Sheet Steel Facts 34

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Distortional Buckling Strength Check for Cold Formed Steel Flexural Members

Introduction

The current edition of CSA-S136-07_S2-10 *North American Specification for the Design of Cold-Formed Steel Structural Members, with Supplement No. 2*, includes design checks for distortional buckling of members in bending. For many conventional members (e.g. C- and Z- sections) distortional buckling may now control the design strength depending on the member shape and type of compression flange bracing. The key parameter in CSA-S136 for the determination of the distortional buckling strength is the elastic distortional buckling stress, F_d. This stress is dependent on a number of parameters as show in the following equation:

$$F_d = \beta \frac{k_{\phi fe} + k_{\phi we} + k_{\phi}}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$

where,

β = Moment gradient coefficient
$k_{\phi fe}$ = Elastic rotational stiffness provided by the flange to the flange/web juncture
$\tilde{k}_{\phi fg}$ = Geometric rotational stiffness demanded by the flange
$k_{\phi we}$ = Elastic rotational stiffness provided by the web to the flange/web juncture
$\tilde{k}_{\phi wg}$ = Geometric rotational stiffness demanded by the web
k_{ϕ} = Rotational stiffness

The first four rotational stiffness parameters listed above are geometric properties of the member and can be calculated in a straight forward manner. The rotational stiffness k_{ϕ}, however, is dependent on the type of sheathing connected to the compression flange. Two characteristics of the sheathing are used in calculating k_{ϕ}: the rotational restraint provided by the flexural stiffness of the attached sheathing, $k_{\phi w}$, and the rotational restraint provided by the connection between the sheathing and the flexural member, $k_{\phi c}$. The rotational restraint will also be affected by any insulation compressed between the sheathing and the flexural member. For some combinations of sheathing, member size and connectors, values of k_{ϕ} have been published. For other configurations it may be necessary to determine this parameter by testing.

To develop load tables for cold formed steel flexural members, such as CSSBI 58-11 *Lightweight Steel Framing Wall Stud and Floor Joist Tables*, it is necessary to make some assumption about the value of k_{ϕ}. One approach is to assume $k_{\phi} = 0$ in which case the tables can be applied conservatively to all configurations of attached sheathing. An alternative is to assume the sheathing provides sufficient rotational restrain to the compression flange of the member so that distortional buckling does not control (i.e. $k_{\phi} = k_{\phi min}$ so that $M_{n\text{-}DB} = M_y$). This approach may be problematic unless very specific guidance is given about the minimum type of sheathing and connectors.

The CSSBI has elected to publish two sets of floor joist load tables in CSSBI 58-11: one set with $k_{\phi} = 0$ and another with $k_{\phi} = k_{\phi min}$. These tables represent the upper and lower limits on the flexural strength. The end user then has the option of using the higher values if the characteristics of the sheathing are known. The CSSBI 58-11 document also includes the other rotational stiffness parameters so that a designer can calculate the distortional buckling flexural strength for other values of k_{ϕ}.

The following three examples demonstrate how the distortional buckling flexural strength is determined for a 1000S200-68 member. Refer to CSSBI 58-11 for the section properties and definition of symbols.

Example 1: Distortional Buckling Strength Check with $k_\varphi = 0$

Determine the factored moment resistance, $M_{rx\text{-}DB}$, of a 1000S200-68 (50 ksi) in the distortional buckling flexural limit state as defined in CSA-S136-07_S2-10.

The section properties for the 1000S200-68 C-section taken from CSSBI 58-11 are:

$S_f = 2.800\ in^3$
$F_y = 50\ ksi$
$F_d = 48.10\ ksi$

$M_{crd} = S_f F_d = (2.800)(48.10) = 134.68$ k-in.
$M_y = S_f F_y = (2.800)(50) = 140.00$ k-in.

Now determine the factored moment resistance in the distortional buckling limit state:

$$\lambda_d = \sqrt{\frac{M_y}{M_{crd}}} = \sqrt{\frac{140.00}{134.68}} = 1.020$$

Since $\lambda_d > 0.673$

$$M_n = \left[\left[1 - 0.22\left(\frac{M_{crd}}{M_y}\right)^{0.5}\right]\left(\frac{M_{crd}}{M_y}\right)^{0.5} M_y\right] = \left[\left[1 - 0.22\left(\frac{134.68}{140.00}\right)^{0.5}\right]\left(\frac{134.68}{140.00}\right)^{0.5} 140.00\right] = 107.7 \text{ k.in.}$$

$M_{rx\text{-}DB} = \phi_b M_n = (0.85)(107.7) = 91.5$ k-in.

Example 2: Distortional Buckling Strength Check with $k_\varphi = 0.095$ kips

Determine the factored moment resistance, $M_{rx\text{-}DB}$, of a 1000S200-68 (50 ksi) in the distortional buckling flexural limit state as defined in CSA-S136-07_S2-10. Assume the flexural member has a sheathing attached to the compression flange sufficient to provide a rotational stiffness $k_\phi = 0.095$ kips.

Conservatively assume $\beta = 1.0$ (constant moment)
The section properties for the 1000S200-68 C-section taken from CSSBI 58-11 are:

$S_f = 2.800\ in^3$
$F_y = 50\ ksi$
$k_{\phi fe} = 0.3930$ kips
$\tilde{k}_{\phi fg} = 0.01050\ in^2$
$k_{\phi we} = 0.3900$ kips
$\tilde{k}_{\phi wg} = 0.00579\ in^2$

$$F_d = \beta \frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}} = (1.0)\left(\frac{0.3930 + 0.3900 + 0.095}{0.01050 + 0.005790}\right) = 53.89 \text{ ksi}$$

$M_{crd} = S_f F_d = (2.800)(53.89) = 150.89$ k-in.
$M_y = S_f F_y = (2.800)(50) = 140.00$ k-in.

Now determine the factored moment resistance in the distortional buckling limit state:

$$\lambda_d = \sqrt{\frac{M_y}{M_{crd}}} = \sqrt{\frac{140.00}{150.89}} = 0.963$$

Since $\lambda_d > 0.673$

$$M_n = \left[\left[1 - 0.22\left(\frac{M_{crd}}{M_y}\right)^{0.5}\right]\left(\frac{M_{crd}}{M_y}\right)^{0.5} M_y\right] = \left[\left[1 - 0.22\left(\frac{150.89}{140.00}\right)^{0.5}\right]\left(\frac{150.89}{140.00}\right)^{0.5} 140.00\right] = 112.1 \text{ k.in.}$$

$M_{rx\text{-}DB} = \phi_b M_n = (0.85)(112.1) = 95.3$ k-in.

Example 3: Distortional Buckling Strength Check with $k_\varphi = k_{\varphi min}$

Determine the factored moment resistance , $M_{rx\text{-}DB}$, of an 1000S200-68 (50 ksi) in the distortional buckling flexural limit state as defined in CSA-S136-07_S2-11. Assume the flexural member has a sheathing attached to the compression flange sufficient to provide a rotational stiffness $k_{\phi min} = 1.010$ kips.

Conservatively assume $\beta = 1.0$ (constant moment)
The section properties for the 1000S200-68 C-section taken from CSSBI 58-11 are:

$S_f = 2.800 \text{ in}^3$
$F_y = 50$ ksi
$k_{\phi fe} = 0.3930$ kips
$\tilde{k}_{\phi fg} = 0.01050 \text{ in}^2$
$k_{\phi we} = 0.3900$ kips
$\tilde{k}_{\phi wg} = 0.005790 \text{ in}^2$

$$F_d = \beta\,\frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}} = (1.0)\left(\frac{0.3930 + 0.3900 + 1.010}{0.01050 + 0.005790}\right) = 110.07 \text{ ksi}$$

$M_{crd} = S_f F_d = (2.800)(110.07) = 308.19$ k-in.
$M_y = S_f F_y = (2.800)(50) = 140.00$ k-in.

Now determine the fatored moment resistance in the distortional buckling limit state:

$$\lambda_d = \sqrt{\frac{M_y}{M_{crd}}} = \sqrt{\frac{140.00}{308.19}} = 0.673$$

Since $\lambda_d > 0.673$

$M_n = M_y = 140.00$ k-in.
$M_{rx\text{-}FY} = \phi_b M_n = (0.85)(140.0) = 119.0$ k-in.

Conclusions

The industry has always provided load tables for cold formed steel structural building products as an aid to designers, and will continue to do so. As discussed above, the current challenge is to provide tables that meet the requirements of the current CSA-S136 standard and still provide the designer the flexibility of accommodating different floor or wall assemblies. This fact sheet is intended to give designers some insight into the calculation of distortional buckling strength, and demonstrate the need to question how published load tables have been determined.

For additional information on calculating the distortional buckling strength, refer to CFSEI Technical Note TN-G101-08, *Design Aids and Examples for Distortional Buckling*, available at their website at www.cfsei.org.

For More Information

For more information on cold formed steel building products, or to order any CSSBI publications, contact the CSSBI at the address shown below or visit the web site at www.cssbi.ca