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Technical Discussion of Revision to Specification Section C3.1.3 on Beams Having One Flange Through-Fastened to Deck or Sheathing

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Changes to the North American Specification for the Design of Cold-Formed Steel Members Section C3.1.3 were approved by the AISI Committee on Specifications in February 2006. Section C3.1.3 deals with uplift on roof or suction on wall systems. The modification included the deletion of the limitation that, "for continuous span systems, the longest member span length shall not be more than 20% greater than the shortest span length". Also, the modification included the addition that, "For continuous purlin systems in which adjacent bay span lengths vary by more than 20%, for the adjacent bays the 'R' value shall be taken from Table C3.1.3-1." The following discussion served as the basis for this Specification change.

JUSTIFICATION

The maximum bay spacing variation of 20% was arbitrarily selected and included in the previous Specification provisions. The prescriptive "R" values are empirical, and the testing of continuous purlins was all based on equal bay spacing. A limit was applied to account for the contingency that the effect on the moment diagram may be detrimental if bays were allowed to vary significantly.

The influence of varying bay spaces may be evaluated analytically by investigation of the effect on the bending coefficient C_b. The value of C_b affects the demand on the stabilizing system both intuitively and quantitatively. The 2005 AISC stability bracing provisions for torsionally braced beams contain the following equations for the required torsional brace strength and stiffness, which are based on a continuous torsional spring model.

Required Torsional Brace Moment Strength:

$$M_{br} = \frac{0.024 M_r L}{n C_b L_b} \qquad \text{(AISC Eq. A-6-9)}$$

Required Torsional Brace Rotational Stiffness:

$$\beta_T = \frac{1}{\phi}\left(\frac{2.4 L M_r^2}{n E I_y C_b^2}\right)(LRFD) \qquad \beta_T = \Omega\left(\frac{2.4 L M_r^2}{n E I_y C_b^2}\right)(ASD) \qquad \text{(AISC Eq. A-6-11)}$$

where

C_b = lateral-torsional buckling modification factor for non-uniform moment diagrams when both

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		ends of the unsupported segment are braced
E	=	modulus of elasticity
I_y	=	out of plane moment of inertia
L	=	span length
L_b	=	distance between braces
M_{br}	=	required bracing moment
M_r	=	required flexural strength of beam being braced
n	=	number of nodal braced points within the span
β_T	=	brace stiffness requirement excluding web distortion
ϕ , Ω	=	resistance and safety factors

From these equations it is seen that the strength demand on a torsional brace is inversely proportional to the value of C_b and that the stiffness demand is inversely proportional to C_b^2. Given the fact that the nature of the brace relied upon within the provisions of Section C3.1.3 is a continuous torsional brace consisting of the connection between the purlin top flange and the roof deck, these stability equations are considered appropriate to show the influence of moment gradient on brace system demand.

Therefore, bay spacing scenarios that tend to reduce C_b would be considered to increase the demand on the stabilizing system, while situations that increase C_b would reduce the demand on the bracing system for the purlin in the affected bay.

THREE BAY EXAMPLE

Consider the three bay continuous purlin systems shown in Figures 1 through 3.

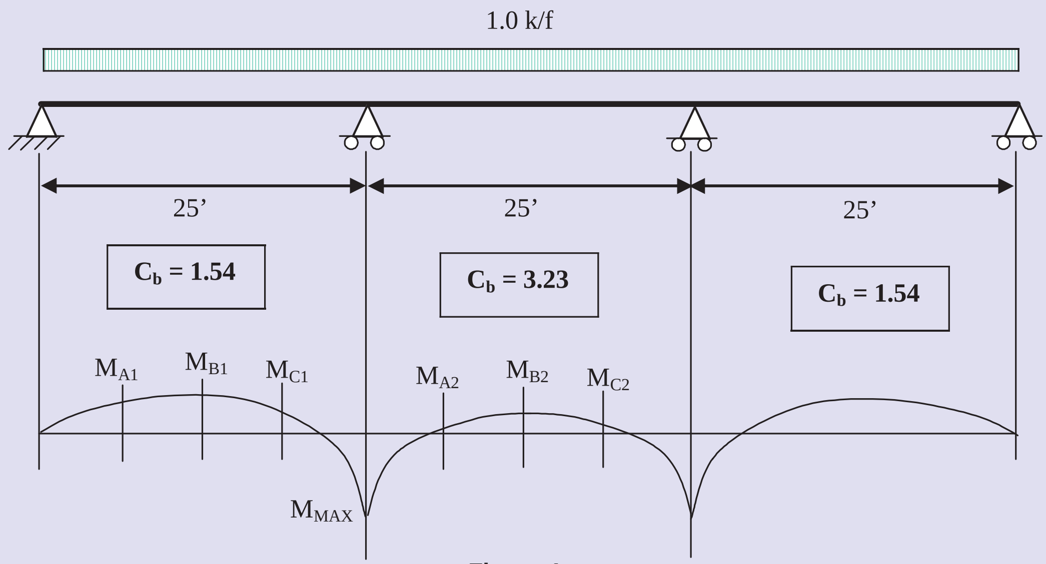

Figure 1

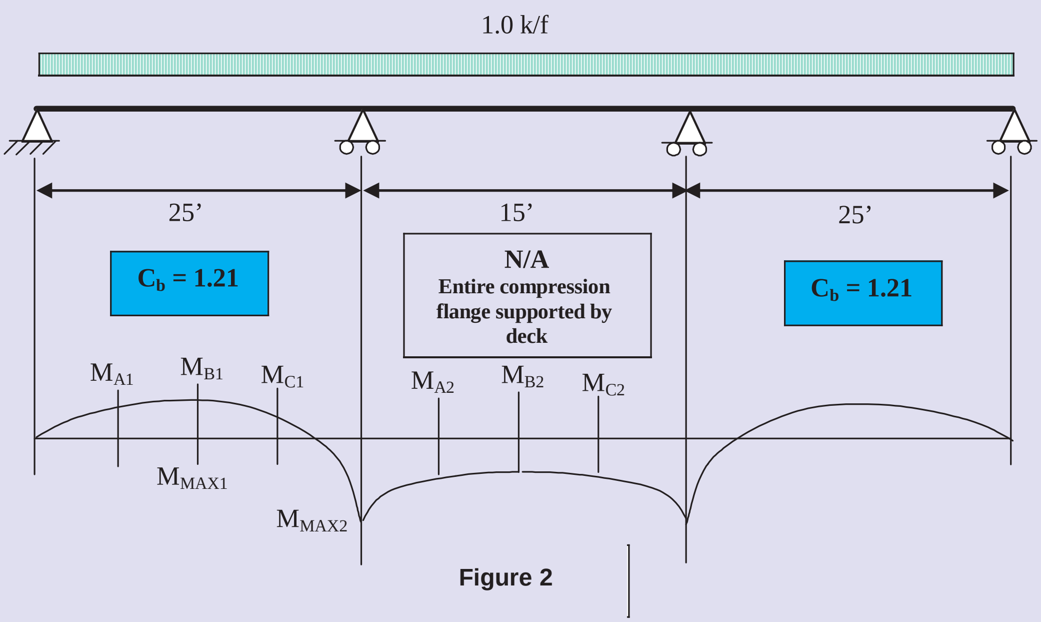

Figure 2

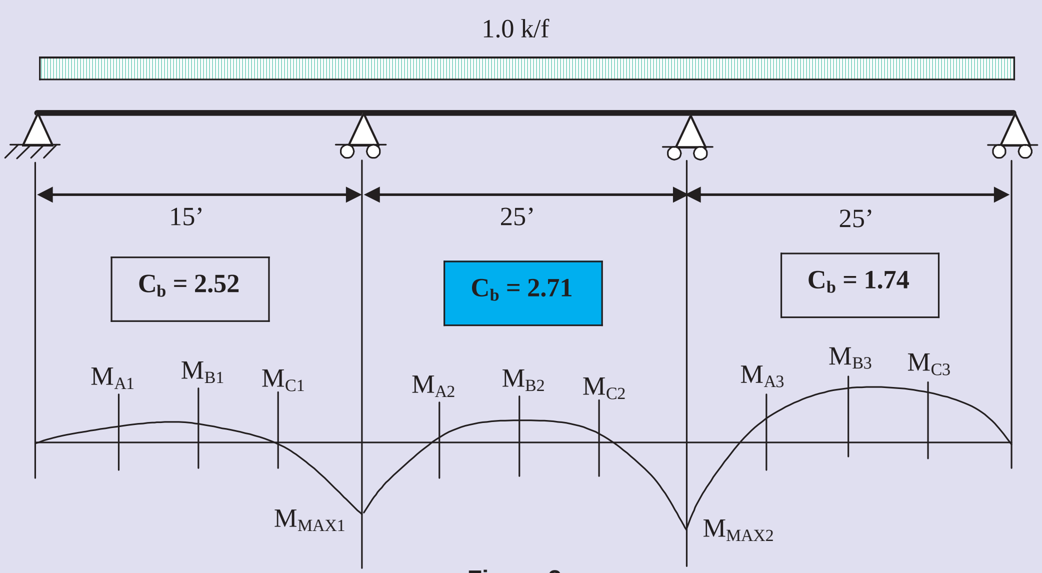

Figure 3

Figure 1 shows the values of C_b for three equal spans.

Figure 2 Results:

- Figure 2 shows that by reducing the center span by 40% the value of C_b in the longer end bays is reduced from 1.54 to 1.21 (Figures 1 and 2).

- The value of C_b in the reduced center bay is also reduced from the base condition in Figure 1. However, because we are dealing with uplift loads and no inflection point exists in bay two, the provisions of section C3.1.3 are not applicable. If the length of bay two were increased to 22.5 feet, the value of C_b would be 3.15, which is within 2.5% of the base value in Figure 1. In this case, 22.5 feet results in a minimal negative moment region in the center span.

Figure 3 Results:

- Figure 3 indicates that by reducing the first end span by 40%, the value of C_b is increased considerably in both end bays as compared with Figures 1 and 2.
- The value of C_b in the center 25 foot bay is reduced from 3.23 to 2.71.

Conclusions and Implications:

1. The three bay example shown in Figures 1 through 3 implies that if a given bay length is reduced from that of an adjacent bay, the value of C_b in the adjacent bay only is reduced.
2. For the three bay condition, the value of C_b in the interior bay is significantly higher than that in the end bays. This indicates that the R factors prescribed in section C3.1.3 are conservative for the interior bay.

FIVE BAY EXAMPLE

Table 1 – Comparison of C_b values by bay (w = 1.0 k/ft)						
		Bay Number				
Case		**1**	**2**	**3**	**4**	**5**
0	**Bay Length (ft)**	**25**	**25**	**25**	**25**	**25**
	C_b	**1.65**	**3.03**	**2.10**	**3.03**	**1.65**
1	Bay Length (ft)	**15**	25	25	25	25
	C_b	2.67	**2.21**	2.43	2.98	1.66
2	Bay Length (ft)	25	**15**	25	25	25
	C_b	**1.25**	**2.06**[1]	**1.83**	3.19	1.61
3	Bay Length (ft)	25	25	**15**	25	25
	C_b	1.80	**2.56**	2.54[1]	**2.56**	1.80
4	Bay Length (ft)	**15**	25	**15**	25	25
	C_b	2.85	**1.68**	2.40[1]	**2.53**	1.81
5	Bay Length (ft)	25	**15**	**15**	25	25
	C_b	**1.41**	3.04	2.70[1]	**2.69**	1.75
6	Bay Length (ft)	**15**	**15**	25	25	25
	C_b	**1.22**	3.31[1]	**1.63**	3.12	1.62

Table 1 shows the results of a five span continuous system with six different scenarios of bay length changes relative

to the base case in which all five bays are equal in length.
Notes:

1. Values denoted with the superscript of 1 are in bays with no negative moment and therefore would have an R value of 1.0.
2. Values in bold shaded cells have reduced values of C_b compared to the base case of all equal bay spac ing.

Conclusions and Implications:

1. Unlike the three bay example, there is one case, (case 2), in which the value of C_b was reduced in all three bays adjacent to a bay space reduction. However, the reduced bay in case 2 has no negative moment and is therefore not applicable to C3.1.3.
2. As for the three bay condition, the value of C_b in all interior bay is higher than that in the end bays indicating that the R factors prescribed in section C3.1.3 are conservative for interior bays.

Uniformly Loaded Simply Supported Beams

All uniformly loaded simple beams have the same value of C_b.

C_b = 1.14 for uniformly loaded simple beams. Upon investigation of the values in the two continuous examples above, it can be seen that the value of C_b is greater than 1.14 in all bays in all cases.

CONCLUSION

Use of the "R" factors for simply supported members prescribed in Table C3.1.3-1 of AISI Section C3.1.3 is rational and probably conservative for all uniformly loaded continuous purlins without regard for changes in bay spacing. Also, there is precedence in the Specification in Section C3.1.4 to apply simple span behavior to continuous span applications. Although the examples indicate that a reduction in the "R" factor is not warranted in all cases for adjacent bays with unequal spans, in the interest of simplicity, the following specification language was adopted:

For continuous purlin systems in which adjacent bay span lengths vary by more than 20%, the R values for the adjacent bays shall be taken from Table C3.1.3-1.

REFERENCES

AISC (2005), Specification for Structural Steel Buildings, One East Wacker Drive, Suite 700, Chicago, Illinois, 60601-1802.