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Comparative Study of the Behavior and Strength of Laterally Supported Steel Beams with Laterally Unsupported Steel Beams

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Abstract

A laterally supported beam is a beam that is supported along its length to prevent lateral buckling. Lateral support can be provided by bracing, sheathing, or other means to prevent the beam form deflecting laterally. This type of support is important in preventing the beam from failing under the influence of lateral loads, such as wind or seismic forces. In contrast, a laterally unrestrained beam is a beam that is not restraint(transversely) along its length which its top flange will be subjected to lateral torsional buckling. To prevent this type of buckling, both flanges of the section or at least its top flange must have lateral support. In a beam, if the flange or its compression region is sufficiently prevented from displacement and twisting, or when the compression flange is directly connected to the roof, the beam is considered braced at the same point.

This paper aims to investigate the comparison of behavior and strength between fully laterally supported and laterally unsupported beams in steel structures.

To carry out this study, extensive parametric analysis is performed by considering different sizes of beams, spacing of the lateral supports and comparing the strength of laterally supported beam compared with laterally unsupported beam by practical examples.

The findings shows that if the steel beams have full lateral support, the plastic hinge is created at the point with the maximum moment and the strength of that beams is not limited by lateral torsional buckling. on the contrary, if the same steel beam does not have lateral support or the unbraced length of compression flange are very large, its strength is limited by lateral torsional buckling, and its strength is more than 15 % lower than if it has a continues lateral support.

Keywords: laterally supported beam, unbraced length, lateral torsional buckling, laterally stability, buckling

1. INTRODUCTION

Lateral stability and lateral torsional buckling of steel beams is a very important parameter in the design of steel members. A bending member carries load applied normal to its longitudinal axis and transfer it to its support points through bending moments and shears. the term beam normally refers to a bending member that directly supporting an applied load [1]. The bending force that is applied on the beam material due to external loads and its own weight is called bending moment. Beams usually carry vertical gravity forces, but they can also be used to carry horizontal loads [2].

Flexural members can fail in one of the following modes and the nominal bending strength of a flexural member is a function of these failure modes [3].

1. Yielding of the entire cross-section at the point of maximum moment.
2. Lateral-torsional buckling (LTB)
3. Flange local buckling (FLB) in compression
4. Web local buckling (WLB) in flexural compression.

The compression region of a bending member cross-section has a tendency to buckle similarly to how a pure compression member buckle. The major difference is that the bending tension region helps to resist that buckling. The upper half of the wide flange member in bending acts as a T in pure compression. This T is fully braced about its horizontal axis by the web so it will not buckle in that direction but it can be unbraced for some distance for buckling about its vertical axis. Thus, it will tend to try to buckle laterally. Because the tension region tends to restrain the lateral buckling, the shape actually buckles in a combined lateral and torsional mode. The beam midspan deflects in the plane down and buckles laterally, causing it to twist, and the beam appears to have a tendency to fall over on its weak axis [1,4].

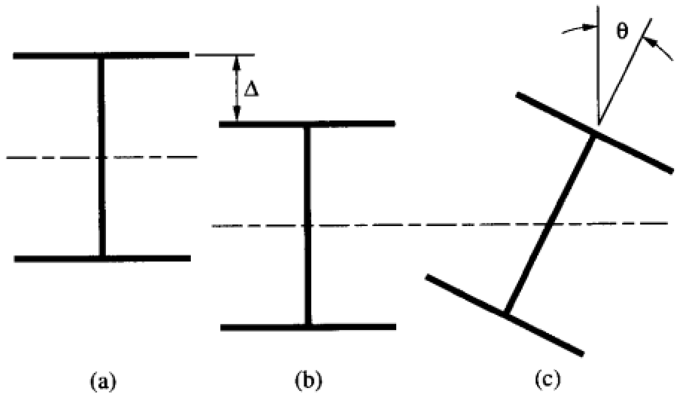

Figure 10 the three positions of a beam cross section undergoing lateral-torsional buckling.

In order to resist this tendency, the specification requires that all bending members are restrained at their support points against rotation about their longitudinal axis. If the beam has sufficient lateral and/or torsional support along its length, the cross-section can develop the yield stress before buckling. If it tends to buckle before the yield stress is reached, the nominal moment strength is less than the plastic moment [5].

In other words, Lateral-torsional buckling occurs when the distance between lateral brace points is large enough that the flexural member (e.g., a beam) fails by lateral displacement perpendicular to the longitudinal axis, in combination with twisting of the section (see figure 2) [6].

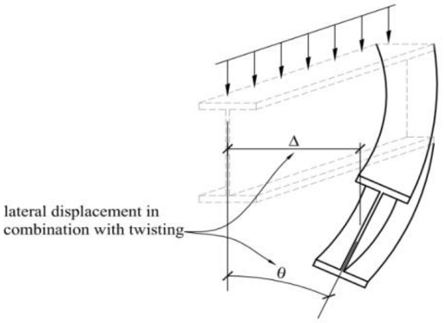

Figure 2 Lateral torsional buckling

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The moment strength of compact shapes is a function of the unbraced length(L_b) defined as the distance between points of lateral support, or bracing. In this article, we indicate points of lateral support with an “X” as shown in figure 3[6].

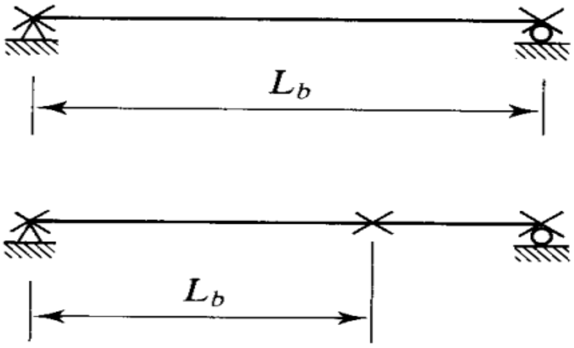

Figure 3 Lateral bracing

the relationship between the nominal strength(M_n) and the unbraced length shown in figure 4. if the unbraced length is no greater than L_p, to be defined presently, the beam is considered to have full lateral support, and $M_n = M_p$. If L_b is greater than L_p but less than or equal to the parameter L_r, the strength is based on inelastic Lateral Torsional Buckling (LTB). If L_b is greater than L_r, the strength is based on elastic LTB [9,10,11].

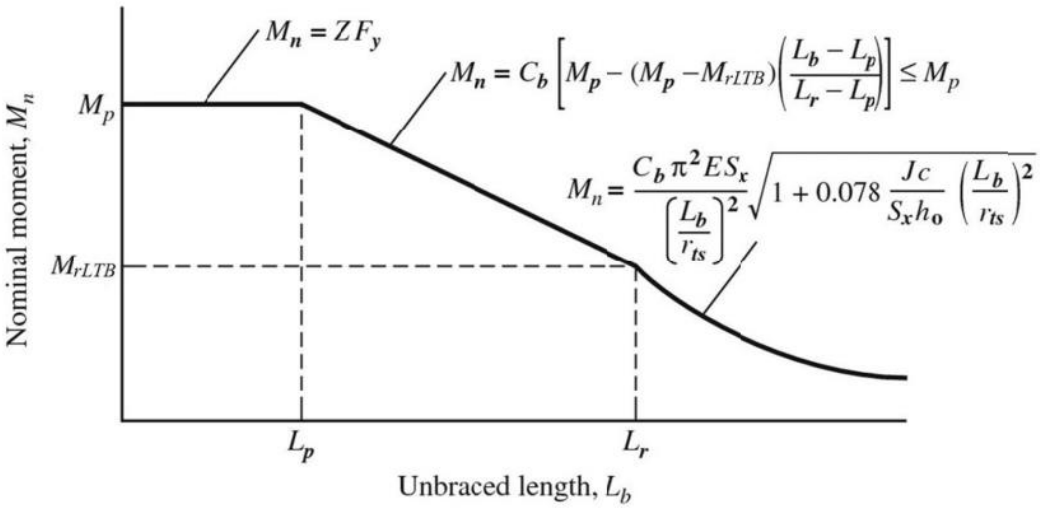

Figure 4 Three zone in Lateral-Torsional Buckling

Lateral buckling will not occur if the compression flange of a member is braced laterally of if twisting of the beam is prevented at frequent [7,8].

2. Methodology

In this study, we will look at beams as follows:

1. First, the beams will be assumed to have continuous lateral bracing for their compression flanges.
2. Finally, the beams will be assumed unbraced or to be braced laterally at larger and larger intervals.

the strength of two steel beams with a length of 8 meters and the same cross-section, one of which laterally supported (its upper flange is connected by shear studs to concrete slab) and the other laterally unsupported, were compared against 2880 kg/m combined load.
if a steel beam has full lateral support, the relation $L_b \leq L_p$ is applied and the beam falls in the first zone of figure 4. In this case no buckling limit states control and the nominal strength of that beam is determined by the limit state of yielding [9].

$$M_n = M_p = F_y \text{ Z} \qquad \text{(AISC F2-1)}$$

By the above equation, the design strength of the 8 meters compact laterally supported steel beam was calculated and compared with the required strength, the result of which is show in table 1.
In the next step, the design strength of the same beam with all the same specifications was calculated without considering the lateral support. When the unbraced length of a beam exceeds L_p , its strength is reduced due to the tendency of the member to buckle laterally at a load level below what would cause the plastic moment to be reached [10].
Since it became $L_b = L_p$, the laterally unsupported beam was placed in the middle zone of figure 4, and in this zone the beam strength is calculated by the following equation [11].

$$M_n = C_b\left[M_p - (M_p - 0.70F_yS_x)\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] \qquad \text{(AISC F2-2)}$$

By the above equation, the design strength of the 8 meters laterally unsupported steel beam and compared with the required strength, the result of which is show in table 1.

Table 1 comparison of two beams

No	Beam section	Type of steel	Lateral support	Design method	Applied load(kg/m)	Required strength(kg.m)	Design strength(kg.m)
1	IPB260	ST37	laterally braced	LRFD	2880	23040	27712.8
2	IPB260	ST37	Laterally unbraced	LRFD	2880	23040	23400

3. RESULTS AND DISCUSSION

After comparing the behavior and strength of two types of steel beams (with full lateral support and without lateral support) and addressing the different aspects of their differences, the following results are obtained:
In this research, it was observed that the laterally full supported beam had 15% more strength than a same laterally unsupported beam or that did not have any type of lateral support between the end supports. This situation allows us to use a smaller cross-section, which in turn makes the structure more economical.

4. CONCLUSION

Based on the findings of this study, the following conclusions can be drawn:

As the name implies, lateral-torsional buckling is an overall instability condition of a beam involving the simultaneous twisting of the member and lateral buckling of the compression [12]. If the steel beams are laterally supported, its strength is higher than that of laterally unsupported beams, and its strength is not limited by lateral torsional buckling; however, if the steel beams do not have lateral supports or the distances between the lateral supports are too large, its strength is low and limited by lateral torsional buckling. In order to prevent such a complex failure of the steel beam, it is suggested that all the bending members be laterally supported in the prescribed intervals, on its longitudinal axis. Increasing the number of restraining points or reducing the unbraced length of the compression flange, increases the performance and strength of these members [13].

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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