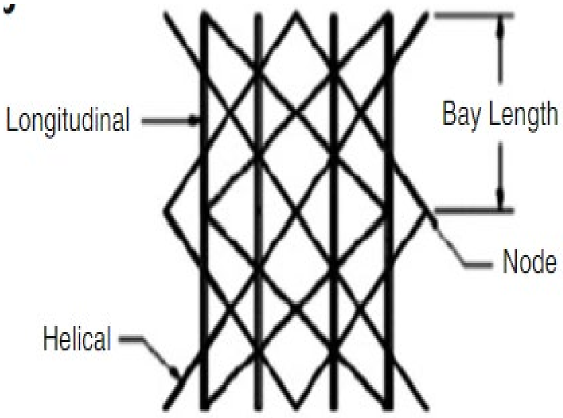

Figure 2. Elevation of eight node IsoTruss
[Rackliffe and Jensen 2006]

2.Literature Review

Behavior of composite IsoTruss as column structure is studied for compressive buckling characteristics in case of local and global buckling (Rackliffe and Jensen 2006). Variation in number of carbon fiber tows in longitudinal and helical direction with different bay length examined for compressive strength. Fixed and free boundary condition is considered along with axial compressive loading for 3m IsoTruss member. Same trends are observed for test results and FE predictions but for shorter bay length error observed is higher. Shorter bay length yields higher buckling load carrying capacity. Bay length shows its impact on local buckling, but global buckling is independent (McCune et al. 2001, Winkel et al. 2001, Sui et al. 2015, Sui et al. 2017)
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Capacity to carry tensile load is observed by modelling and analysis in finite element software for IsoTruss structure (Gavade and Roy 2016). Two sets with different position of longitudinal element with respect to bay length is studied for tensile strength.

3.Problem Definition

This study is done to observe and understand that how the critical buckling load carrying capacity of light weight composite lattice structure called IsoTruss varies with the change in the outer diameter and bay length by keeping the same diameter of carbon fiber tows.

4.Methodology

Modelling and analysis work of IsoTruss is carried out in FE software. Following steps are followed to complete analysis of isotruss (Figure 3).

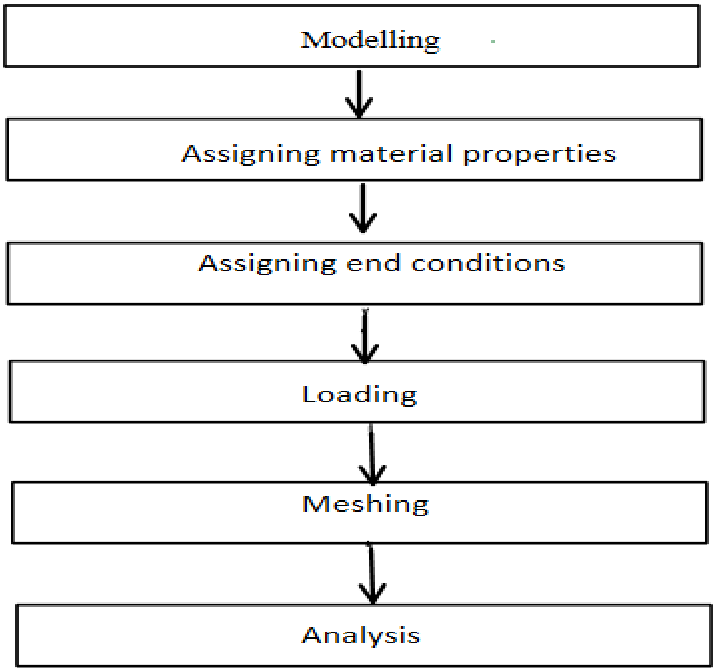

Figure 3. Methodology

4.1. Modelling and Analysis Work

Modelling of eight node IsoTruss is carried out in finite element software by using two node beam elements. Cross section of eight node single isotruss is shown on Figure 2. The nodes in cross section of Isotruss represent longitudinal elements. Geometry of IsoTruss is comprises of eight longitudinal nodes and sixteen helical nodes. Bottom nodes of IsoTruss are assigned fixed end condition while reference lode of 1N is distributed on top nodes. In the present study buckling analysis of eight node Isotruss having different bay lengths and diameters is carried out to understand the relation of bay length and diameter. Finite element (FE) modelling and analysis work completed in ABAQUS 6.10 FE software. Finite element analysis gives the results in terms of Eigen value (λ), which is used as load factor. Load carrying capacity of IsoTruss is found by using Equation 1, where P is critical buckling load (P) and P_r is reference load, λ is load factor.

$$P = P_r + \lambda P_r \qquad [1]$$

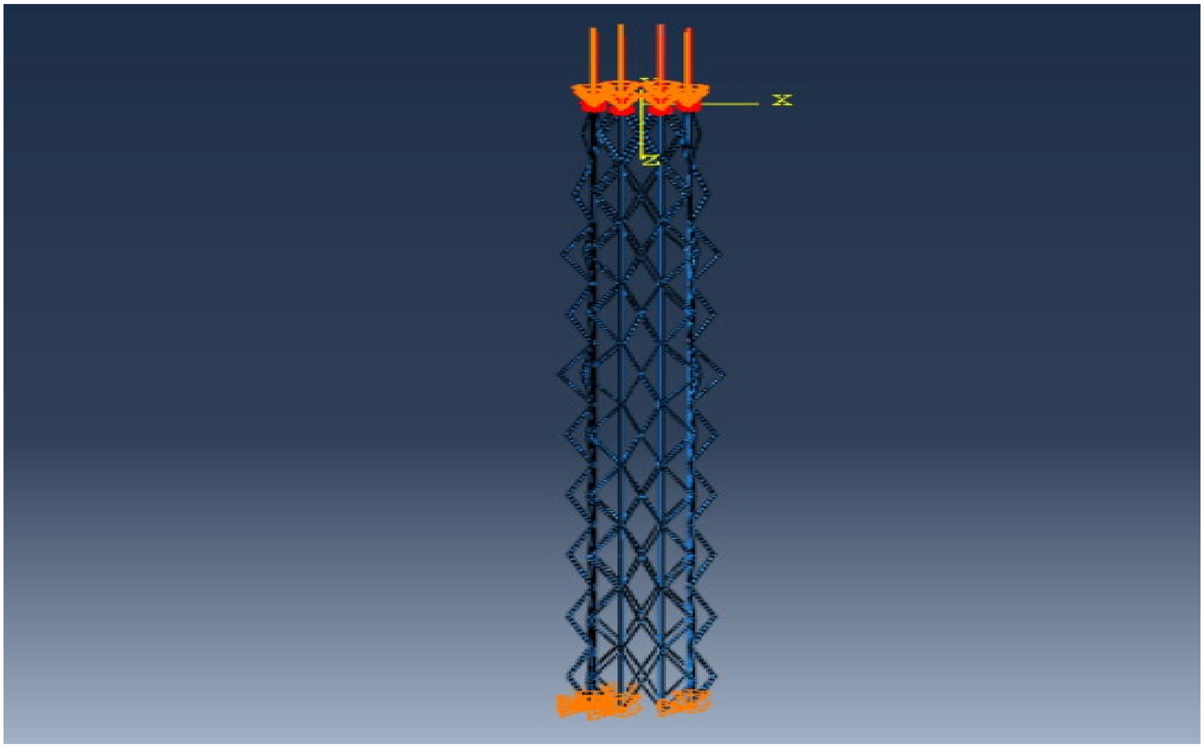

Figure 4. Loading conditions of Isotruss with end supports

Euler's buckling load formula of column can be used to find the compressive load carrying capacity (Figure 4). Critical load P_{cr} is calculated by Equation (2) for one end fixed and other end free condition, where E is modulus of elasticity of material, I is moment of inertia and L is length of column.

$$P_{cr} = \frac{\pi^2 EI}{4L^2} \tag{2}$$

4.2. Material Properties

24K carbon fiber cordage coated with epoxy resin having final diameter of 2mm is used for finite element modelling and simulation. Following material properties are considered in simulation (Table 1).

Table 1. Properties of carbon fibre

Modulus of Elasticity (GPa)	255
Density (gms/cubic meter)	0.0025
Diameter of carbon fiber tow(mm)	2.0

5. Results and Discussion

It is observed that if diameter of isotruss is reduced then the distance between the longitudinal elements if isotruss decreases so finally moment of inertia of isotruss get reduced and in this condition isotruss is more likely to fail under global buckling (Table 2 and Figure 5 and Figure 6).

Table 2. Critical Buckling load (N)

Bay Length	Diameter 10 cm	Diameter 15 cm	Diameter 20 cm	Diameter 25 cm
10	1491	1389	1282	1123
15	1382	1263	1154	1019
20	1087	1026	956	883
25	956	892	853	793

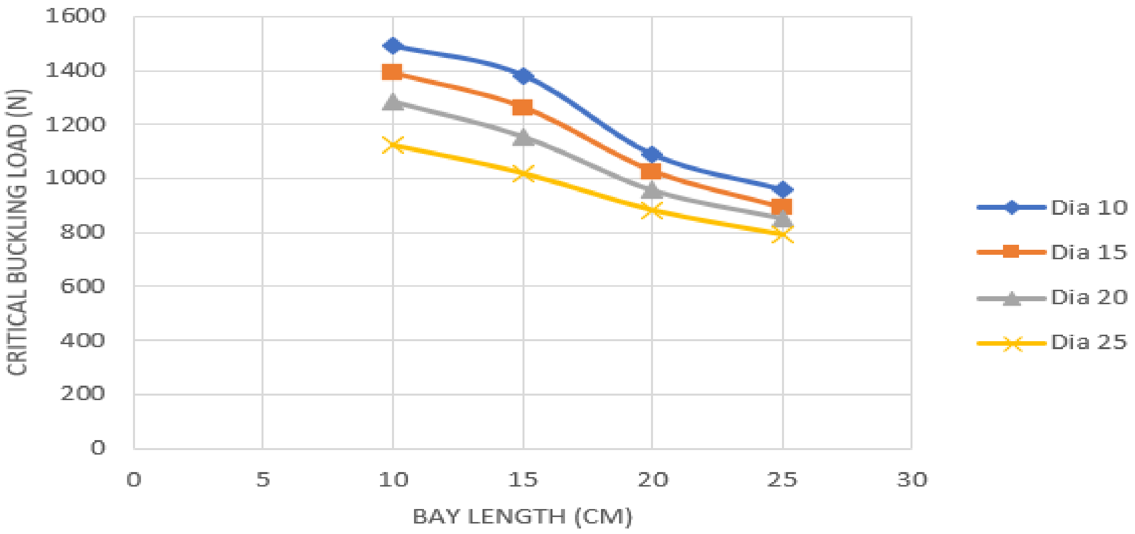

Figure 5. Critical buckling load v/s bay length

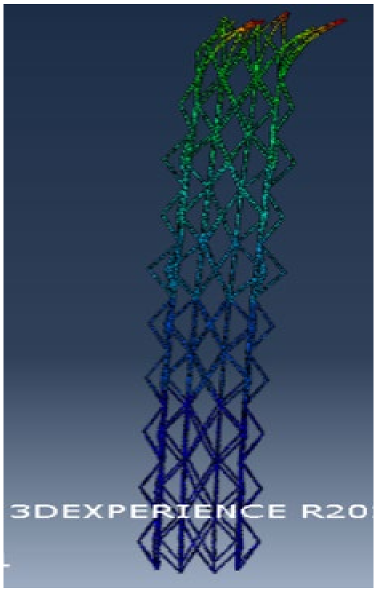

Figure 6. Failure under local buckling.

By keeping the same number of longitudinal elements if diameter of isotruss is increased then it's moment of inertia get increased but the distance between the longitudinal elements increases so isotruss is more likely to fail by local buckling.

6. Conclusions

For same element diameter isotruss with smaller diameter fails in global buckling and with larger diameter fails in local buckling. For higher bay lengths isotruss fails in local buckling. Isotruss with same diameter yields maximum critical buckling load when global buckling observed. From the results it can be concluded that for maximum critical buckling load, bay length will decrease with increase in diameter of isotruss.

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Biographies

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