STUDY ON LATERAL TORSIONAL BUCKLING BEHAVIOUR OF BEAM SECTIONS

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Abstract: The aims of the designers are safety, functionality and economy. The structure must not fail locally or overall. Although safety of the structure is very important, the economy should also be considered which plays a vital role in the design of the structures. Economy is a major factor, which demands the effective use of the resources and it is for this reason there has been a relentless effort for steel.

The aim and scope of this study are:

- To study the Lateral torsional buckling behavior of beam sections.
- Development of an ANSYS model and performing Finite Element Analysis to predict the lateral torsional buckling.
- Development of a Design charts for computing elastic critical moment (Mcr).
- Comparison of ratio of elastic critical moment (Mcr) and bending strength (Md) values for beams with different sectional parameters.
- Performing a co-relation study for different sections with different length

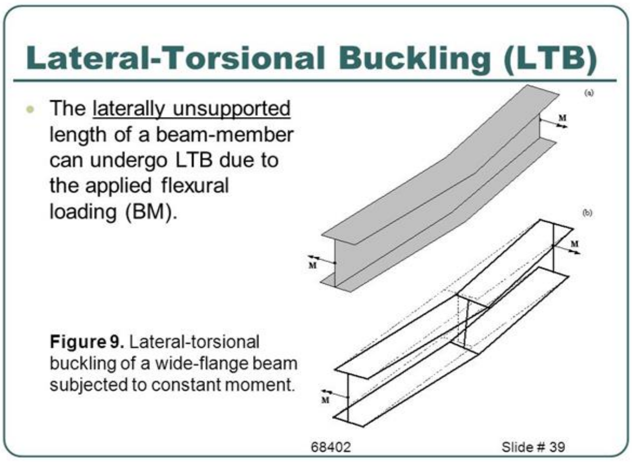
***IndexTerms* –Lateral Torsional Buckling, Steel Structures, Ansys.**

I. INTRODUCTION

Metals such as mild steel, stainless steel and aluminum have a wide range of applications in building structures for their high strength-to-weight ratios. In the process of structural design, engineers need to consider the effects of instability. It is common to note that many structural failures and collapses are due to structural instability which is more difficult and complex to consider than material yielding in the design context.

Beam is a flexure member and when it is adequately supported against lateral buckling, the beam failure occurs by yielding of the material at the point of maximum moment. The beam is thus capable of reaching its plastic moment capacity under the applied loads. Thus the design strength is governed by yield stress and the beam is classified as laterally supported beam. When a beam is un braced against lateral deflection and twisting, they are vulnerable to failure by lateral torsional buckling prior to the attainment of their full in plane plastic moment capacity. Such beams are classified as laterally un supported beam

Lateral torsional buckling: Lateral-torsional buckling is the simultaneous out-of-plane deflection and twisting of the beam without deformation of the cross section. Long beams generally buckle in a lateral-torsional buckling (LTB) mode. Lateral torsional buckling occurs when the compression portion of cross section is restrained by the tension portion and the deflection due to flexural buckling is accompanied by torsion or twisting. For laterally unrestrained beams under predominant bending moments, the failure mode tends to be lateral-torsional buckling. As a result, the member load resistance will be greatly reduced and the collapse may occur suddenly before or after material yielding.When a beam fails by lateral torsional buckling, it buckles about its weak axis, even though it is loaded in strong plane. The lateral-torsion buckling is characterized by the mode of rigid body movements of the whole member in which individual cross-sections rotate and translate but do not distort in shape. To prevent such structural failure, the buckling phenomenon has to be studied. The expression for critical moment (Mcr) given in IS:800-2007 is only for doubly symmetric sections.



II. LITERATURE REVIEW

The basic differential equation governing Lateral torsional buckling (Euro code 3) is

$$EI_W \frac{d^4\emptyset}{dx^4} - GI_t \frac{d^2\emptyset}{dx^2} - \frac{1}{EI_Z} M_y^2 \emptyset + \frac{1}{EI_Z} M_y M_z = 0$$

With

$$\frac{dM_y}{dx} = V_z \; ; \; \frac{dV_z}{dx} = -q_z \; ; \; \frac{dM_z}{dx} = -V_y \; ; \; \frac{dV_y}{dx} = 0$$

Where q_z is the distributed load acting on the beam, V_y and V_z are the shear forces, M_y and M_z are the bending moments and $\emptyset$ is torsion deformation. In order to be able to impose appropriate boundary conditions at supports, the internal shear forces and the bending moment components in above two equations are referred to the axis in the un deformed configuration.

An exact solution for above equations is obtained for a double symmetric beam with simply supported conditions, free warping and subjected to a uniform moment diagram. i.e,

The elastic critical moment is

$$M_{cr} = \frac{\pi^2 EI_z}{L^2} \sqrt{\frac{I_w}{I_z} + \frac{L^2 GI_t}{\pi^2 EI_z}}$$

Once the elastic critical moment for the basic case has been obtained, it is multiplied by the equivalent uniform moment factor, C_1, to take into account the actual bending moment diagram. Thus, the value of M_{cr} may be computed by the expression

$$M_{cr} = C_1 \frac{\pi^2 EI_z}{(k_z L)^2} \left\{ \sqrt{\left(\frac{k_z}{k_w}\right)^2 \frac{I_w}{I_z} + \frac{(k_z L)^2 GI_t}{\pi^2 EI_z}} \right\}$$

Where the lateral torsional bending coefficient k_z and the warping coefficient k_w are introduced to consider support conditions different from the simply supported beam.

These coefficients are equal to 1 for free lateral bending and free warping and 0.5 for prevented lateral bending and prevented warping

ANALYTICAL STUDIES ON LATERAL TORSIONAL BULKING OF BEAM

Serna et .Al.(2006) Studied the equivalent uniform moment's factors for lateral torsion buckling of steel beams, and proposed a closed-form expression for the equivalent uniform moment factor (c_1) applicable to any moment distribution. The proposed formula incorporates the end support conditions through a parameter related to the lateral torsion buckling length of the beam.

Cheng et. Al. (2006) Studied Lateral buckling of laterally-unrestrained aluminum beams subjected to a concentrated, uniformly loading and pure-bending action. The design methods of lateral stability of aluminum beams in the current codes are discussed. The influence of material property on the lateral buckling of aluminum beams is investigated with finite element analysis (FEA) methods. The design method on lateral stability of steel beams specified in the Chinese standard GB50017-2003 is modified to calibrate the stability factors of aluminum beams according to the European code, British code, and American code.

Andrade et. Al (2007) Studied Lateral-torsion buckling behaviour of singly symmetric web-tapered thin-walled I-beams, addressed the most relevant procedures involved in the LTB analysis of thin-walled open beams by the FEM. Presented the results of the comparative study based on one dimensional model and two-dimensional shell finite element modelling using commercial code ANSYS.

Kati et. Al (2008) The Studied bending behavior of unbraced castellated steel beam is investigated and some empirical equations are proposed to predict the bending coefficient of Cb. The acquired results are compared with some published papers in the technical literature, and by applying the proposed modification factor Cc on the relations of I-sections.

Korrani and Molanaei et. Al (2010) Developed a three-dimensional finite-element model using ANSYS for the inelastic nonlinear flexural-torsion analysis of I-girder and used it to investigate the effects of the corrugation profiles of the web on the lateral-torsion buckling strength. All I-girders are simply supported and models flange are constant but webs used of I-girder are different, critical moment of beams have calculated and compared.

Nandini and kalyanaraman et. Al (2010) Developed ANSYS software based on finite element analysis is used to analyze the interaction behavior of local, distortional and lateral torsional buckling modes in this study. The finite element model, after calibration with experimental results available in the literature, is used to perform parametric studies, to evaluate the behavior and strength of such beams under different types of interactions due to variation of material and member properties. The large volume of synthetic data thus generated over a range of failure modes along with the available test results are used to evaluate different equations and calculations of lateral torsional buckling.

M. S. Ahmed et. Al(2011) Developed ANSYS software was employed to derive the finite element model to determine the natural frequencies and mode shapes of the slabs. Then, the obtained results through numerical analysis (finite element analysis) would be compared with the exact solution. The main goal of the research study is to predict how the boundary conditions change the behavior of the slab structures prior to performing experimental modal analysis. Based on the results, it is concluded that simply support boundary condition has obvious influence to increase the natural frequencies and change the shape of the mode when it is compared with freely supported boundary condition of slabs. This means that such support conditions have the direct influence on the dynamic behavior of the slabs. Thus, it is suggested to use free-free boundary condition in experimental modal analysis to precisely reflect the properties of the structure.

III. METHODOLOGY

The analysis of lateral torsion buckling in various ways such as analytically, experimentally, manually by using some software's etc. So, referring from all these papers some steps to be taken to analyze lateral torsional buckling of steel some such as Design of steel structures Limit design beam by using Indian Standard codes IS 800:2007.In which ANNEX E gives the formulae for the calculation of elastic critical moment which is useful to calculate the effect of lateral torsional buckling in terms of moment. From all this one problem of simply supported of different span with apply unit end moment. This calculation is done by manually by using procedure which is given in of steel structure, Design of steel structures(BY SUBRAMANYAM).From this calculation of elastic critical moment manually. Analyze the beam by using ANSYS SOFTWARE in which design the steel section by using some methods such as directly take the section from section menu which is given left side of the ANSYS programme give their properties then analyze the beam by applying uniformly distributed load. Analyze the various effects such as shear force, bending moment, and critical moment. This critical moment values are compared with the manually calculations.

IV. MODELING

ANSYS software is a comprehensive finite element analysis (FEA) tool for structural Analysis, including linear, nonlinear, dynamic, hydrodynamic and explicit studies. It provides a Complete set of elements behavior, material models and equation solvers for a wide range of Mechanical design problems. Using ANSYS software solutions, you can import geometries of complex assemblies, optimally mesh them, and apply realistic boundary conditions. Following these preprocessing steps, you can perform analyses to assess the strength, vibration, motion and thermal response characteristics of the system. A variety of graphical tools allow you to easily visualize the results of your simulation, showing you how best to modify your design and optimize your product so you can get it to market quickly.

Element type: 2 node 189
Boundary conditions: simply supported   Loading: Unit End moments
Young's modulus of steel (E): 2.1×10^5 N/mm^2
Poisson's ratio (υ): 0.3

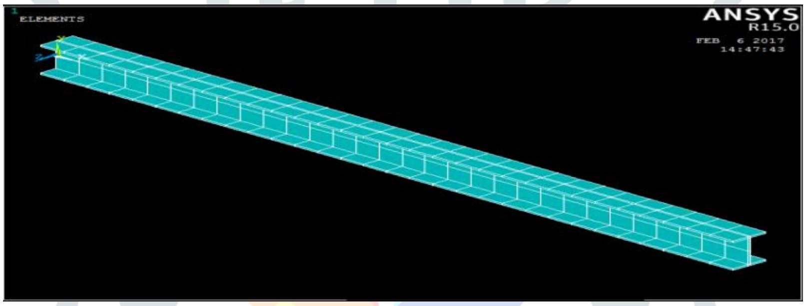


Fig:1 Modelling of I-Section

MESHING:

Basic meshing is a two-stage operation:

1. seeding the edges of the part instance, and then
2. Meshing the part instance.

We have to select the number of seeds based on the desired element size or on the number of elements that we want along an edge, and ANSYS places the nodes of the mesh at the seeds whenever possible

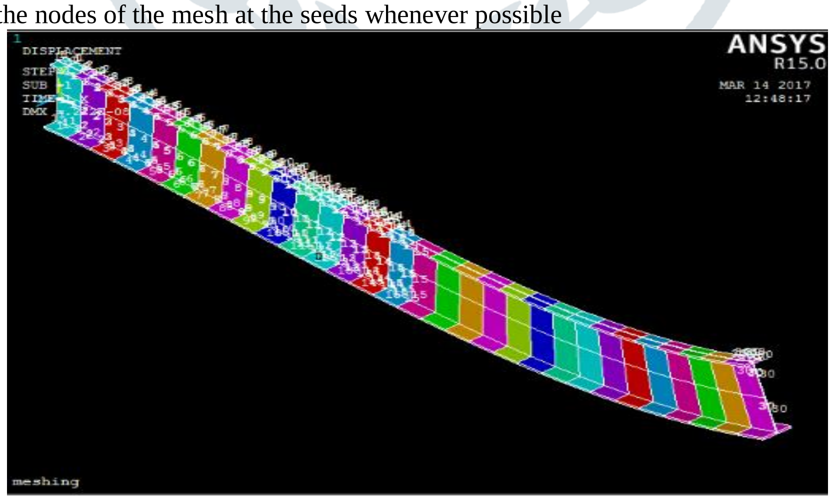


Fig:2 Meshing of I-Section

SOLUTION:

The modeling of the beams are done using eight-node doubly curved quadrilateral thick beam element having six degrees of freedom per node proper care is taken to discredited the plate elements of beam to avoid ill-conditioned elements. Discretization of the model is done in accordance with the mesh obtained from the convergence study. All nodes along the bottom edge of one side of the beam are restrained in longitudinal direction i.e. X-direction of beam. In order to arrest the displacements vertically, all nodes of bottom two edges of the beam are restrained in vertical direction i.e. Y- direction. To arrest the beam displacement laterally, two edges of the beam are restrained laterally i.e. in Z-direction. Two equal and opposite end moments are applied at web flange junctions of both edges of the beam as buckling shown in

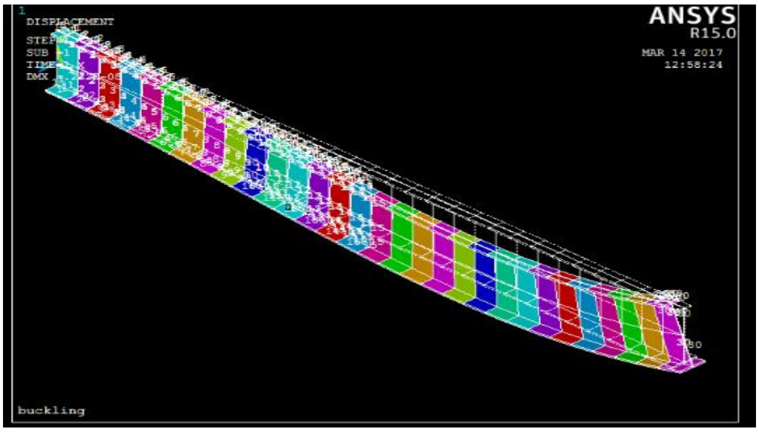


Fig:3 Buckling Of I-Section

V. RESULTS AND DISCUSSION

DOUBLY SYMMETRIC BEAMS

Problem Description: The present study deals with buckling analysis of a laterally unrestrained simply supported doubly symmetric I-beam subjected to equal end moments using ANSYS, and comparison of the Mcr from IS-800. The beam sections taken for this study are ISMB 125, ISMB 225, ISMB 300, ISMB 350, ISMB 400, and ISMB 450 with varying lengths

Table 1 Material properties for the beam models

Young's modulus for beam (E), N/mm^2	Yield stress for beam (f_y), N/mm^2	Poisson ratio (υ)	Partial safety factor for material (γ_{m0})
$2x10^5$	250	0.3	1.1

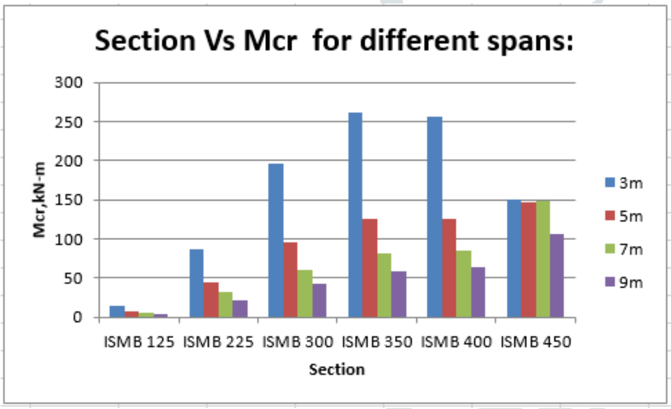


Fig: 4 Section Vs M_{cr} for different spans

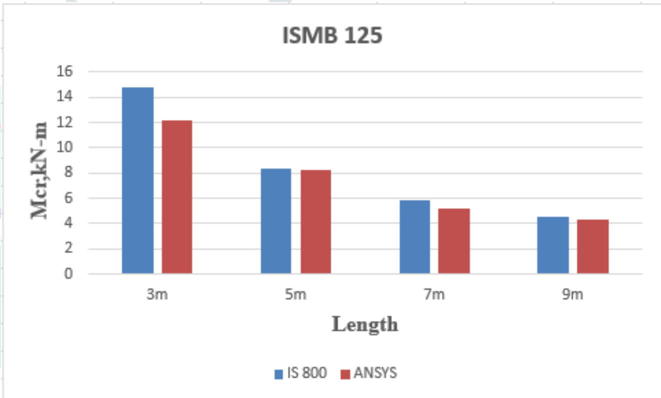


Fig: 5 Length Vs M_{cr} for different spans at ISMB 125

Fig: 6 Length Vs $M_{cr}$for different spans at ISMB 225

Fig: 7 Length Vs M_{cr} for different spans at ISMB 300

Fig: 8 Length Vs M_{cr} for different spans at ISMB 350

Fig: 9 Length Vs M_{cr} for different spans at ISMB 400

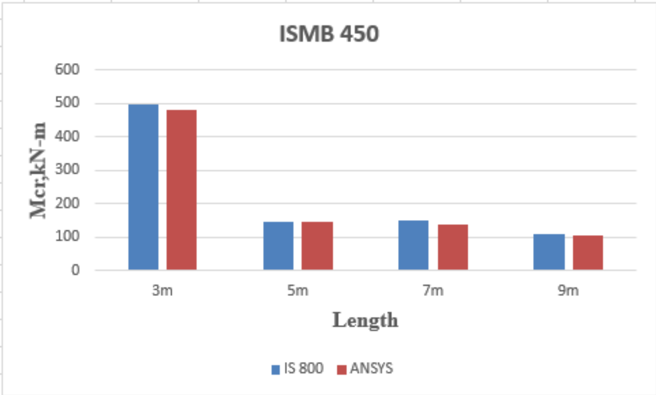


Fig: 10 Length Vs M_{cr} for different spans at ISMB 450

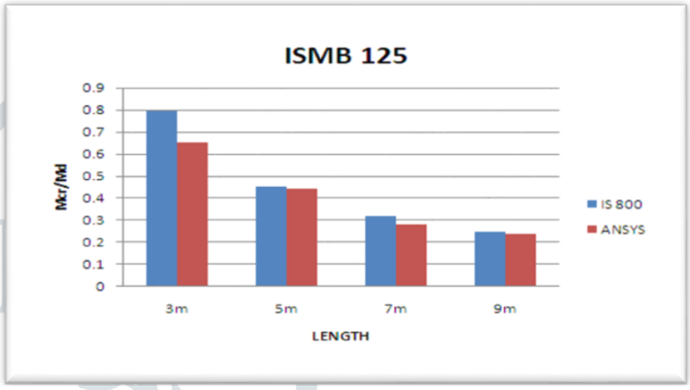


Fig: 11 Length Vs M_{cr}/M_d for different spans at ISMB 125

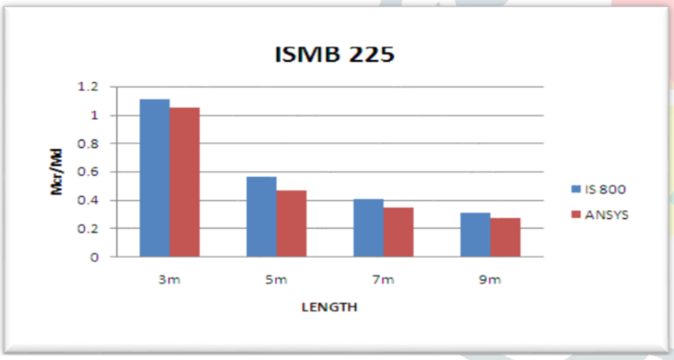


Fig: 12 Length Vs M_{cr}/M_d for different spans at ISMB 225

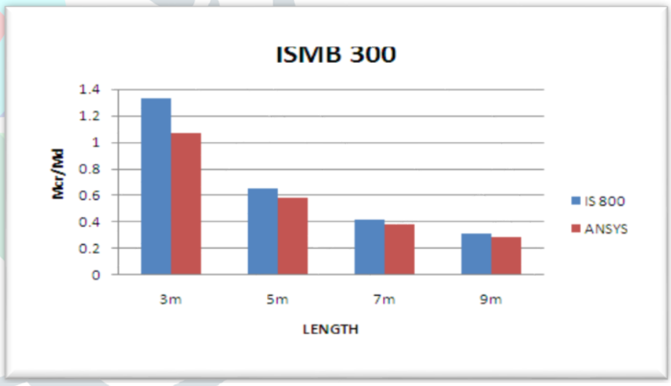


Fig: 13 Length Vs M_{cr}/M_d for different spans at ISMB 300

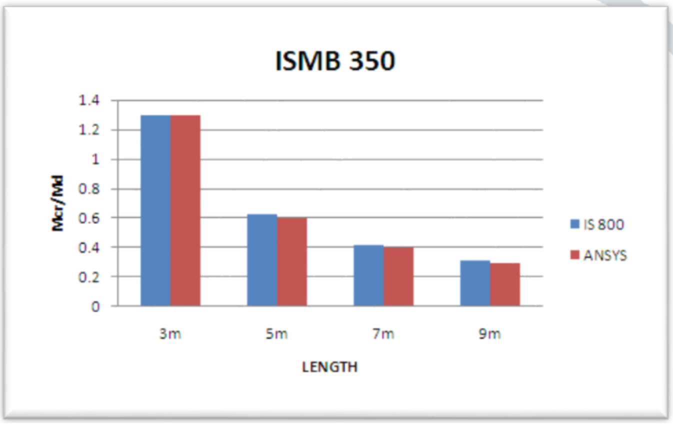


Fig: 14 Length Vs M_{cr}/M_d for different spans at ISMB 350

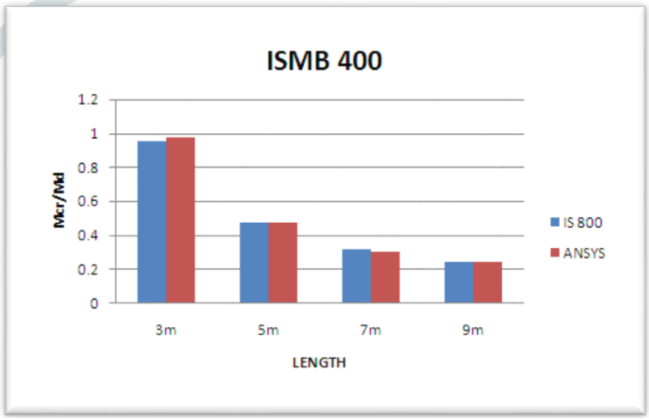


Fig: 15 Length Vs M_{cr}/M_d for different spans at ISMB 400

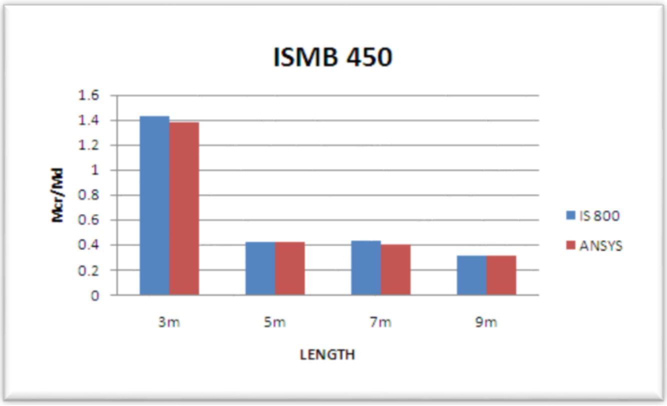


Fig: 16 Length Vs M_{cr}/M_d for different spans at ISMB 450

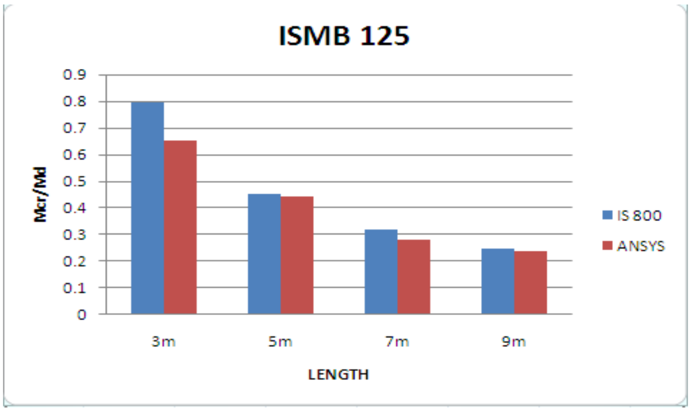


Fig:17 M_{cr}/M_d for ISMB 125 with different spans

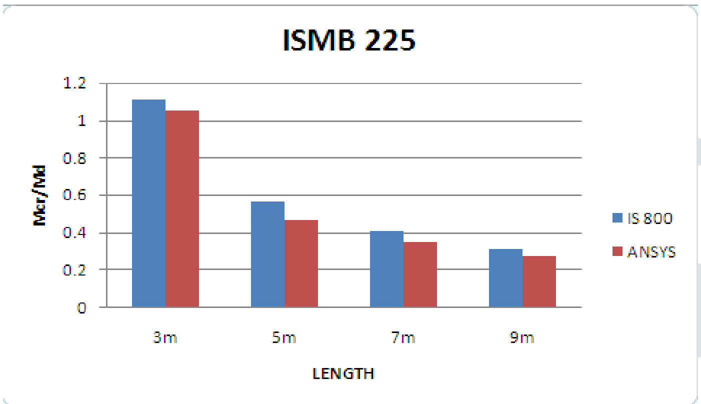


Fig: 18 M_{cr}/M_d for ISMB 225 with different spans

Fig:19 M_{cr}/M_d for ISMB 300 with different spans

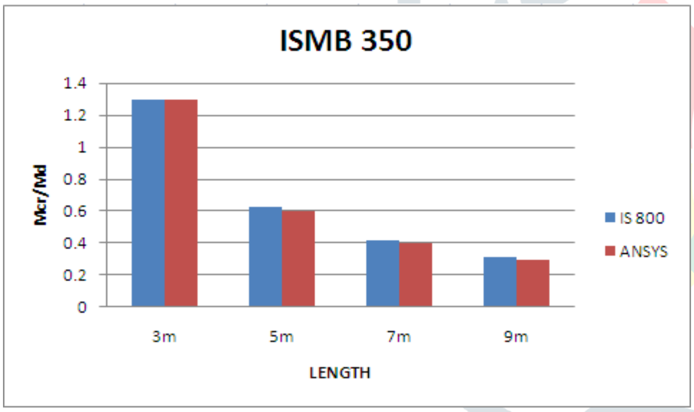


Fig: 20 M_{cr}/M_d for ISMB 350 with different spans

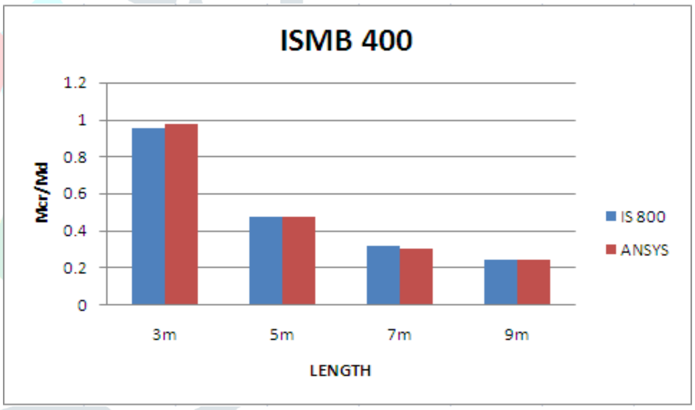


Fig: 21 M_{cr}/M_d for ISMB 400 with different spans

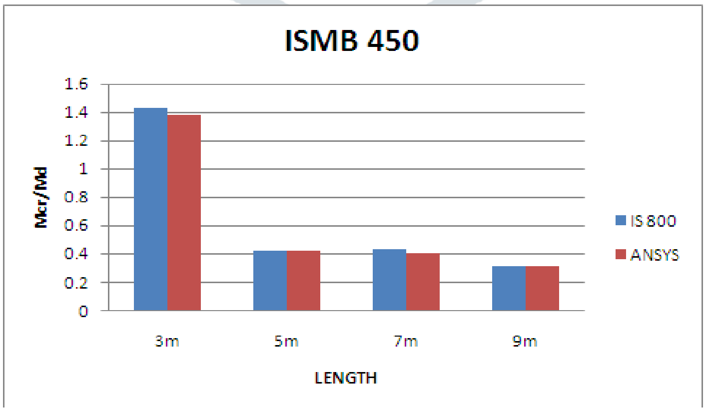


Fig: 22 M_{cr}/M_d for ISMB 450 with different spans

VI. CONCLUSIONS

- It is clear from the values obtained that the Elastic critical moment reduces with increase in length and vice versa.
- The Expression for calculating M_{cr} of a doubly symmetric section from IS-800 is in safe side, whereas the expression for calculating M_{cr} of a mono-symmetric section from IS-800 is over estimating the buckling capacity of the beam.
- By using graphs obtained, the mode of failure can be judged for given section and spans. And the type of section required for given span and failure condition can be selected.

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