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Study of Buckling Behaviour of Beam and Column Subjected To Axial Loading for Various Rolled I Sections

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ABSTRACT: In this paper the buckling behaviour of an I - beam under axial load on column and beam is examined. Buckling loads are critical loads where certain types of structure become unstable. The results of an extensive parametric study are presented in graphical form and summarized by simple design curves and evaluating the effect of critical buckling load for various symmetrical rolled I - sections like Indian Standard Junior Beam (ISJB), Indian Standard Light Weight Beam (ISLB), Indian Standard Medium Weight Beam (ISMB), Indian Standard Wide Flange Beam (ISWB), Indian Standard Heavy Weight Beam (ISHB) for different depth are calculated by using software Ansys. The results of critical buckling load calculated using Ansys are compared with the conventional method of Euler Buckling theory analytically.

KEYWORDS: Euler Buckling, Finite Element Analysis, Beams, Columns, Axial Loading, Critical Buckling Load.

I. INTRODUCTION

Buckling is a phenomenon which occurs in structures which are stiff in the loaded direction and slender in another direction. Initially equilibrium is stable but when the load is increased there is a sudden increase in deflection in loading direction due to a displacement in the slender direction. This is at the location of the bifurcation point. For structural behaviour this is a very important point because it is for slender constructions often governing and the plastic or elastic cross-sectional capacity is not reached. When buckling does not occur at a certain load level, a structure is considered stable.

The commonly used hot rolled and built up steel compression members, due to small thickness of the constituting elements, are prone to excessive flexural deformation and may fail by flexural buckling. Sometimes a type of buckling are called *Local Buckling* [1] characterised by wrinkling at isolated locations occurs wherein some thin portions of the cross section of a member buckle locally in compression before other modes of buckling can occur. In such a situation, the cross section is no longer effective and the member may fail. As a typical example, thin flange and web elements of an I - shaped cross section may individually buckle locally resulting in failure of column.

Finite Element Method: - Finite element method (FEM) has a powerful tool for the numerical solution of a wide range of engineering problems. In this method of analysis, a complex region defining a continuum is descretized into simple geometric shapes called finite element. The material properties and the governing relationship are considered over these elements and expressed in terms of unknown values at element corners. An assembly process duly considering the loading and constraints result in a set of equations. Solution of these equations gives us the approximate behavior of the continuum.

Euler Buckling analysis:

Buckling of axially loaded beam and column is given by Euler buckling formula [38]. The critical buckling load 'P_{cr}' for columns is theoretically given by Eq. (1)

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$$P_{cr} = \frac{\pi^2 E\,I}{(K\,L)^2} \qquad (1)$$

Where, I = Moment of inertia about axis of buckling.
K = Effective length factor based on end boundary condition of compression members.
E = Modulus of elasticity.
L = Length of member

II. BEHAVIOR OF COMPRESSION MEMBERS

The susceptibility of compression member to local buckling is usually governed by width to thickness ratios of the parts of the cross sections; hence, can be prevented by providing suitable width to thickness ratios for the element parts of the cross – sections [4]. On the other hand, when an axially loaded compression member becomes unstable in its entirety, it is called *overall instability* [19]. In addition to local buckling, there are three general modes of failure of axially loaded steel members, namely flexural buckling, torsional buckling and flexural torsional buckling, as well as for overall buckling; general modes of failure of axially loaded steel members are namely lateral buckling and laterally torsion buckling. These buckling modes may be defined as follows:

1. Flexural buckling: - Flexural buckling is also called Euler Buckling. It is the primary type of buckling wherein members subjected to bending or flexural action became unstable due to deflection about the axis having smallest radius of gyration, i.e. largest slenderness ratio.
2. Torsional Buckling: - Torsional buckling consists in failure of compression member of certain configuration twisting or torsion about the longitudinal of the member. This type of buckling may occur when the torsional rigidity of member significantly smaller than its flexural rigidity. Thin walled members with open cross sections are particularly susceptible to torsional buckling. The possibility of occurrence of the complex buckling can be significantly reduced by providing sufficient end supports and intermediate lateral restraints [18].
3. Flexural Torsional Buckling: - It consists in failure of compression members of certain configuration by a combination of flexural buckling and torsional buckling due to simultaneous bending and twisting of the section. This type of buckling may occur in the members having unsymmetrical cross section including those with one axis of symmetry such as channels, structural tees, double angles and those without any axis of symmetry and unequal legs single angle sections.
4. Lateral Buckling: - The lateral buckling involves three kinds of deformation, namely, lateral bending, twisting and warping; it is feasible to think of various types of end conditions. But the supports should either completely prevent or offer no resistance to each type of deformation. Solutions for partial restraint conditions are complicated [15].
5. Laterally Torsional Buckling:-When the in-plane compressive load acting on a plate is increased gradually, it continues to supports loads up to a maximum; at this load it deflects laterally and assumes more than one deflected shape without disturbing the equilibrium [2]. This out of plane deflection is called *buckling* and the corresponding buckling is called *critical buckling load*. At that instant, the section is in equilibrium in either a straight and bent configuration. As soon as the critical load is exceeded, the section fails in buckling, i.e. in excessive bending. Similarly, a column which is treated as one dimensional line element, represented by its centroidal axis of line may assumes that more than one bent configuration without disturbing the equilibrium at the critical or buckling load. The bent configuration is always about the weaker axis of the sections. If the buckling is prevented by the weaker axis, there will be another higher load under which the column may assumes different bent configurations about the minor and major axis without disturbing the equilibrium. When buckling occurs the whole length of the column may participated in buckling, known as *general or overall buckling* [21].

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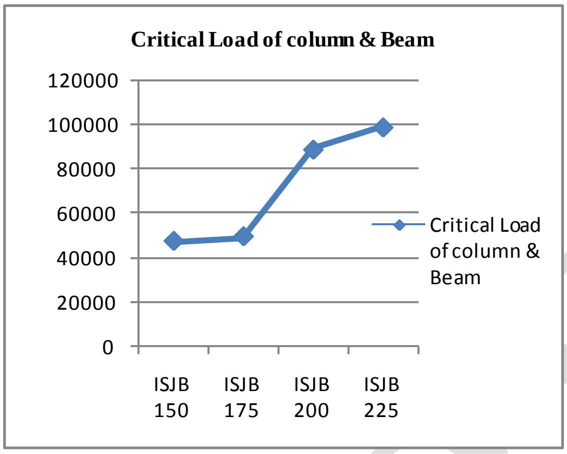
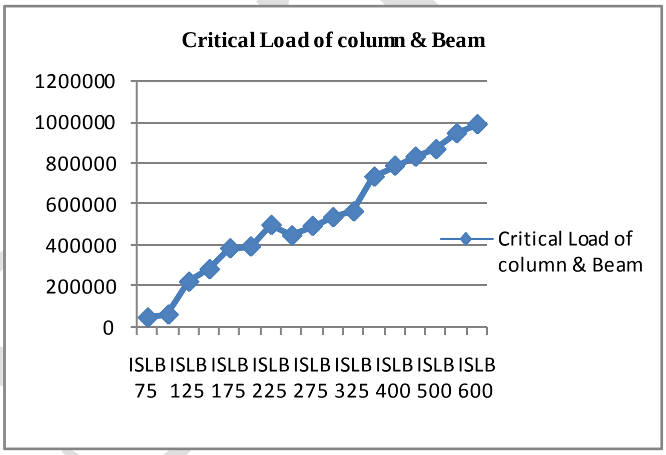
III. PROBLEM STATEMENT

In this study, cantilever beam (I-section) is selected. Analysis of various I sections (i.e. ISJB, ISLB, ISMB, ISWB, ISHB) was carried out in ANSYS. All the sections were run for spans of 1m in ANSYS as well as the results for Pcr were obtained by Ansys as well as conventional method that are Euler Buckling Formula in spreadsheet.

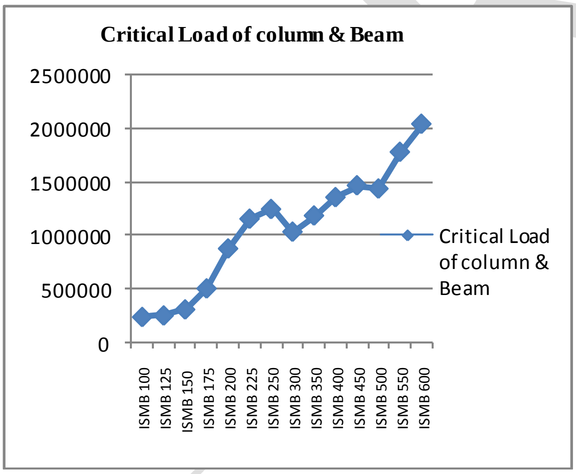
IV. RESULT AND DISCUSSION

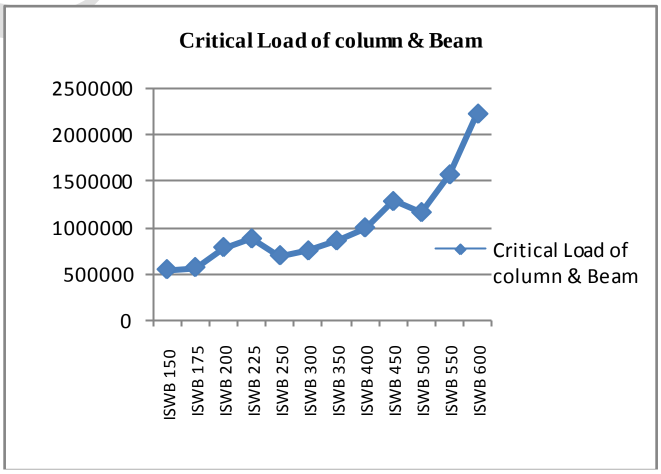
After analysing cantilever I - steel column and beam, critical buckling load using ansys of various I sections like Indian standard junior beam, long beam, medium beam, wide flange beam and heavy weight beam. Also comparative study of critical buckling load using ANSYS software and Euler buckling formula has done. Parametric curve of all column and beam is as shown below:





Graph 1. Critical Load Of Column & Beam For ISJB And ISLB





Graph 2. Critical Load Of Column & Beam For ISMB And ISWB

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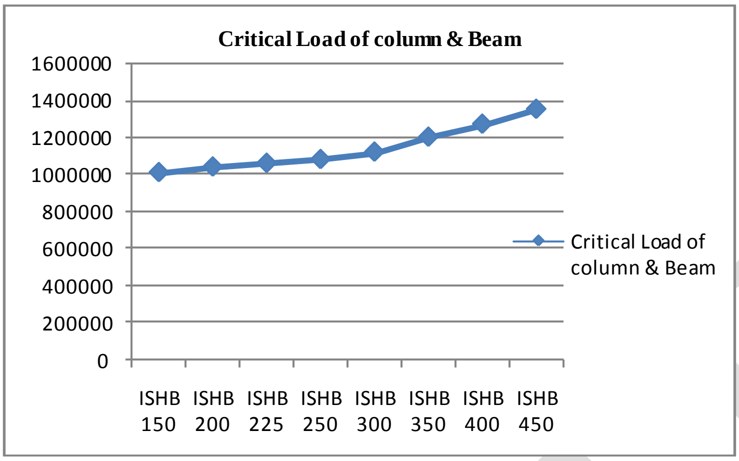
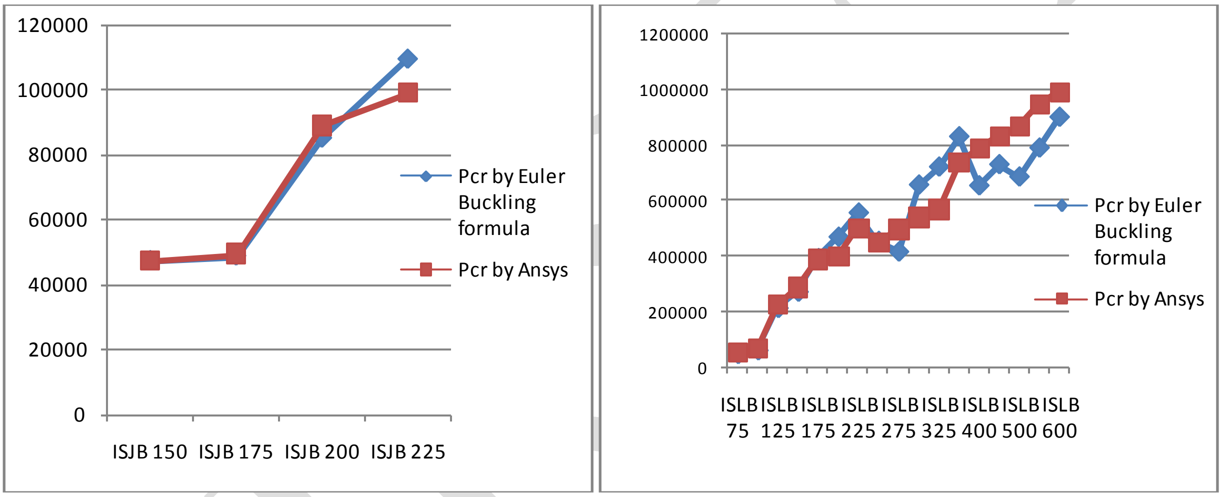
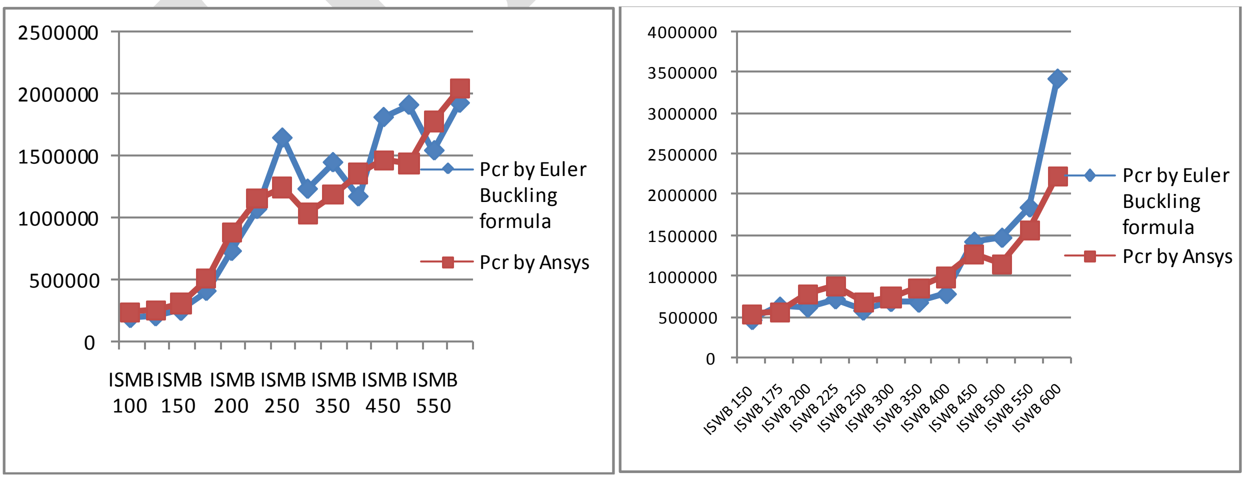


Graph 3.Critical Load Of Column & Beam For ISHB



Graph 4. Comparison Of Critical Load Using Ansys And Euler Buckling Formula For ISJB And ISLB



Graph 5. Comparison Of Critical Load Using Ansys And Euler Buckling Formula For ISMB And ISWB

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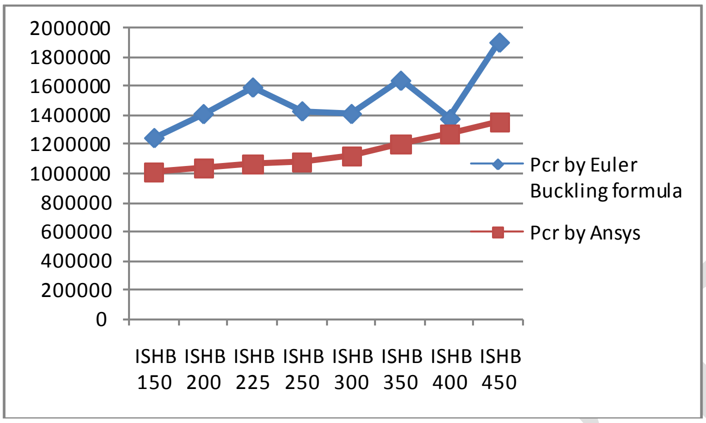

Graph 6. Comparison Of Critical Load Using Ansys And Euler Buckling Formula For ISHB

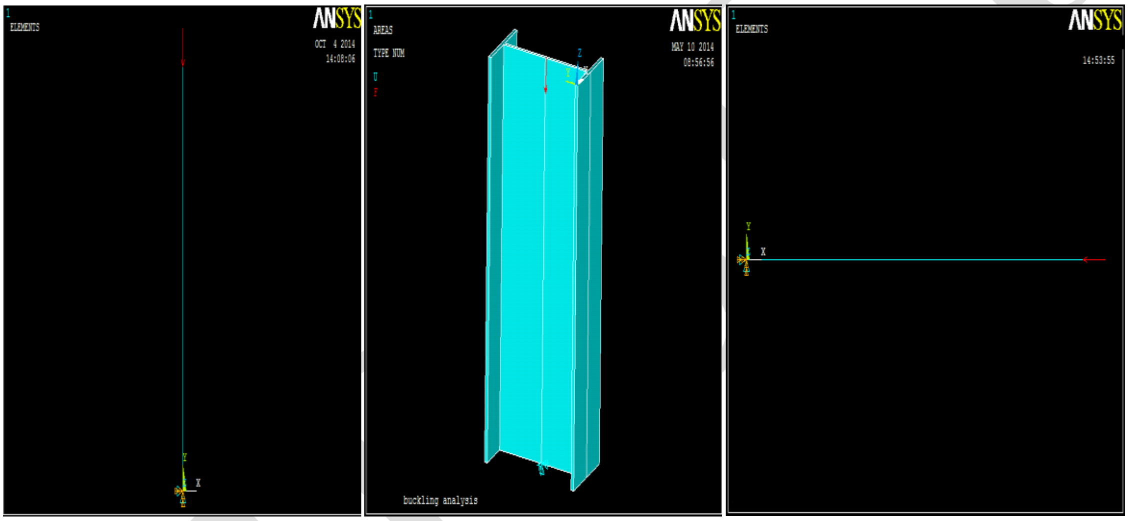

Fig. 1. Axial Loading on Column & Beam

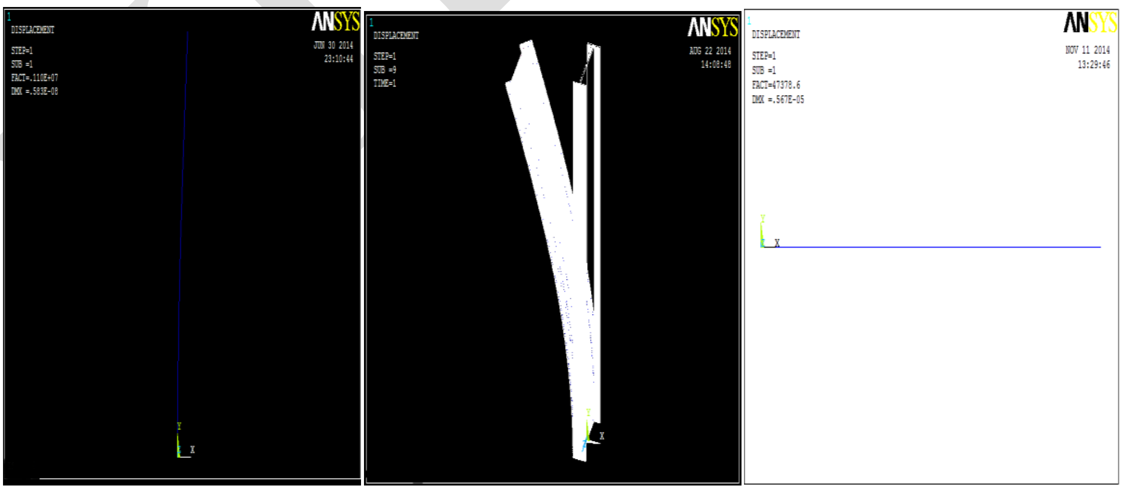

Fig. 2. Buckling Mode Shape Of Column And Beam

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V. CONCLUSION

Buckling Behaviour Of Column:- The finite element analysis includes the effects of residual stresses and geometric imperfections. These are included as a representative single geometric imperfection. The finite element model is not an extremely advanced model and therefore the results should not be seen as the exact answer for the collapse load but the results are especially suitable for a Comparative study. The finite element analysis has been done on many cross-sections. Not only I-columns have been studied, Also I-beams under axial loading have been studied. The results for those I-beams are very similar to the I-columns. Critical buckling curve shows the increase in critical load of increase in depth of section. As depth increases, the critical load also increases. In column analysis the constraint used is one end fixed and other end free therefore from mode shape it seen that majorly web buckling is occurred in column at particular boundary condition.

Buckling Behaviour Of Beam:- In this thesis report, the analysis of beam has done. The critical buckling load of beam is similar to column but mode shape of beam has straight, it means that buckling load magnitude is same in beam but beam cant buckle because the force is applied on beam is on longitudinal direction of its geometry that is major axis of beam along length, Therefore the buckling mode shape not seen. In beam the buckling or deformation has seen when the force is applied to its minor axis or its transverse direction.

Comparative study:- This behaviour of the analysed structures signifies that under loaded condition the structure does not become unstable and buckle immediately. These load values are compared to the Eigen buckling load values and Eigen Value buckling load is found to be higher. At this load the structure becomes unstable and buckles immediately. Ansys software is based on the Timoshenko theory, and Timoshenko theory includes residual stresses, shear stresses and geometric imperfections. In Euler Buckling theory these minor stresses and geometric imperfection are neglected, therefore the analysis done by manually and using Ansys software shows the difference in critical buckling load. Timoshenko theory gives more accuracy as compared to Euler Buckling theory. As well as in Ansys Timoshenko theory with finite element method is used that's why descritisation of structure in number of small element have done and individual element is solved by matrix method therefore the accuracy of results are more in Ansys.

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