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Study of Limit State Design of Steel Beam

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Abstract: *This Steel Design Codes Are In The Process Of Evolution Over The Years. The Design Approach Has Been Changing Over The Years. The Indian Codes Now Follow Limit State Design Approach In Line With Other International Codes. Different Tools Are Used In The Steel And Offshore Steel Industry For The Design Of Steel Elements. The Need Of Such Design Tools Is Required In Situations Of Primary, Secondary And Tertiary Steel Elements In The Steel Industry. The Three Kinds Of Steel Elements Are The Elements That Support Major, Moderate And Minor Equipment Or Loading. There Are Two Types Of Beam One Is Laterally Supported Beam And Other Is Laterally Unsupported Beam .In Laterally Supported Beams Full Lateral Support Is Provided By Rc Slab. But In Some Cases It Is Not Possible To Provide This Ideal Condition. In Industrial Structures, Many Times Steel Beams Or Beams Used In Framework Support Equipment And Machinary. Also, The Floor In Industrial Building May Comprise Steel Plates, Which May Not Provide Lateral Restraint. Therefore Such Cases Acquire Design Of Beam As Laterally Unsupported. Gantry Girder Is The Classic Example Of Laterally Unsupported Beam. This Girder Is Subjected To The Moving Load Due To Travelling Crane Running On Rails Connected To Top*
flange, and therefore it lacks lateral support over the length .The reduction in bending strength depends on cross-sectional dimensions, length of compression flange, type of restraint support and type of cross-section such as doubly symmetric, mono symmetric or asymmetric. Lateral Torsional Buckling (LTB) is a failure criteria for beams in flexure.
Key Words: *Laterally Unsupported Beam, Lateral Torsional Buckling, Gantry Girder*

I. Introduction

Steel design codes are in the process of evolution over the years. The design approach has been changing over the years. The Indian codes now follow limit state design approach in line with other international codes. Different tools are used in the steel and offshore steel industry for the design of steel elements. The need of such design tools is required in situations of primary, secondary and tertiary steel elements in the steel industry. The three kinds of steel elements are the elements that support major, moderate and minor equipment or loading.

There are two types of beam one is Laterally supported beam and other is Laterally unsupported beam .In laterally supported beams full lateral support is provided by RC slab. But in some cases it is not possible to provide this ideal condition. In Industrial structures, many times steel beams or beams used in framework support equipment and machinary. Also, the floor in Industrial building may comprise steel plates, which may not provide lateral restraint. Therefore such cases acquire design of beam as laterally unsupported. Gantry Girder is the classic example of Laterally Unsupported Beam. This girder is subjected to the moving load due to travelling crane running on rails connected to top flange, and therefore it lacks lateral support over the length .The reduction in bending strength depends on cross-sectional dimensions, length of compression flange, type of restraint support and type of cross-section such as doubly symmetric, mono symmetric or asymmetric. Lateral Torsional Buckling (LTB) is a failure criteria for beams in flexure. The AISC defines Lateral Torsional Buckling as: the buckling mode of a flexural member involving deflection normal to the plane of bending occurring simultaneously with twist about the shear centre of the cross-section. LTB occurs when the compression portion of a beam is no longer sufficient in strength and instead the beam is restrained by the tension portion of the beam (which causes deflection or twisting to occur).If the laterally unrestrained length of the compression flange of the beam is relatively longer then a phenomenon known as lateral buckling or lateral torsional buckling of the beam may take place therefore the beam would fail well before it can attain its full moment capacity.

The distance between lateral braces has considerable influence on the lateral torsional buckling of the beams. The restraints such as warping restraint, twisting restraint, and lateral deflection restraint tend to increase the load carrying capacity. If concentrated loads are present in between lateral restraints, they affect the load carrying capacity. If this concentrated loadLateral-torsional buckling is a limit-state of structural usefulness where the deformation of a beam changes from predominantly in-plane deflection to a combination of lateral deflection and twisting while the load capacity remains first constant, before dropping off due to large deflections. The analytical aspects of determining the lateral-torsional buckling strength are quite complex, and close form solutions exist only for the simplest cases.

For a beam with a particular maximum moment-if the variation of this moment is non-uniform along the length the load carrying capacity is more than the beam with same maximum moment uniform along its length. If the section is symmetric only about the weak axis (bending plane), its load carrying capacity is less than doubly symmetric sections. For doubly symmetric sections, the torque-component due to compressive stresses exactly balances that due to the tensile stresses. However, in a mono-symmetric beam there is an imbalance and the resistant torque causes a change in the effective torsional stiffeners, because the shear centre and centroid are not in one horizontal plane. This is known as "Wagner Effect". If the beam is non-prismatic within the lateral supports and has reduced width of flange at lesser moment section the lateral buckling strength decreases. The effect of residual stresses is to reduce the lateral buckling capacity. If the compression flange is wider than tension flange lateral buckling strength increases and if the tension flange is wider than compression flange, lateral buckling strength decreases. The residual stresses and hence its effect is more in welded beams as compared to that of rolled beams. The initial imperfections in geometry tend to reduce the load carrying capacity. The design buckling (Bending) resistance moment of laterally unsupported beams are calculated as per Section 8.2.2 of the code.

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The distance between lateral braces has considerable influence on the lateral torsional buckling of the beams. The restraints such as warping restraint, twisting restraint, and lateral deflection restraint tend to increase the load carrying capacity. If concentrated loads are present in between lateral restraints, they affect the load carrying capacity.

On the other hand, if it is below shear centre, then it has stabilizing effect. For a beam with a particular maximum moment-if the variation of this moment is non-uniform along the length the load carrying capacity is more than the beam with same maximum moment uniform along its length. If the section is symmetric only about the weak axis (bending plane), its load carrying capacity is less than doubly symmetric sections. For doubly symmetric sections, the torque-component due to compressive stresses exactly balances that due to the tensile stresses. However, in a mono-symmetric beam there is an imbalance and the resistant torque causes a change in the effective torsional stiffeners, because the shear centre and centroid are not in one horizontal plane. This is known as "Wagner Effect". If the beam is non-prismatic within the lateral supports and has reduced width of flange at lesser moment section the lateral buckling strength decreases. The effect of residual stresses is to reduce the lateral buckling capacity. If the compression flange is wider than tension flange lateral buckling strength increases and if the tension flange is wider than compression flange, lateral buckling strength decreases. The residual stresses and hence its effect is more in welded beams as compared to that of rolled beams. The initial imperfections in geometry tend to reduce the load carrying capacity.The design buckling (Bending) resistance moment of laterally unsupported beams are calculated as per Section 8.2.2 of the code. If the non-dimensional slenderness $\lambda LT \leq 0.4$, no allowance for lateral-torsional buckling is necessary. ANNEX E (CL.8.2.2.1,IS 800:2007) of the code gives the method of calculating Mcr,, the elastic lateral torsional buckling moment for difficult beam sections, considering loading and a support condition as well as for non-prismatic members.

The structural/civil Designer has to ensure that the structures and facilities he designs are (i) fit for their purpose (ii) safe and (iii) economical and durable. Thus safety is one of the paramount responsibilities of the designer. However, it is difficult to assess at the design stage how safe a proposed design will actually be – consistent with economy. There is, in fact, a great deal of uncertainty about the many factors, which influence both safety and economy. Firstly, there is a natural variability in the material strengths and secondly it is impossible to predict the loading, which a structure (e.g. a building) may be subjected to on a future occasion. Thus uncertainties affecting the safety of a structure are due to Uncertainty about loading Uncertainty about material strength and Uncertainty about structural dimensions and behaviour.These uncertainties together make it impossible for a designer to guarantee that a structure will be absolutely safe.

All that the designer could ensure is that the risk of failure is extremely small, despite the uncertainties. Earlier for designing steel structures working stress method is used (IS: 800-1984). Now designing done using limit state method (IS: 800-2007).

Design is basically a trial and error process, initially a section is assumed and it is checked, for its capacity to withstand the applied load. In case of design of steel structural elements according to IS: 800-2007, no ready to-use design tools are available to aid the initial selection.

Formulation of Present Work

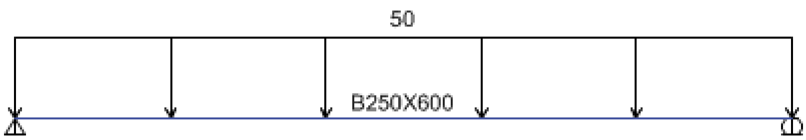
The conventional composite beam is composed of steel beam with H-shaped section and concrete slabs, and headed studs are used as shear connectors to combine the steel beam and concrete slab together, as shown in Fig. 1(a) (Newmark et al., 1951; Johnson, 1975; Crisinel, 1990; Li and Li, 2009b). In H-shaped steel concrete composite beams, the top flange of the steel beam is at the vicinity of the neutral axis of the section, its stress level is low and its contribution to the moment-resistance of the composite beams is little (Li and Li, 2009c; Li et al., 2011; Li et al., 2009; Grant and Fisher, 1977). The steel-concrete composite beam with notched web of inverted T-shaped steel section is formed by removing the top flange of the H-shaped steel beam, which reduces the cost of steel and avoids the wielding process by replacing headed studs with the trapezoid connectors, generally designed to bear sagging moment, as shown in Fig. 1(b). In order to promote the application of the novel composite beam in engineering practice, it is necessary to study the bend and shear behavior of the steel-concrete composite beam with notched web of inverted T-shaped steel section.Modeling is done in E-Tabs.

Study of limit state design of beam is done by creating different models.

Model I is RCC beam of dimensions 250 mm X 600 mm. Its span is 8 m. It is build in M 20 grade of concrete and grade of steel is Fe 500. This modeling is done in E-Tabs . This RCC beam is subjected to loading to analyze it. It is loaded with 50 kN/mm.

3.1 Model I: RCC Beam

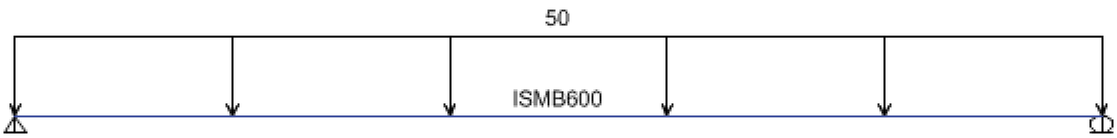
Size: 250x600mm
M20/FE500
Span: 8m



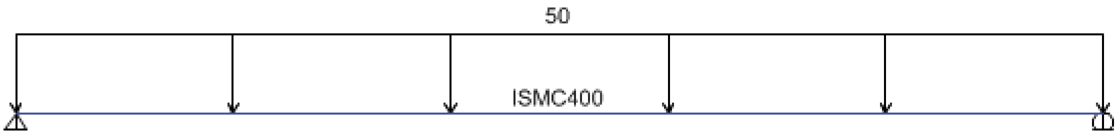
3.2 Model II: SteelI section Beam

Size: ISMB600
Span: 8m

Model II consist of ‘ I ‘ section Beam of size ISMB 600. Span is 8 m .This modeling is done in E-Tabs . It is loaded with 50 kN/mm load.

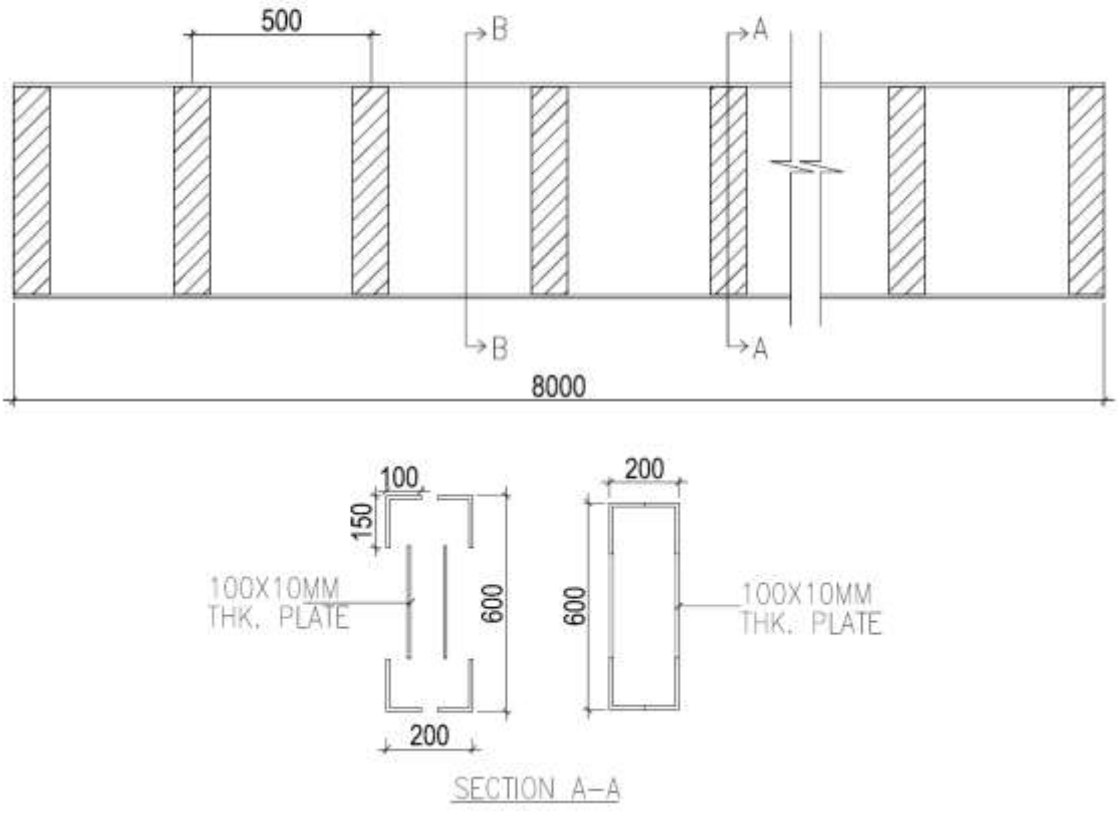


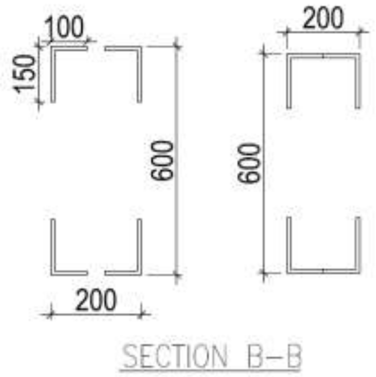
3.3 Model III: Steel Chanel section Beam
Size: ISMC 400
Span: 8m



Model III consist of steel channel section for beam. Its ISMC 400 having span of 8 m.Its loaded with load of 50 kN/mm.

3.4 Model IV: Composite Steel Beam
Size: 200X600mm
Span: 8m
Model IV consist of Composite Steel Beam of dimension 200 mm X 600 mm having span of 8 m. This modeling is done in E-Tabs. It consist of concrete of grade M 20 and grade of Steel is Fe 500.





II. Conclusion & Suggested Further Work

From all this some of the most important remarks in the study are outlined as follows:
1.Etabscan be used to determine Elastic lateral torsional buckling moment.
2.The proposed analysis can lead to a more uniform factor of safety for the structural system, because it can capture the strength of the structural system as well as the individual members directly.
3.This analysis is also used to strengthen the beam like structural member against lateral torsional buckling and bending.
4.Lateral torsional buckling effect should not be neglected.
5. Design charts for the design of steel sections made up of Indian standard channel sections. These design charts are presented based on IS: 800-2007.
6. The graphs can be prepared for the flexural members (Laterally Supported and Unsupported) channel sections, which can be used to select the section directly for different effective span and the factored load (kN/m), the member can with stand. These graphs can be used as designed aids for selecting steel sections.
7. In case of Beam-Columns (channel sections), the design aid graphs are prepared for the factored axial load against factored moment which is a slopping straight line for different effective spans.
Etabs give models for Steel Section including I section, C section, Angle section . These section are compared with Composite Beam Column Section subjected to loading of 50 kN/mm. Results are given as below.

Table 4.1 Results:

Deflection	28.4 mm
Bending Moment	430 kNm
Shear Force	215 kN

Table 4.2 : Results:

Deflection	14.8 mm
Bending Moment	409.6 kNm
Shear Force	204.8 kN

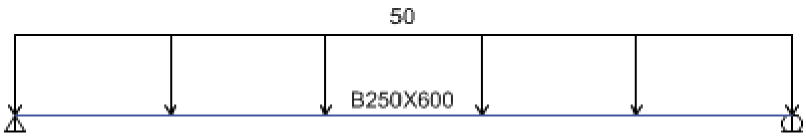
Table 4.3 : Results:

Deflection	89 mm
Bending Moment	403.86 kNm
Shear Force	201.93 kN

Table 4.4 : Results

Deflection	20.2 mm
Bending Moment	389kNm
Shear Force	194kN

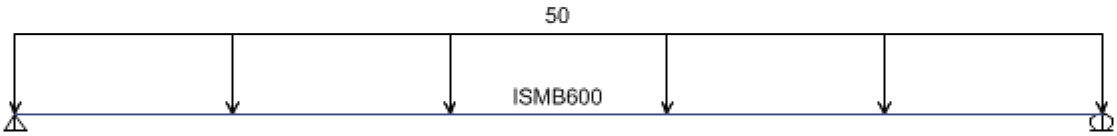
Model I: RCC Beam
Size: 250x600mm
M20/FE500
Span: 8m



Results:

Deflection	28.4 mm
Bending Moment	430 kNm
Shear Force	215 kN

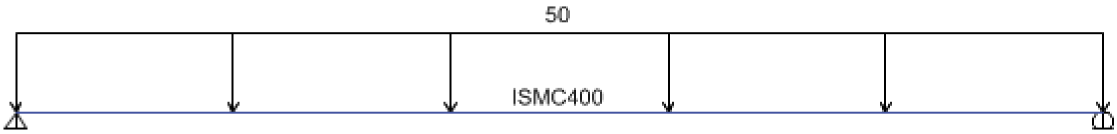
Model II: SteelI section Beam
Size: ISMB600
Span: 8m



Results:

Deflection	14.8 mm
Bending Moment	409.6 kNm
Shear Force	204.8 kN

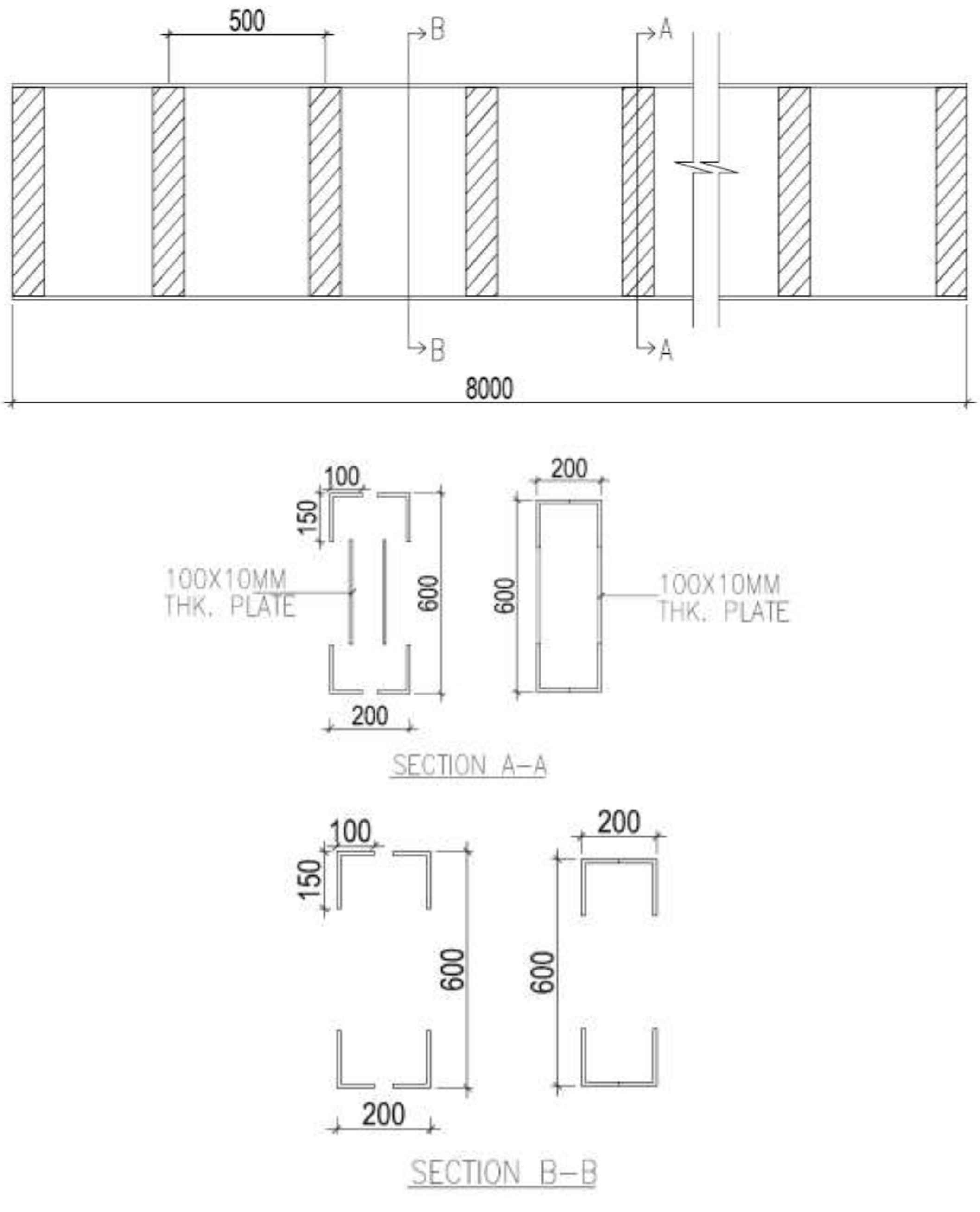
Model III: SteelChanel section Beam
Size: ISMC 400
Span: 8m



Results:

Deflection	89 mm
Bending Moment	403.86 kNm
Shear Force	201.93 kN

Model IV: Composite Steel Beam
Size: 200X600mm
Span: 8m



Deflection	20.2 mm
Bending Moment	389kNm
Shear Force	194kN

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