Numerical Studies on Stability Problems in Thin Walled Laminated Composite Box Beams with Emphasis on Stiffeners

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***Abstract*— The presence of in-plane loading may cause buckling of laminated composite box beams. An accurate knowledge of critical buckling load and mode shapes are essential for reliable and lightweight structural design. This paper presents some parametric studies on stability problems in thin walled laminated composite box beams. Many models were analysed using ANSYS 15. Studies are carried out by changing the fiber orientation in web, laminate thickness. Rotational restraint which prevents distortional buckling an important parameter in this paper. The stiffeners in the box beam reduces the buckling effect.**

Keywords—Buckling , Fiber orientation, laminated composites , Rotational restraint, stiffeners

I. INTRODUCTION

Composite material are becoming increasingly used in structural applications because of their high stiffness and strength-to weight ratios, long fatigue life ,resistance to electrochemical corrosion, wear resistance, attractiveness, thermal insulation, thermal conductivity & acoustical insulation. These are gaining popularity in structural applications such as long span bridge decks, ship deck hulls and superstructure of offshore oil platforms. [1] studied the effects of fiber orientation and loading configuration on the buckling of composite stiffened plates.[2] have given importance to the rotational restraint factor on different support conditions.[3] reviewed the Buckling of laminated composite stiffened panels subjected to in-plane shear .[4] studied the Buckling of Composite Plates

II. METHODOLOGY

In this paper the Finite element package ANSYS 15 have been used. In modelling the laminated composite box beam needs care in defining the properties of the laminated composite, number of layers, symmetrical or unsymmetrical, laminate thickness and fiber orientations of each layer. In this Element type Shell 281 is used, which is designed to model thin plates and shell structures. It is an eight-noded linear shell element with six D.O.F at each node. Those are translation in x, y, z direction and rotation about x, y, z axis. It is well-suited for linear, large rotation, or large strain nonlinear applications.

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A. F.E. Modelling

The element formulation is based on logarithmic strain and true stress measures. For modelling the laminated composite box beam graphite epoxy is used, and its material properties are E1=145000, E2=16500, µ1=0.314, µ2=0.037 & G1=4480. By keeping the breadth of the flange as 250mm, fiber orientation of flange as [0/0/0] s, ratio of breadth of web to thickness of plate as 100 as constant values & by changing the fiber orientation of web, buckling factor is calculated. Many models have been generated with 6 symmetrical layers using ANSYS 15

B. Buckling analysis

The equilibrium displacement of the structure carrying certain external load might become extremely large if the load reaches a critical level and increases further by a tiny quantity. The state at such a critical load level is generally called buckling, and the corresponding load is considered to be the critical buckling load. Buckling failure is usually caused by elastic instability. Due to thin-walled configurations, and plate/shell structures are more likely to buckle under compressive loads. External load usually represents nonlinear relationship with the structural deformation in buckling phase A 3D finite element model of thin walled composite box-beam as shown in fig 1 is developed in ANSYS 15 & Eigen-buckling analysis is performed . The buckling factor for different laminate thickness is analysed with different fiber orientation in web by keeping fiber orientation in flange as constant in ANSYS 15 is tabulated in Table 1. Fig 2 shows how the buckling factor is influenced by laminate thickness.

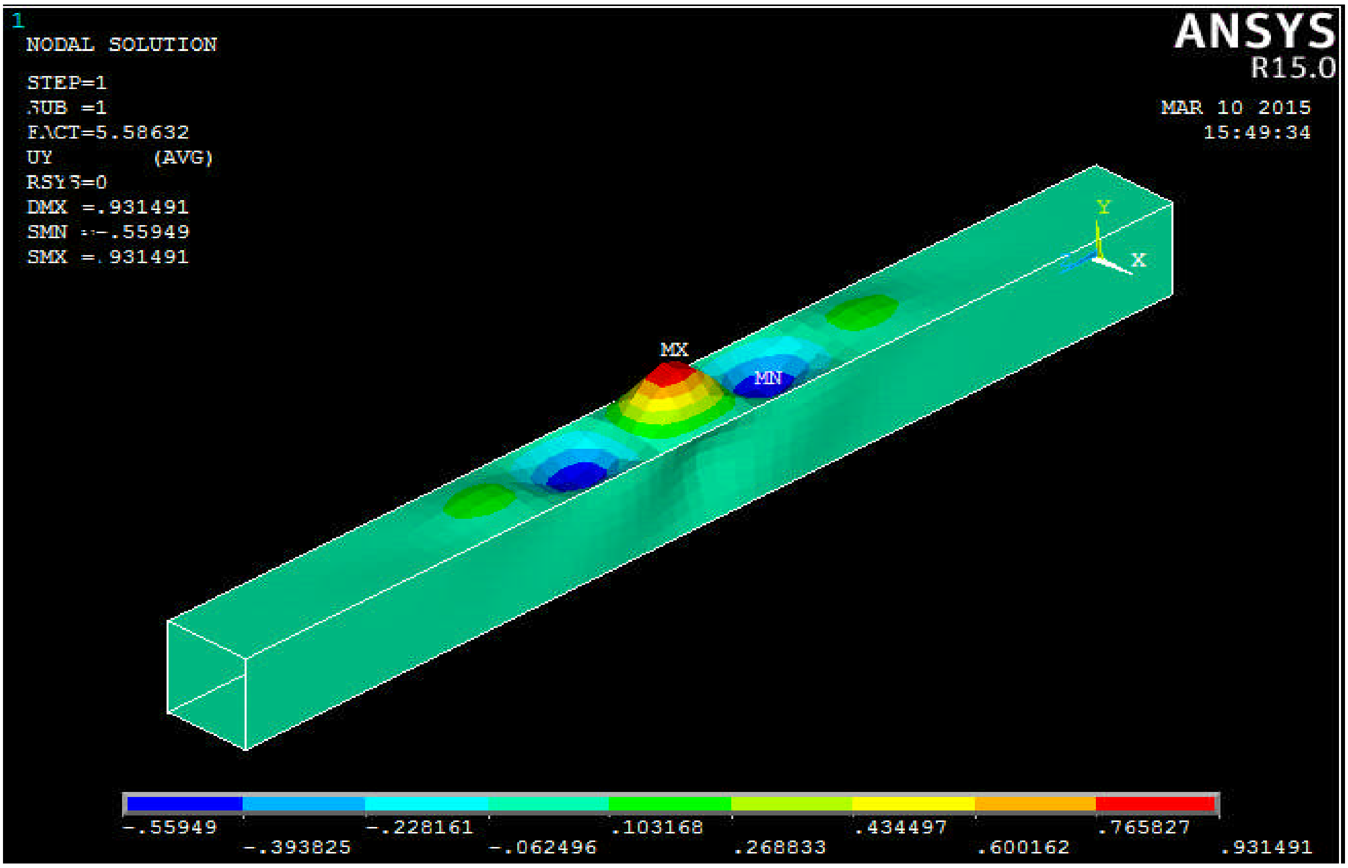

Fig 1 A 3D finite element buckled model of thin walled composite box-beam

Table1 Buckling factor for different fiber orientation.

S No	Fiber Orientation	Bucking Factor Laminate th (mm)			
		2	3	4	6
1	[0/0/0]	1.139	5.586	16.413	44.095
2	[90/90/90]	1.759	6.023	13.025	24.4
3	[45/-45/45]	1.891	9.946	18.808	56.27
4	[0/45/0]	1.26	5.697	16.88	47.102
5	[0/90/0]	1.537	7.54	20.64	57.6

Also from fig 2 it is clear that buckling factor is increased with laminate thickness and it is maximum when the fiber orientation is [45/45/45/]s up to 3 mm thick laminate and maximum when fiber orientation is [0/90/0]s above 3mm

C. Rotational restraint γ

One of the important parameter considered in this paper is Rotational restraint/Warping restraint which prevents the rotation of the flange in its plane. and rms do not have to be

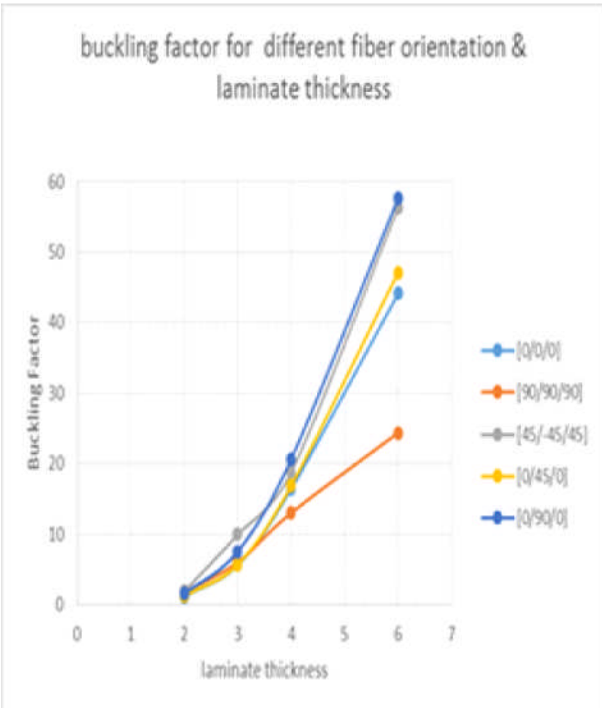

Fig 2 Effect of laminate thickness (mm) on the rotational restraint.

Rotational restraint ɣ

Rotational restraint $\gamma = \frac{D22\ flange}{D22\ web}$ (1)

Where, $D_{22} = \frac{1}{3}\sum_{k=0}^{n}[Q22^{'}](Z_k^3 - Z_{k-1}^3)$ (2)

D_{22} is the Bending Stiffness

Q'_{22} is the transformed reduced matrix

Z_k is the distance of the K^{th} ply to the middle of the laminate thickness

Rotational restraint is maximum for the fiber orientation [0/0/0/0/0/0] and it is minimum for [90/90/90/90/90/90] in web by keeping the fiber rotation of the flange as constant. Rotational restraint is the ratio of bending stiffness of the flange to the bending stiffness of the web. . There are three potential modes of instability local, distortional, and global buckling in structural components. Rotational restraint may prevent or retard distortional buckling. It is necessary to quantify the available rotational restraint against distortional buckling so that it may be used in design. The bending stiffness which depends on the thickness of the each ply and This factor can be very predominant in laminated composite beams. Fig 3 shows how the fiber orientation in web causes changes in the Buckling factor

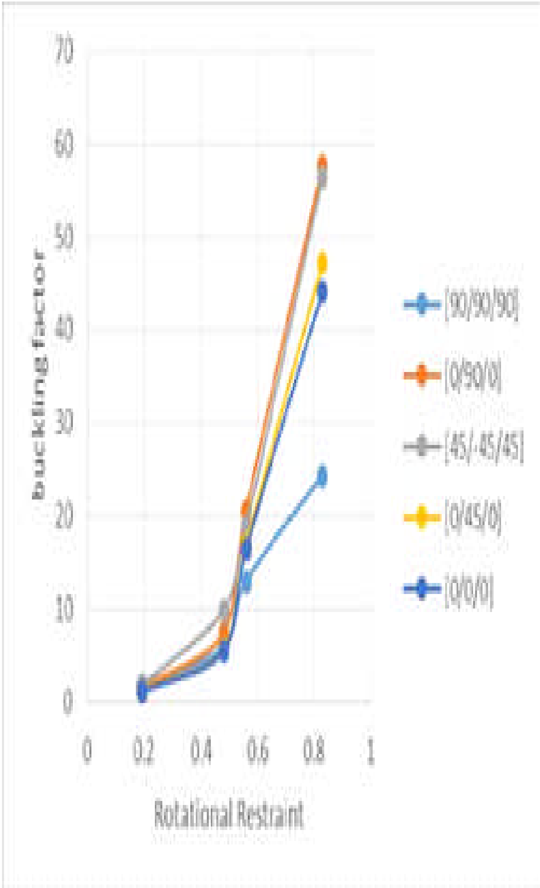

Fig 4. The effect of rotational restraint factor on buckling

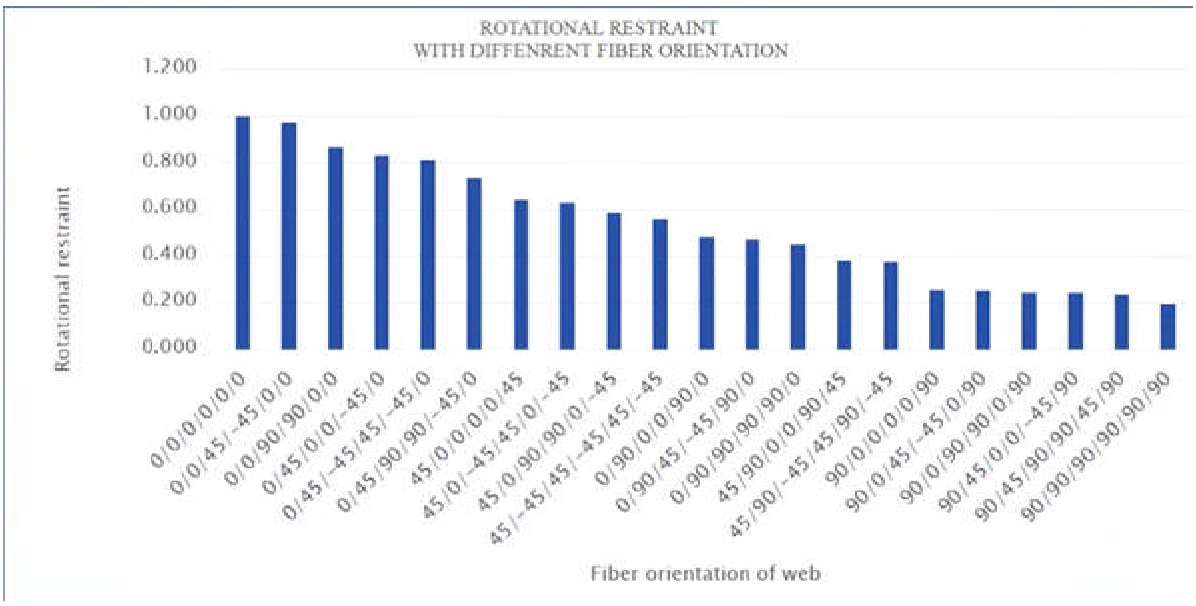

Fig 3 Rotational restraint with different fiber orientation

D. Addition of stiffeners

Another important factor in this paper is the reduction of buckling factor by introducing the stiffeners inside the surface of laminated box beam longitudinally. The dimensions of the box sections are 300 mm square with a varying length of 600 mm to 1300. Single longitudinal blade stiffeners is located at center on the inside surfaces of each wall of the box and the lay-up configuration of the structural assembly is [(0/90),],. The skin and stiffener laminates are thus of cross-ply symmetric arrangement with 6 plies, giving a laminate thickness of 3 mm. A point load of 5 kN is applied.

The buckling factor is highly influenced by the addition of the stiffeners. Fig 5 shows the isometric view of buckling effect of the laminated box beam with stiffeners .Fig 6 shows the front view of the bucked box beam with stiffeners

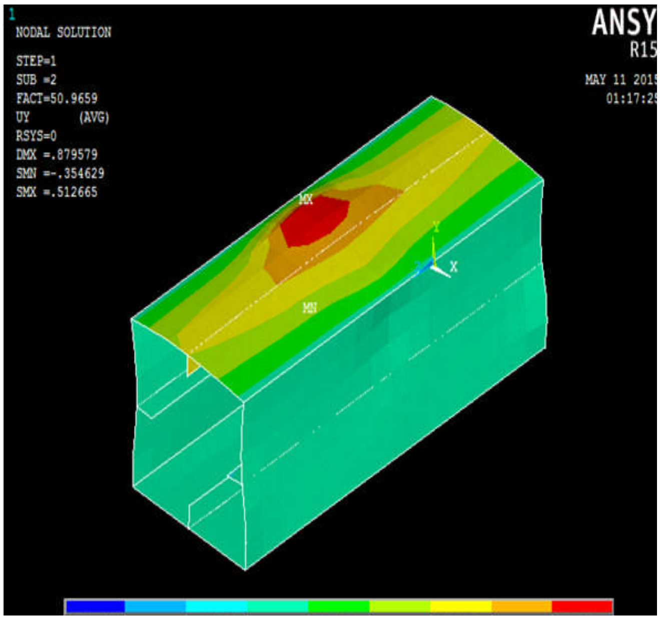

Fig 5 Buckling of box beam with stiffeners

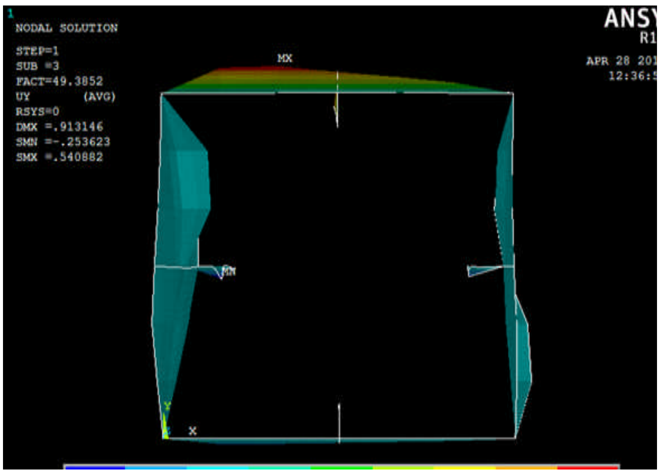

Fig 6 Front view of the buckled box beam with stiffener

The stiffener have great influence on the buckling of slender laminated box beams .Fig 7 shows comparison of buckling factor of the box beam with and without the stiffener Fig 8 shows how the buckling factors of box beam is influenced with various stiffener depth

Fig 7 Comparison of buckling factor of the box beam with and without the stiffeners

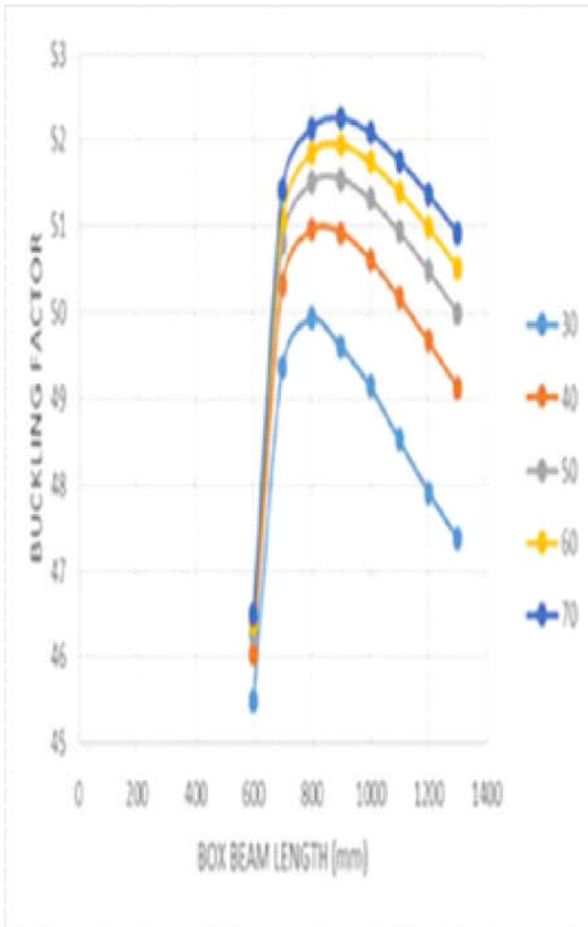

Fig 8 Buckling factors of box beam with various stiffener depth

III .CONCLUSIONS

- The buckling load is an important parameter in the analysis of the laminate composite box beam as the laminated composites are very slender in sections
- The buckling factor is increased with increase in laminate thickness and buckling factor is maximum for fiber orientation of [45/-45/45] s up to 3mm thickness. and maximum for fiber Orientation of [0/90/0]s above 3mm thickness
- Rotational restraint is maximum for [0/0/0] s
- and minimum for [90/90/90]s. it is an important factor which reduces the torsional buckling.
- Buckling factor is almost 3.5 times more in laminated box beam with stiffeners as compared to the box beam without stiffeners.
- By the addition of stiffeners the buckling factor is increased with the increase in the length of the box beam when the ratio of depth of stiffener to the length of the box beam is between .0375to .06 ,then buckling factor is maximum, afterwards it reduces.

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