Steel Structures Design Manual To AS 4100

First Edition

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Thus a segment is classified as FF if both ends are fully restrained against both lateral movement and twisting. A section is fully restrained if the critical flange is laterally restrained. If one end of a segment is fully restrained and the other partially restrained, it is classified as FP, and if both ends are partially restrained it is PP. A sub-segment has one end only laterally restrained, so sub-segments may be FL, PL or LL.

The effective length (L_e) of a segment or sub-segment shall be determined as follows:

$L_e = k_t\, k_l\, k_r\, L$ *AS*4100 *Cl* .5.6.3(1),(2),(3)

where

k_t = twist restraint factor given in table 5.6.3(1) of AS 4100. This factor accounts for the reduction in the member moment capacity resulting from thin web distortion, by increasing the effective length of a segment or sub-segment with a one or both ends partially restrained.

k_l = load height factor given in table 5.6.3(2) of AS 4100. For example a monorail or a crane runway beam or any other beam which has a gravity load on its top flange without any lateral restraint is more likely to buckle than the same beam with the same load applied to its bottom flange. This is because any twisting will cause the load on the top flange to move sideways so as to increase the twisting effect. In most case k_l = 1, but if $k_l > 1$, we take this effect into account by increasing the effective length.

k_r = lateral rotation restraint factor given in table 5.6.3(3) of AS 4100. This is equal to 1 unless one or both ends of the segment are restrained from rotating about the vertical or y-axis, assuming the load is in the y- direction, i.e. moment about z- axis – see figure 7.2. For example even the I section column at the left would have little torsional stiffness and could not provide much lateral rotational restraint. If it were a box section it would provide some restraint and k_r would be <1. But for most case k_r = 1.

The length L in the effective length equation shall be taken as either

(a) the segment length, for segments without intermediate restraints, or for segments unrestrained at one end, with or without intermediate lateral restraints; or
(b) the sub-segment length, for segments formed by intermediate lateral restraints, in a segment, which is fully or partially restrained at both ends.

7.2.1.5 Member moment capacity of a segment

The nominal member moment capacity of a beam, a segment of a beam, or a sub-segment of a beam is given by the following equation:

$M_b = \alpha_m \alpha_s M_s$ *AS*4100 *Cl*.5.6.1.1(1)

The design capacity is given by:

$\phi M_b = \phi \alpha_m \alpha_s M_s$ *AS*4100 *Cl*.5.6.1.1(1)

The greater the effective length L_e of a segment, the more easily it will buckle and the smaller is its moment capacity. This effect is taken into account by the slenderness reduction factor α_s, which gets smaller as L_e gets bigger. This factor can be calculated using Equations 5.6.1.1(2) and 5.6.1.1(3) of AS 4100[1]. However it is much easier to use tables or charts prepared by the Australian Institute of Steel construction [2] These give ϕM_b for the case where the moment modification factor α_m = 1 (i.e. $\phi M_b = \phi \alpha_s M_s$). Using these tables will always give a safe design because $\alpha_m \geq 1$ for doubly symmetrical sections. However, they will often give a very conservative design if you do not take α_m into account.

Moment shape factor α_m

As explained in 7.2.1.1, the flange of a beam in compression will tend to buckle like a column, and like a column, it may need to be restrained at intervals to prevent buckling. If a beam or segment is subjected to a uniform bending moment along its whole length, then the compressive stress in the compression flange will be uniform along its length, as it is in a centrically loaded column. But if the bending moment changes along the length of the segment (as it usually does), then some of the compression flange will be less prone to buckle. And if the bending moment reverses over the length of the segment, only part of the length of each flange will be in compression. This means there is a shorter length over which any one flange tends to buckle and the tendency to buckle is less. AS 4100 allows for this effect by introducing the moment modification factor α_m, which may offset the slenderness reduction factor.

In Fig.7.9, the top flange is the critical flange over the whole length of the beam. If there are no lateral restraints to the top flange, it will be able to buckle over its full length. But if there are lateral restraints to the top flange at the two load points (typically provided by purlins or crossing beams), they effectively divide the beam into 3 sub-segments, 1-2, 2-3 and 3-4, each of which must be assessed independently for moment capacity, although in this case 3-4 is simply a mirror image of 1-2, so only 2 sub-segments need be assessed.

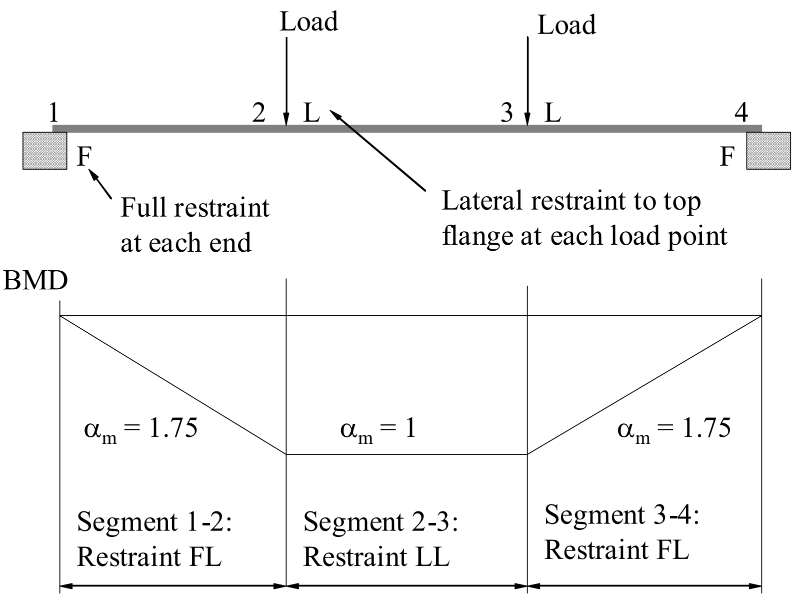

Figure 7.9 *Beam under* 4 *point loading, with lateral restraints at load points, showing dependence of* α_m *on moment shape*

There is a uniform bending moment on sub-segment 2-3, so the maximum compressive stress in the top flange will act over its full length and it will have maximum tendency to buckle over its full length. Thus from AS 4100 Table 5.6.1, 3rd to bottom row, $\alpha_m = 1$, i.e. no increase in moment capacity. Sub-segments 1-2 and 3-4, in contrast, each have the same maximum bending moment as sub-segment 2-3 at one end, but it decreases to zero at the other end. So they are less likely to buckle and from AS 4100 Table 5.6.1, 2nd row from bottom, $\alpha_m = 1.75$, i.e. 75% increase in moment capacity before buckling will occur – as long as yielding does not occur first.

Now if the loading is changed so one load acts upwards, as shown in Fig.7.10 below, the bottom flange is now critical between sections 1 and 3, and if only lateral restraint is provided to the top flange at sections 2 and 3, without rotational restraint, this will now provide no effective restraint at section 2, so it can buckle over the full length from section 1 to section 3. The beam is now divided into only 2 sub-segments. α_m for the longer sub-segment on the left is found from AS4100 Table 5.6.1, 4^{th} row down, to be 1.2.

However if restraint were provided to the bottom flange at section 2, we would again have 3 sub-segments and α_m for the central sub-segment is found from AS4100 Table 5.6.1, top row, to be 2.5.

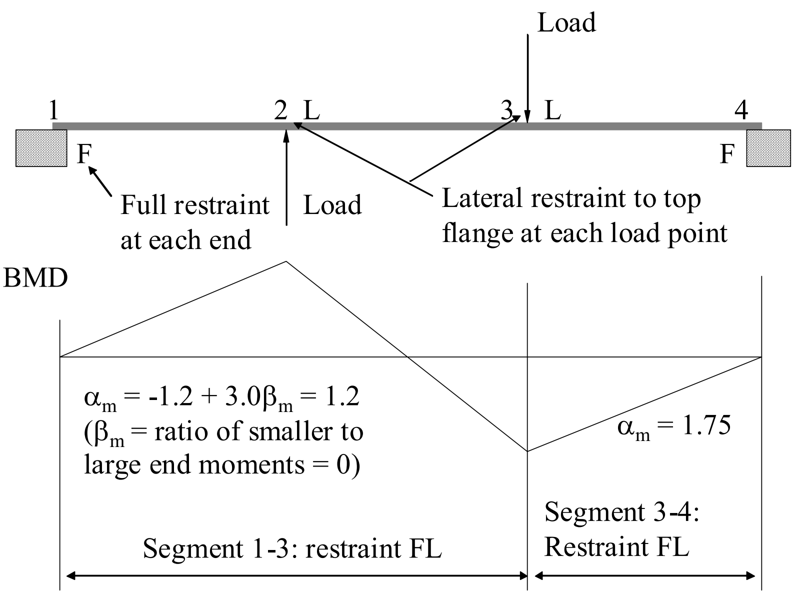

Figure 7.10 *Same beam as in* Figure 7.9, *but one load reversed, showing change in sub-segments and* α_m