

# On North American and Chinese Standards for Design of Cold-formed Steel C-section Flexural Members

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**Abstract:** Nominal flexural strengths of cold-formed steel C-sections evaluated by the North American standard CSA S136-07 and the Chinese standard GB 50018—2002 were investigated. To quantify the differences of the nominal flexural strength between the two standards, 6 m span joists with typical C-sections subjected to the uniformly distributed load and uniform bending moment were investigated. The study results show that discrepancies between the two standards are resulted from both the difference in evaluating the effective section modulus and the difference in computing the lateral-torsional buckling stress. The lateral-torsional buckling stress evaluated based on GB 50018—2002 is generally not less than that of CSA S136-07 whereas the flange effective width of C-section calculated by GB 50018—2002 is much smaller than that of CSA S136-07. The adequacy of flange to prevent lateral-torsional buckling and the applied load patterns are the important factors resulting the differences of the nominal flexural strength between the two standards. If the flange is inadequate to resist later-torsional buckling and local buckling does not govern, the strength associated with GB 50018—2002 is greater than that of CSA S136-07 if members are subjected to the uniformly distributed load but there is no difference for case of uniform bending moment; in the case that flange is adequate to resist later-torsional buckling but local buckling governs the strength, then the nominal flexural strength obtained from GB 50018—2002 becomes less than that of CSA S136-07 in both foregoing applied load patterns.

**Key words:** cold-formed steel; C-section member; nominal flexural strength; lateral-torsional buckling; effective width; buckling coefficient

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# 北美规范与中国规范关于冷弯薄壁型钢 C 形截面受弯构件设计的比较

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**摘要:**对比了北美规范 CSA S136-07 和中国规范 GB 50018—2002 关于冷弯薄壁型钢 C 形截面受弯构件的名义抗弯强度。首先介绍了 2 本规范计算名义抗弯强度的方法, 然后分析了控制构件名义抗弯强度的 2 个主要参数, 即弯扭屈曲应力和有效截面模量, 并对 2 本规范进行了深入对比, 最后对典型的 6 m 跨长的 C 形托梁构件进行了名义抗弯强度比较。研究表明: 依据 GB 50018—2002 计算的弯扭屈曲应力不小于依据 CSA S136-07 规范计算的结果, 而根据 GB 50018—2002 计算的翼缘有效宽度则远远小于根据 CSA S136-07 规范计算的结果; 2 本规范名义抗弯强度的不同主要由 C 形截面翼缘尺寸和构件所受荷载类型控制; 当翼缘尺寸较小, 名义抗弯强度主要由弯扭屈曲而非局部屈曲控制时, 如果构件用于均布荷载, 则 GB 50018—2002 的计算结果大于 CSA S136-07 规范的结果, 但是当构件用于抵抗均布弯矩时, 则没有区别; 当翼缘尺寸较大, 名义抗弯强度主要由局部屈曲而非弯扭屈曲控制时, 在 2 种工况下 GB 50018—2002 的计算结果均小于 CSA S136-07 规范的计算结果。

**关键词:**冷弯薄壁型钢; C 形截面构件; 名义抗弯强度; 弯扭屈曲; 有效宽度; 屈曲系数

## 0 Introduction

C-section is the most widely used section shape in cold-formed steel framing construction. Typical applications of C-sections as flexural members are load bearing floor or roof joists and non-load bearing curtain wall studs. In North America, procedures for design of cold-formed steel members are specified in CSA S136-07<sup>[1]</sup>. In China, the design procedures for cold-formed steel members concerning with local buckling and lateral-torsional buckling are stipulated in GB 50018—2002<sup>[2]</sup>, while the procedure for evaluating the distortional buckling is specified in the standard JGJ 227—2011<sup>[3]</sup>. Although theoretical basis for evaluating the nominal flexural strength of C-section members are similar in the North American and the Chinese standards, there are differences in the procedure of evaluating the strength. The primary objectives of this study are to identify the differences in the procedures of evaluating the nominal flexural strength between CSA S136-07 and GB 50018—2002 for cold-formed steel C-section members and to investigate how the nominal flexural strength is affected by the differences of the procedures.

In the paper, procedures associated with the

foregoing two standards for evaluating the nominal flexural strength of cold-formed steel C-section members are firstly discussed. Then, two key parameters used for determining the nominal flexural strength of cold-formed steel members, the buckling stress and the associated effective width of cross-sectional elements, are compared, respectively. Finally, the differences in the nominal flexural strength between the two standards are investigated for the typical C-section load bearing floor joists.

## 1 Expression of Nominal Flexural Strength

Profile of C-section members is shown in Fig. 1. As seen from Fig. 1,  $w_w$  is the flat portion of the web;  $w_f$  is flat portion of the flange;  $b_o$  is the outer-to-outer dimension of the flange;  $h_o$  is outer-to-outer depth of the C-section members;  $x_o$  is the distance from shear center to centroid along principal axis;  $d$  is flat portion of the stiffener;  $D$  is height of the stiffener;  $R$  is inside bend radius;  $r$  is centerline bend radius. Assumptions made for the comparison of the nominal flexural strength of the C-section members shown in Fig. 1 are as follows:

① the load is applied through the shear center of

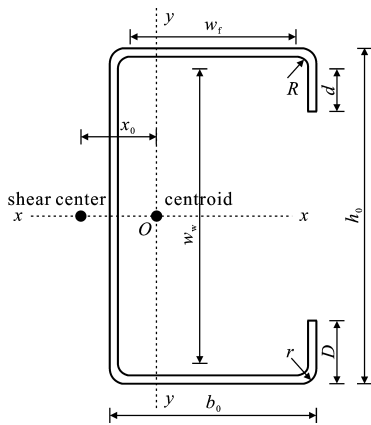


Fig. 1 Profile of C-section Member

图 1 C 形截面构件剖面

the C-section and the resulted bending is about the  $x$  axis; ② there are no holes in the C-section members; ③ distortional buckling is not considered; ④ the yield stresses of the steel are either  $f_y = 345$  MPa or  $f_y = 235$  MPa.

In CSA S136-07, the equation to evaluate the nominal flexural strength (nominal moment)  $M_n$  of the flexural member is

$$M_n = \min\{f_y S_e, f_c S_c\} \quad (1)$$

where  $f_c$  is the nominal stress computed based on lateral-torsional buckling<sup>[4-6]</sup>;  $S_e$  and  $S_c$  are the effective section moduli associated with the yield stress  $f_y$  and nominal stress  $f_c$ , respectively.

On the other hand, in GB 50018—2002, although the nominal flexural strength  $M_n$  is not explicitly expressed, the standard provides the following equation to check the strength and stability

$$\sigma = \frac{M_{\max}}{S_e} \leq f \quad (2)$$

$$\sigma = \frac{M_{\max}}{\varphi_{bx} S_c} \leq f \quad (3)$$

where  $M_{\max}$  is the maximum factored load;  $f$  is the design strength;  $\varphi_{bx}$  is the stability coefficient;  $S_e$  and  $S_c$  are the effective section moduli concerning with the design strength  $f$  and stress  $\varphi_{bx} f$ , respectively.

To obtain the equivalent nominal moment  $M_n$  based on GB 50018—2002, Eq. (2) and Eq. (3) can be rewritten as

$$M_n = \min\{f_y S_e, \varphi_{bx} f_y S_c\} \quad (4)$$

Because the stability coefficient  $\varphi_{bx}$  is a stress reduction coefficient to account for the lateral-tor-

sional buckling of the flexural member, the products of  $\varphi_{bx}$  and  $f_y$  in Eq. (4) can be considered as the equivalent to the nominal stress  $f_c$  shown in Eq. (1) as both of them are calculated based on lateral-torsional buckling.

Comparing Eq. (1) to Eq. (4), it can be seen that the two standards are similar to each other by specifying the minimum value of the section (local buckling) strength  $f_y S_e$  and the lateral-torsional buckling strength  $f_c S_c$  (or  $\varphi_{bx} f_y S_c$ ) being the nominal flexural strength  $M_n$ . The stress  $f_c$  (or  $\varphi_{bx} f_y$ ) is evaluated based on the lateral-torsional buckling, and the effective section moduli  $S_e$  and  $S_c$  are obtained with the consideration of the local buckling at the stress levels  $f_y$  (or  $f$ ) and  $f_c$  (or  $\varphi_{bx} f$ ), respectively. In order to compare the nominal flexural strength  $M_n$  between the two standards, the procedures of evaluating the lateral-torsional buckling stress  $f_c$  (or  $\varphi_{bx} f_y$ ) and the effective section moduli  $S_e$  and  $S_c$  are needed to be investigated.

## 2 Lateral-torsional Buckling Stress

In CSA S136-07, the nominal stress  $f_c$  is calculated as follows

$$f_c = \begin{cases} f_y & f_e \geq 2.78 f_y \\ \frac{10}{9} f_y \left(1 - \frac{10 f_y}{36 f_e}\right) & 2.78 f_y > f_e > 0.56 f_y \\ f_e & f_e \leq 0.56 f_y \end{cases} \quad (5)$$

where  $f_e$  is the elastic lateral-torsional buckling stress.

$f_e$  is evaluated as

$$f_e = \frac{C_b r_0 A}{S_f} \sqrt{\sigma_{ey} \sigma_t} \quad (6)$$

where  $S_f$  is the elastic section modulus of fully unreduced section relative to extreme compressive fibre;  $r_0$  is the polar radius of gyration;  $\sigma_{ey}$  is the elastic flexural buckling stress about the  $y$  axis;  $\sigma_t$  is the elastic torsional buckling stress;  $C_b$  is introduced to account for the increasing moment resistant capacity if the applied bending moment is not uniform along the span of the beam.

$r_0$ ,  $\sigma_{ey}$ ,  $\sigma_t$  and  $C_b$  are calculated as follows

$$r_0 = \sqrt{r_x^2 + r_y^2 + x_0^2} \quad (7)$$

$$\sigma_{ey} = \pi^2 E / (K_y L_y / r_y)^2 \quad (8)$$

$$\sigma_t = \frac{1}{Ar_0^2} \left[ GJ + \frac{\pi^2 EC_w}{(K_t L_t)^2} \right] \quad (9)$$

$$C_b = \frac{12.5M'_{\max}}{2.5M'_{\max} + 3M_A + 4M_B + 3M_C} \quad (10)$$

where  $K_y$ ,  $L_y$  and  $r_y$  are effective length factor, laterally unbraced length, and radius of gyration of fully unreduced cross section about the  $y$  axis;  $r_x$  is the radius of gyration of fully unreduced cross section about the  $x$  axis;  $K_t$  and  $L_t$  are the effective length factor and the unbraced length for twisting;  $A$  is the gross area;  $E$  and  $G$  are the elastic modulus and shear modulus, respectively, with  $E=203$  GPa and  $G=78$  GPa in CSA S136-07;  $C_w$  is the warping constant;  $J$  is the torsional constant;  $M_A$ ,  $M_B$  and  $M_C$  are absolute values of moments at the quarter point, centerline and three-quarter point of the unbraced segment;  $M'_{\max}$  is the absolute value of the maximum moment in the unbraced segment.

In GB 50018—2002, the stability coefficient  $\varphi_{bx}$ , which is the equivalent to the ratio  $f_c/f_y$ , is evaluated as

$$\varphi_{bx} = \begin{cases} \varphi'_{bx} & \varphi'_{bx} \leq 0.7 \\ 1.091 - 0.274/\varphi'_{bx} & \varphi'_{bx} > 0.7 \end{cases} \quad (11)$$

$$\varphi'_{bx} = \frac{4.320Ah_0}{(K_y L_y / r_y)^2 S_f} \zeta_1 \cdot \sqrt{\frac{4C_w}{h_0^2 I_y} + \frac{0.156J}{I_y} \left(\frac{L_y}{h_0}\right)^2 \frac{235}{f_y}} \quad (12)$$

where  $I_y$  is the moment of inertia about the  $y$  axis; and  $\zeta_1$  is the equivalent to  $C_b$  in Eq. (6).

Substitute elastic modulus  $E=206$  GPa (specified in GB 50018—2002) and  $E/G=2.6$  into Eqs. (8) and (9), the resulted elastic lateral-torsional buckling stress  $f_e$  in Eq. (6) will be the same as the product of  $\varphi'_{bx}$  and the yield stress  $f_y$  if the bending coefficient  $\zeta_1$  in Eq. (12) is identical to the coefficient  $C_b$  in Eq. (5). If  $C_b$  is not identical to  $\zeta_1$ , however,  $f_e$  in Eq. (6) would be different from the product of  $\varphi'_{bx}$  and the yield stress  $f_y$ .

Bending coefficients  $C_b$  in CSA S136-07 and  $\zeta_1$  in GB 50018—2002 are both introduced to account for the increasing moment resistant capacity when the applied bending moment is not uniformly distributed along the span of the flexural member. However, procedures of the evaluation of  $C_b$  and  $\zeta_1$

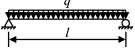
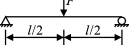
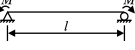
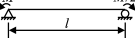
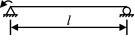
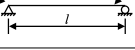
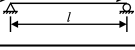
in the two standards are different. In CSA S136-07,  $C_b$  is evaluated based on the actual applied moment distribution through Eq. (10), whereas in GB 50018—2002, tabulated values of  $\zeta_1$  provided in Appendix A. 2 are listed for only seven load patterns. Values of  $C_b$  calculated based on CSA S136-07 and the tabulated  $\zeta_1$  in GB 50018—2002 for the seven load patterns are presented in Tab. 1. It can be seen from Tab. 1 that differences between  $C_b$  and  $\zeta_1$  are not greater than 10% except: ①  $\zeta_1$  are 18.0%, 41.6%, 49.1%, 13.4% greater than  $C_b$  for load patterns 4, 5, 6, 7, respectively, if the weak axis of the member is braced at the midpoint; ② except load pattern 3,  $\zeta_1$  is 22.3% to 62.4% greater than  $C_b$  if the weak axis of the member is braced at 1/3 point and 2/3 point. For these cases, since  $C_b$  is considerably different from  $\zeta_1$ , the resulted difference between  $\varphi'_{bx}$  of GB 50018—2002 and the ratio  $f_c/f_y$  of CSA S136-07 cannot be neglected.

For the case that  $\zeta_1 = C_b$ , that is  $\varphi'_{bx}$  of GB 50018—2002 is equivalent to the ratio  $f_c/f_y$  of CSA S136-07, the variations of stability coefficient  $\varphi_{bx}$  and ratio  $f_c/f_y$  calculated based on GB 50018—2002 and CSA S136-07, are presented in Fig. 2. It can be seen from Fig. 2 that the difference between the stability coefficient  $\varphi_{bx}$  and the ratio  $f_c/f_y$  is in the range of  $-1\%$  to  $4\%$ , which is not significant. Therefore, if  $\zeta_1$  is equal to  $C_b$ , the nominal lateral-torsional buckling stress  $f_e$  and  $\varphi_{bx} f_y$  in the two standards can be considered as approximately equivalent.

However, if  $C_b$  and  $\zeta_1$  are not identical, the nominal lateral-torsional buckling stress evaluated based on GB 50018—2002 may be quite different from that of CSA S136-07. In fact, as  $\zeta_1$  is usually not less than  $C_b$ , the lateral-torsional buckling stress calculated by GB 50018—2002 is generally greater than that of CSA S136-07. In the following investigation, the differences on the element effective width and member nominal flexural strength between the two standards will be firstly investigated for the case  $\zeta_1 = C_b$ . The comparisons of the strength for the cases that  $\zeta_1$  and  $C_b$  are not identi-

Tab. 1    Comparison of Bending Coefficients  $C_b$  and  $\zeta_1$

表 1    弯曲系数  $C_b$  和  $\zeta_1$  的比较

Load Pattern	No Lateral Bracing			One Lateral Bracing					Two Lateral Bracing					
	$C_b$ in CSA S136-07	$\xi_1$ in GB 50018— 2002	Difference/ %	CSA S136-07			$\xi_1$ in GB 50018— 2002	Difference/ %	CSA S136-07				$\xi_1$ in GB 50018— 2002	Difference/ %
				$C_{b1}$	$C_{b2}$	$C_b$			$C_{b1}$	$C_{b2}$	$C_{b3}$	$C_b$		
1. 	1.136	1.130	−0.5	1.299	1.299	1.299	1.350	4.0	1.460	1.014	1.460	1.014	1.370	35.1
2. 	1.316	1.350	2.6	1.667	1.667	1.667	1.830	9.8	1.667	1.087	1.667	1.087	1.680	54.6
3. 	1.000	1.000	0.0	1.000	1.000	1.000	1.000	0.0	1.000	1.000	1.000	1.000	1.000	0.0
4. 	1.250	1.320	5.6	1.111	1.154	1.110	1.310	18.0	1.071	1.087	1.111	1.071	1.310	22.3
5. 	1.667	1.830	9.8	1.250	1.667	1.250	1.770	41.6	1.154	1.250	1.667	1.154	1.750	51.6
6. 	2.174	2.390	9.9	1.429	2.174	1.429	2.130	49.1	1.250	1.667	1.667	1.250	2.030	62.4
7. 	2.273	2.240	−1.4	1.667	1.667	1.667	1.890	13.4	1.364	2.273	1.364	1.364	1.770	29.8

**Note:** In CSA S136-07, if the weak axis of the member is braced at the 1/2 point, or is braced at 1/3 point and 2/3 point,  $C_{bn}$  represents  $C_b$  of the  $n$ th unbraced segment, while the final  $C_b$  of the member is determined by the unbraced segment which controls the member strength;  $l$  is the length of the member;  $F, M$  and  $q$  represent the applied force, bending moment and uniform distributed load, respectively.

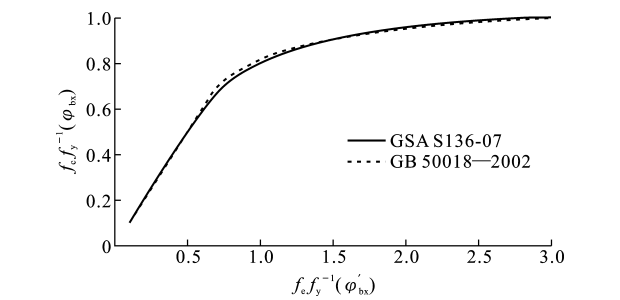


Fig. 2    Comparison of Lateral-torsional Buckling Stresses

图 2    弯扭屈曲应力的比较

cal will be subsequently demonstrated through examples in section 4.

### 3    Element Effective Width of Flexural Member

The procedures on evaluating the cross-sectional element effective width in both standards are compared by Zhou, et al. According to Tab. 1 by Zhou, et al.<sup>[7]</sup>, the differences between the two standards on evaluating the element effective width for C-section flexural members are primarily resulted from:

- (1) The maximum stresses  $\sigma_{\max}$  defined in the

two standards are different. In CSA S136-07,  $\sigma_{\max} = f_y$  is specified to calculate the local buckling strength; whereas in GB 50018—2002,  $\sigma_{\max} = f$ , where  $f$  is the design strength which is less than  $\sigma_{\max} = f_y$ . According to GB 50018—2002,  $f = 300$  MPa and  $f = 205$  MPa for  $f_y = 345$  MPa and  $f_y = 235$  MPa steel, respectively. While evaluating the lateral-torsional buckling strength based on CSA S136-07 and GB 50018—2002, the maximum stresses are specified as  $\sigma_{\max} = f_c$  and  $\sigma_{\max} = \varphi_{bx} f$ , respectively. For the case that  $\zeta_1 = C_b$ , the ratio  $f_c/f_y$  in CSA S136-07 is considered to be equivalent to  $\varphi_{bx}$  in GB 50018—2002. Therefore, the maximum stress  $\sigma_{\max}$  for evaluating both the local buckling strength and lateral-torsional buckling strength defined in GB 50018—2002 is approximately 87% of that specified in CSA S136-07.

Since the maximum stresses  $\sigma_{\max}$  defined in the two standards are different, to avoid confusion, in the following discussions, the maximum stress  $\sigma_{\max}$  refers to the maximum stress specified in CSA S136-07 unless otherwise indicated.

(2) The plate buckling coefficient  $k$  evaluated by CSA S136-07 and the products of  $k$  and  $k_1(kk_1)^{[8-9]}$  calculated by GB 50018—2002 are different. The comparison of the plate buckling coefficient  $k$  defined in CSA S136-07 and the products of  $k$  and  $k_1(kk_1)$  stipulated in GB 50018—2002 for the stiffener, flange and web of the C-section flexural member are presented in sections 3.1-3.3.

It is worth pointing out as to be discussed in sections 3.1-3.3, the buckling coefficients and the resulted effective widths for web and stiffener of a flexural member are both evaluated based on the cross-sectional neutral axis shown in Fig. 3. However, to determine the location of the neutral axis, the cross-sectional element effective width should be specified at first. Therefore, the procedure to evaluate the element effective width of the C-section flexural member in both standards is an iterative process with the assumption that the initial neutral axis is usually located at the center of the web.

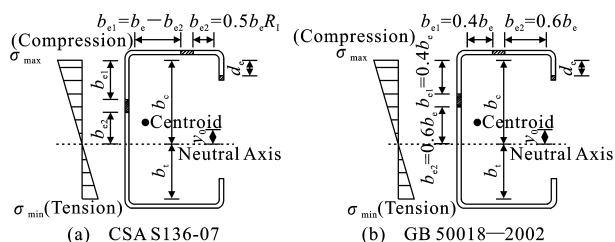


Fig. 3 Comparison of Effective Width Distribution

图 3 有效宽度分布的比较

(3) The web effective width  $b_e$  of CSA S136-07 is evaluated based on the entire flat portion of the element  $w$ , whereas  $b_e$  of GB 50018—2002 is calculated based on the compressed flat portion of the element  $b_c$ .

(4) The two standards use different approaches to distribute the flange effective width and web effective width, as shown in Fig. 3. For the flange,  $b_{e1}$  is effective width adjacent to the web whereas  $b_{e2}$  is the effective width adjacent to the stiffener. For the web,  $b_{e1}$  is effective width adjacent to the flange and  $b_{e2}$  is the effective width adjacent to the neutral axis.

The difference of the flange effective width distribution between the two standards for the flexural member is the same as that for the com-

pressive member<sup>[7]</sup>. From Fig. 3, it can be seen the nominal moment  $M_n$  is only affected by the total flange effective width  $b_{e1} + b_{e2}$ , but not the flange  $b_{e1}$  or  $b_{e2}$ . Therefore, the comparison of flange effective width between the two standards is only carried out for the total flange effective width.

However, as shown in Fig. 3, even with the same total web effective width  $b_{e1} + b_{e2}$ , different web effective widths  $b_{e1}$  and  $b_{e2}$  would result in different nominal flexural strengths  $M_n$ . Therefore, the comparison of the web effective width between the two standards is conducted for both  $b_{e1}$  and  $b_{e2}$ .

The resulted differences of the effective widths for the stiffener, flange and web of the C-section flexural member between the two standards are discussed in detail in the following sections.

### 3.1 Stiffener Effective Width

In CSA S136-07, the stiffener buckling coefficient  $k_L$  of stiffener of typical C-section flexural members is calculated as follows

$$k_L = \frac{0.578}{\Psi + 0.34} \quad (13)$$

$$\Psi = \left| \frac{\sigma_{\min}}{\sigma_{\max}} \right| \quad (14)$$

where  $\sigma_{\min}$  is the minimum stress of the considered element, with  $\sigma$  being positive for compressive stress and negative for tensile stress;  $\Psi$  is the stress ratio.

On the other hand, based on GB 50018—2002, the stiffener buckling coefficient  $k_L$  is calculated as

$$k_L = 1.70 - 3.025\Psi_L + 1.75\Psi_L^2 \quad (15)$$

$$\Psi = \frac{\sigma_{\min}}{\sigma_{\max}} \quad (16)$$

It is worthy to mention that stress ratio  $\Psi$  defined in GB 50018—2002 (Eq. 16) is different from that specified in CSA S136-07 (Eq. 14). To avoid confusion, in the following discussions, stress ratio  $\Psi$  refers to the one stipulated in CSA S136-07 unless otherwise indicated.

The variations of stiffener buckling coefficients  $k_L$  versus the stress ratio  $\Psi_L$  calculated according to the two standards are presented in Fig. 4, in which the differences of the buckling coefficients of the stiffener range from  $-21.1\%$  to

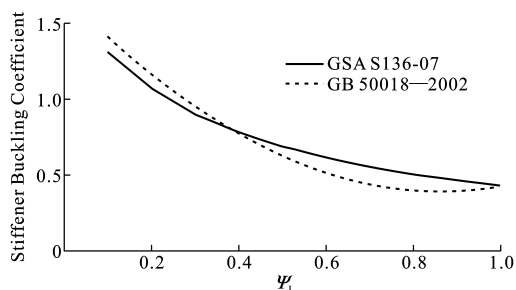


Fig. 4 Comparison of Stiffener Buckling Coefficients

图 4 卷边屈曲系数的比较

8.8%, which is not very significant.

Further investigation was conducted to reveal reasons that resulted in the difference of the stiffener effective widths between the two standards. The study concluded that the difference of the stiffener effective widths between the two standards for the C-section flexural member is similar to that for the compressive member<sup>[7]</sup>, because:

(1) The stiffener  $\Psi_L$  for the common C-section flexural member is usually close to 1. Consequently, for both standards, the stiffener buckling coefficient of the flexural member is quite close to that of the compressive member,  $k_L = 0.43$ .

(2) Moreover, for a given C-section with the specified maximum stress  $\sigma_{\max}$ , the calculated values of coefficients  $k_{1L}$  and  $R_1$  for the stiffener of the flexural member are essentially equivalent to those of the compressive members.

### 3.2 Flange Effective Width

The study found that the discussions on the flange buckling coefficients defined in the two standards and associated differences for the flexural member were similar to those obtained from the investigation for the compressive member<sup>[7]</sup>. The flange buckling coefficient  $k_f$  evaluated based on GB 50018-2002 is considerably less than that of CSA S136-07.

The coefficient  $k_{1f}$  of the flange for the flexural member is presented in Fig. 5. It can be seen from Fig. 5, the flange for the flexural member has much larger value of  $k_{1f}$  than that of the compressive member. However, the coefficient  $k_{1f}$  for the flexural member is still less than 1 if  $w_w/w_f > 5$ ; even in the case that  $w_w/w_f \leq 5$ ,  $k_{1f}$  of flange is on-

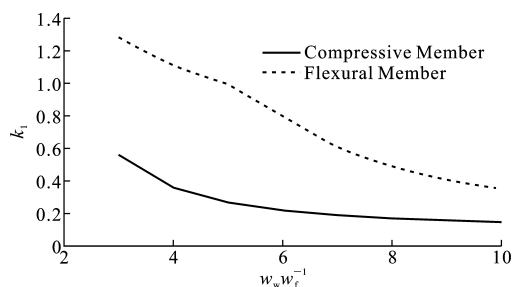


Fig. 5 Comparison of Plate Constraint Coefficient  
Flange  $k_{1f}$  Between Flexural and  
Compressive Members

图 5 受弯与受压构件的翼缘板组约束系数  $k_{1f}$  的比较

ly slightly greater than 1. The products of  $k_f$  and  $k_{1f}$  stipulated in GB 50018-2002 is still much less than the buckling coefficient  $k_f$  specified in CSA S136-07 for the flange of flexural members. Therefore, similar to that of the compressive member, the flange effective width of the flexural member with C-section calculated based on GB 50018-2002 is considerably less than that evaluated in accordance with CSA S136-07.

### 3.3 Web Effective Width

In accordance with CSA S136-07, the web effective widths  $b_{e1}$  and  $b_{e2}$  shown in Fig. 3 (a) can be calculated as follows

$$b_{e1} = \frac{\rho_w w_w}{3 + \Psi_w} \quad (17)$$

$$b_{e2} = \begin{cases} \min\left\{\rho_w w_w - b_{e1}, \frac{w_w}{1 + \Psi_w} - b_{e1}\right\} & h_0/b_0 \leq 4, \Psi_w \leq 0.236 \\ \min\left\{\frac{\rho_w w_w}{2}, \frac{w_w}{1 + \Psi_w} - b_{e1}\right\} & h_0/b_0 \leq 4, \Psi_w > 0.236 \\ \frac{\rho_w w_w}{1 + \Psi_w} - b_{e1} & h_0/b_0 > 4 \end{cases} \quad (18)$$

where  $\rho_w$  is the web local reduction factor;  $\Psi_w$  is the web stress ratio.

It is noted that based on CSA S136-07 for the case  $\Psi_w > 0.236$ , the equation to evaluate  $b_{e2}$  is different from that when  $\Psi_w \leq 0.236$ . Considering  $\Psi_w$  is usually greater than 0.236 for the most of C-sections, the discussion in this study is limited to the case where  $\Psi_w > 0.236$ .

On the other hand, based on GB 50018-2002, the web  $b_{e1}$  and  $b_{e2}$  shown in Fig. 3 (b) can be evaluated as

$$b_{e1} = 0.4 \frac{\rho_w w_w}{1 + \Psi_w} \quad (19)$$

$$b_{e2} = 0.6 \frac{\rho_w w_w}{1 + \Psi_w} \quad (20)$$

Comparing Eq. (17) and Eq. (18) to Eq. (19) and Eq. (20), respectively, it is seen that the differences of the web effective widths  $b_{e1}$  and  $b_{e2}$  between the two standards are not easy to identify. The differences between the two standards are primarily resulted from:

(1) Although there appears to be a similarity between Eqs. (14) and (16), values of the web stress ratio  $\Psi_w$  obtained from the two standards may be different. This is because as shown in Fig. 3, the distance from the section neutral axis to the centroid  $y_0$  is calculated based on the effective widths of web, flange and stiffener. Since the flange and stiffener effective widths of the two standards may be different as previously discussed in sections 3.1-3.2, the values of  $y_0$  and  $\Psi_w$  obtained from the two standards may be different.

In fact, the difference of the web stress ratio  $\Psi_w$  between the two standards can be determined only if cross-sectional properties of the C-section and bracing conditions of the flexural member are provided. With the absence of specific information on the cross-sectional properties and bracing conditions, it is assumed that values of the web stress ratios  $\Psi_w$  obtained from the two standards are the same in following discussions for the reason of convenience. For the case that values of  $\Psi_w$  are different in the two standards, the effects of difference of  $\Psi_w$  on the web effective width will be discussed in section 4 through demonstrated examples.

(2) The two standards may have different web local reduction factors  $\rho_w$ . According to Tab. 1 of the accompanying paper<sup>[7]</sup>, the difference of web local reduction factors  $\rho_w$  between the two standards is primarily induced by the difference of the web buckling coefficient  $k_w$  defined in CSA S136-07 and the product  $k_w k_{1w}$ <sup>[7]</sup> specified in GB 50018—2002.

(3) The equations to evaluate effective widths  $b_{e1}$  and  $b_{e2}$  are different between the two standards.

The differences between CSA S136-07 and GB 50018—2002 on the web local reduction factors  $\rho_w$ , the procedures of distributing web effective widths and the resulted web effective widths are discussed in detail in sections 3.3.1-3.3.3.

### 3.3.1 Difference of Local Reduction Factor $\rho_w$

In CSA S136-07, the web buckling coefficient is calculated as

$$k_w = 4 + 2(1 + \Psi_w)^3 + 2(1 + \Psi_w) \quad (21)$$

On the other hand, in accordance with GB 50018—2002, the web buckling coefficient is calculated as

$$k_w = 7.8 - 6.29\Psi_w + 9.78\Psi_w^2 \quad (22)$$

The web buckling coefficients calculated based on the two standards are shown in Fig. 6. It can be seen from Fig. 6, the two standards can be generally considered as equivalent in terms of the web buckling coefficients of the C-section in flexural bending. The web buckling coefficient defined in GB 50018—2002 is only from 0.5% to 4.1%, which is less than that specified in CSA S136-07.

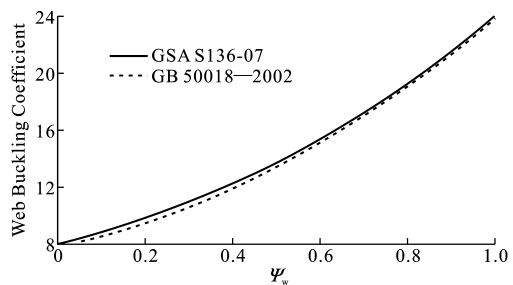


Fig. 6 Comparison of Web Buckling Coefficients

图 6 腹板屈曲系数的比较

The difference of the web local reduction factors  $\rho_w$  between the two standards is primarily resulted from the coefficient  $k_{1w}$  of GB 50018—2002. As demonstrated in Fig. 7, the coefficient  $k_{1w}$  is much less in the case of flexural bending than that of in axial compression. Coefficient  $k_{1w}$  is less than 1 if  $w_w/w_t < 5$ , with the minimum value being 0.47 for the case  $w_w/w_t = 3$ . Therefore, different from the case that the C-section is in axial compression in which  $k_w k_{1w}$  of GB 50018—2002 is always not less than the coefficient  $k_w$  of CSA S136-07, the product  $k_w k_{1w}$  for the web may become less than the coefficient  $k_w$  for case that the C-section is subjected to flexural bending. For the flexural mem-



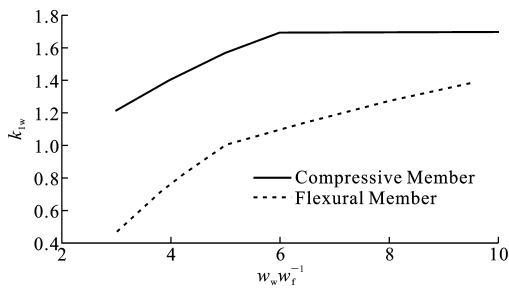


Fig. 7 Comparison of Web Restraint coefficient  $k_{1w}$  Between Flexural and Compressive Members

图 7 受弯与受压构件的腹板约束系数  $k_{1w}$  的比较

ber with C-section, if the product of  $k_w k_{1w}$  evaluated based on GB 50018—2002 is less than 87% of the web buckling coefficient  $k_w$  defined in CSA S136-07, the ratio  $\sigma_{\max}/(k_w k_{1w})$  of GB 50018—2002 would be greater than  $\sigma_{\max}/k_w$  of CSA S136-07. As a result, according to Tab. 1 of the study by Zhou, et al<sup>[7]</sup>, the web local reduction factor  $\rho_w$  evaluated based on GB 50018—20012 would be less than that of CSA S136-07.

Coefficients  $k_1$  for both the flange and web of C-sections in flexural bending are functions of the web buckling coefficient  $k_w$  defined in GB 50018—2002<sup>[2]</sup>. As defined in Eq. (22), the web buckling coefficient  $k_w$  is a function of the web stress ratio  $\Psi_w$ . Therefore, coefficients  $k_1$  of both flange and web are related with the web stress ratio  $\Psi_w$ . The coefficients  $k_1$  for the flange and web shown respectively in Fig. 5 and Fig. 7 are evaluated based on the web stress ratio  $\Psi_w = 1$  and the web buckling coefficient  $k_w = 24$ .

Relations of the web local reduction factors  $\rho_w$  evaluated based on the two standards are illustrated in Fig. 8 when  $w_w/t = 200$ ,  $\sigma_{\max} = f_y$  and  $\Psi_w = 1$ . It can be seen from Fig. 8 that the factors  $\rho_w$  for CSA S136-07 remain as constants of 0.5, 0.58 for  $f_y = 345$  MPa and  $f_y = 235$  MPa steel, respectively. However, in the case of GB 50018—2002, when  $w_w/w_t$  increases from 3 to 10, due to the increase of  $k_{1w}$  shown in Fig. 7, the factors  $\rho_w$  increase from 0.41 to 0.67 and 0.48 to 0.75 for  $f_y = 345$  MPa and  $f_y = 235$  MPa steel, respectively. The differences of the web local reduction factors  $\rho_w$  between the two standards range from -19.9% to 35.5% and -17.5% to 28.5% for  $f_y = 345$  MPa and  $f_y =$

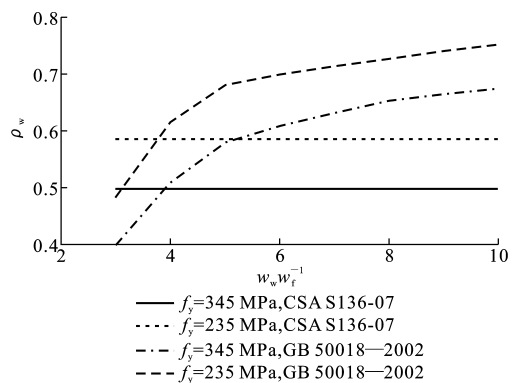


Fig. 8 Comparison of Web Local Reduction Factor  $\rho_w$  when  $w_w/t = 200$ ,  $\sigma_{\max} = f_y$ ,  $\Psi_w = 1$

图 8  $w_w/t = 200$ ,  $\sigma_{\max} = f_y$ ,  $\Psi_w = 1$  时腹板局部折减系数  $\rho_w$  的比较

235 MPa steel, respectively, in which that the difference is positive denotes the value associated with GB 50018—2002 is greater than that of CSA S136-07. The factors  $\rho_w$  obtained from the both standards are the same when  $w_w/w_t = 4.0$  and  $w_w/w_t = 3.8$  for  $f_y = 345$  MPa and  $f_y = 235$  MPa steel, respectively.

### 3.3.2 Procedure of Distributing Web Effective Widths

Once the web local reduction factor  $\rho_w$  is obtained, the two standards use different approaches to distribute the web effective widths  $b_{e1}$  and  $b_{e2}$  as shown in Fig. 3. Presented in Fig. 9 are ratios  $b_{e1}/(\rho_w w_w)$  and  $b_{e2}/(\rho_w w_w)$  calculated based on the two standards. As shown in Fig. 9(a), ratios  $b_{e1}/(\rho_w w_w)$  in the two standards decrease with the increase of the stress ratio  $\Psi_w$ , but the rate of decrease associated with CSA S136-07 is much less than that of GB 50018—2002. When  $\Psi_w$  is greater than 0.3 which is the case satisfied by the most of C-sections in flexural bending, ratio  $b_{e1}/(\rho_w w_w)$  of GB 50018—2002 is less than that of CSA S136-07. As  $\Psi_w$  increases from 0.3 to 1, the differences of the ratios  $b_{e1}/(\rho_w w_w)$  increase from 0% to 20%.

The comparison of ratios  $b_{e2}/(\rho_w w_w)$  between the two standards is presented in Fig. 9 (b). It can be seen the difference is not only associated with the stress ratio  $\Psi_w$ , but also related to the ratio  $h_0/b_0$  and the web local reduction factor  $\rho_w$ :

(1) When  $h_0/b_0 > 4$ , the ratio  $b_{e2}/(\rho_w w_w)$

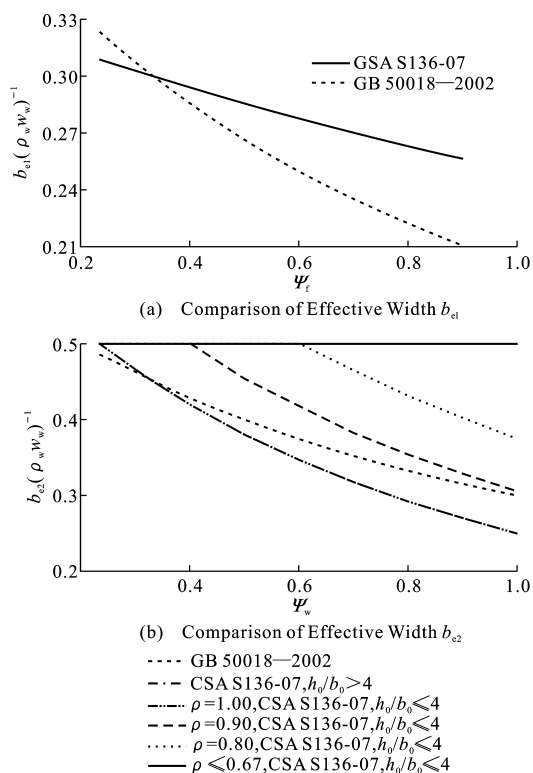


Fig. 9 Comparisons of Web Effective Width Distribution

图 9 腹板有效宽度分布的比较

stipulated in CSA S136-07 is less than that defined in GB 50018—2002 if  $\Psi_w > 0.3$ . Moreover, the difference between the two standards increases with the increase of  $\Psi_w$ . As  $\Psi_w$  increases from 0.3 to 1, the difference of ratios  $b_{e2}/(\rho_w w_w)$  between the two standards increases from 0% to 20%.

(2) When  $h_0/b_0 \leq 4$ , ratio  $b_{e2}/(\rho_w w_w)$  defined in CSA S136-07 is related to the factor  $\rho_w$ : ① when  $\rho_w = 1$ , ratio  $b_{e2}/(\rho_w w_w)$  calculated using CSA S136-07 is the same as the case that  $h_0/b_0 > 4$ , and ratio  $b_{e2}/(\rho_w w_w)$  defined in GB 50018—2002 is larger than that specified in CSA S136-07 if  $\Psi_w > 0.3$ ; ② as  $\rho_w$  decreases, ratio  $b_{e2}/(\rho_w w_w)$  calculated using CSA S136-07 gradually increases, and when  $\rho_w \leq 0.9$ , ratio  $b_{e2}/(\rho_w w_w)$  defined in GB 50018—2002 becomes less than that evaluated based on CSA S136-07; ③ when  $\rho_w \leq 0.67$ , ratio  $b_{e2}/(\rho_w w_w)$  of CSA S136-07 remains a constant of 0.5. For the case if  $\rho_w \leq 0.67$ , the difference of ratios  $b_{e2}/(\rho_w w_w)$  between the two standards increase from -8.3% to -78.5% as  $\Psi_w$  increases from 0.3 to 1.

It is worthy to mention that as the web local

reduction factor  $\rho_w$  is usually not greater than 0.9, for the given stress ratio  $\Psi_w$  and web local reduction factor  $\rho_w$ , the ratio  $b_{e2}/(\rho_w w_w)$  evaluated based on CSA S136-07 will experience an abrupt change at  $h_0/b_0 = 4$  as shown in Fig. 9(b). The abrupt change of the ratio  $b_{e2}/(\rho_w w_w)$  in CSA S136-07 can be clearly visualised in Fig. 10(b) for  $w_w/w_t = 4$ , which is resulted from  $h_0/b_0 = 4$ . When  $h_0/b_0 \leq 4$ , the ratio  $b_{e2}/(\rho_w w_w)$  calculated based on GB 50018—2002 is less than that of CSA S136-07. However, when  $h_0/b_0 > 4$ , since the ratio  $b_{e2}/(\rho_w w_w)$  defined in CSA S136-07 reduces abruptly, the ratio  $b_{e2}/(\rho_w w_w)$  evaluated by GB 50018—2002 suddenly becomes greater than that of CSA S136-07. The ratio  $h_0/b_0$  has a significant influence on the differences of the ratios  $b_{e2}/(\rho_w w_w)$  between the two standards.

### 3.3.3 Difference of Web Effective Width

The effects of ratio  $w_w/w_t$  on the web effective widths  $b_{e1}$  and  $b_{e2}$  of the two standards, are demonstrated in Fig. 10 for a C-section with the web width-to-thickness ratio  $w_w/t = 200$ , stress ratio  $\Psi_w = 1$  and the maximum stress  $\sigma_{\max} = f_y$ . From Fig. 10(a), it can be seen the difference of effective width ratios  $b_{e1}/t$  between the two standards is greatly influenced by the ratio  $w_w/w_t$ :

(1) When  $w_w/w_t = 3$ , ratios  $b_{e1}/t$  evaluated based on GB 50018—2002 are 35.9% and 34.0% less than those of CSA S136-07 for  $f_y = 345$  MPa and  $f_y = 235$  MPa steel, respectively. The smaller values of  $b_{e1}/t$  associated with GB 50018—2002 are resulted from the smaller values of web local reduction factor  $\rho_w$  and ratio  $b_{e1}/(\rho_w w_w)$ . The web local reduction factors  $\rho_w$  evaluated based on GB 50018—2002 are 19.9% and 17.5% less than those evaluated in accordance with CSA S136-07 for  $f_y = 345$  MPa and  $f_y = 235$  MPa steel, respectively, as discussed in section 3.3.1; whereas the ratio  $b_{e1}/(\rho_w w_w)$  calculated using GB 50018—2002 is 20% less than that of CSA S136-07 as discussed in section 3.3.2.

(2) As the ratio  $w_w/w_t$  increases, the ratio  $b_{e1}/t$  evaluated based on GB 50018—2002 gradually increases, whereas that calculated in accordance

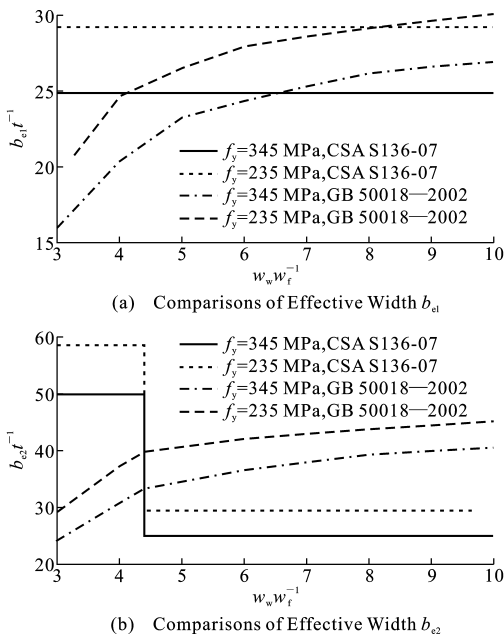


Fig. 10 Comparisons of Web Effective Widths  
when  $w_w/t=200$ ,  $\sigma_{\max}=f_y$ ,  $\Psi_w=1$

图 10  $w_w/t=200$ ,  $\sigma_{\max}=f_y$ ,  $\Psi_w=1$  时腹板有效宽度的比较

with CSA S136-07 remains as a constant. Therefore, when  $w_w/w_f \geq 6.7$ ,  $w_w/w_f \geq 8.2$  for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively, ratios  $b_{e1}/t$  calculated by GB 50018—2002 becomes greater than those of CSA S136-07. The differences of ratios  $b_{e1}/t$  between the two standards range from  $-35.9\%$  to  $8.4\%$  and  $-34.0\%$  to  $2.8\%$  when  $w_w/w_f$  increases from 3 to 10 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively.

The increase of the ratio  $b_{e1}/t$  associated with GB 50018—2002 is induced by the web local reduction factor  $\rho_w$ . As the increase of ratio  $w_w/w_f$ , the factor  $\rho_w$  in GB 50018—2002 increases, as discussed in section 3.3.1; whereas the ratio  $b_{e1}/(\rho_w w_w)$  remains as a constant, as discussed in section 3.3.2. Therefore, the ratio  $b_{e1}/t$  associated with GB 50018—2002 gradually increases with the increase of  $w_w/w_f$ .

The relations of ratios  $b_{e2}/t$  calculated using the two standards are shown in Fig. 10(b). From Fig. 10(b), it can be seen the difference of effective width ratios  $b_{e2}/t$  between the two standards is also greatly influenced by the ratio  $w_w/w_f$ :

(1) When  $w_w/w_f \leq 4.4$  ( $h_0/b_0 \leq 4$  with  $R =$

$2t$ ), the differences between the factors  $\rho_w$  stipulated in GB 50018—2002 and CSA S136-07 range from  $-17.5\%$  to  $13.3\%$  and  $-19.9\%$  to  $11.4\%$  for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively, as shown in Fig. 8. Meanwhile, the ratio  $b_{e2}/(\rho_w w_w)$  in GB 50018—2002 is  $40\%$  less than that of CSA S136-07 for both  $f_y=345$  MPa and  $f_y=235$  MPa steel, as shown in Fig. 9(b). Therefore, as  $b_{e2}/t = \rho_w b_{e2}/(\rho_w w_w)$ , ratios  $b_{e2}/t$  defined in GB 50018—2002 are considerably less than those of CSA S136-07 for both  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively. Ratios  $b_{e2}/t$  evaluated based on GB 50018—2002 increase from 23.9 to 33.3 and 29.0 to 39.8 when  $w_w/w_f$  increases from 3 to 4.4 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively; whereas ratios  $b_{e2}/t$  in CSA S136-07 remain as constants being 49.8 and 58.5 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively. Consequently, differences of  $b_{e2}/t$  between the two standards decrease from  $-51.9\%$  to  $-32\%$  and  $-50.5\%$  to  $-33.1\%$  when  $w_w/w_f$  increases from 3 to 4.4 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively.

(2) However, for the case  $w_w/w_f > 4.4$  ( $h_0/b_0 > 4$ ), ratios  $b_{e2}/t$  evaluated based on GB 50018—2002 are much greater than those of CSA S136-07. As discussed in section 3.3.2, when  $h_0/b_0 > 4$ , the ratio  $b_{e2}/(\rho_w w_w)$  calculated based on GB 50018—2002 is usually greater than that of CSA S136-07. Meanwhile, due to the increase of  $w_w/w_f$ , the web local reduction factor  $\rho_w$  stipulated in GB 50018—2002 also becomes greater than that defined in CSA S136-07 as shown in Fig. 8. Consequently, ratios  $b_{e2}/t$  defined in GB 50018—2002 are much greater than those of CSA S136-07 for both  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively. Ratios  $b_{e2}/t$  calculated using CSA S136-07 decrease abruptly and remain as the constants 24.9 and 29.2 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively. Meanwhile, as ratio  $w_w/w_f$  increases from 4.4 to 10, ratios  $b_{e2}/t$  evaluated based on GB 50018—2002 increase from 33.3 to 40.5 and 39.8 to 45.1 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively. The corresponding differences of ratios  $b_{e2}/t$

between the two standards increase from 33.7% to 62.6% and 36% to 54.2%.

From the foregoing analysis, it is concluded that the differences of web effective widths  $b_{e1}$  and  $b_{e2}$  between the two standards are greatly influenced by ratio  $w_w/w_f$  of GB 50018—2002 (or ratio  $h_0/b_0$  in CSA S136-07). When the ratio  $w_w/w_f=3$ , the ratio  $b_{e1}/t$  evaluated based on GB 50018—2002 is less than that of CSA S136-07. However, as the increase of  $w_w/w_f$ , the ratio  $b_{e1}/t$  of GB 50018—2002 increases whereas that of CSA S136-07 remains as a constant. Thus, the ratio  $b_{e1}/t$  calculated in accordance with GB 50018—2002 may become greater than that of CSA S136-07 when  $w_w/w_f$  further increases. For the ratio  $b_{e2}/t$ , for the case  $h_0/b_0>4$ , the ratio  $b_{e2}/t$  calculated using GB 50018—2002 is considerably greater than that of CSA S136-07, and vice versa.

#### 4 Comparison of Nominal Flexural Strength

Three commonly used floor joist sections shown in Tab. 2 are selected from the *Handbook of Steel Construction*<sup>[10]</sup> for nominal flexural strength comparison in this study. The length of each member is 6 m and the weak axis of the member is braced at 1/3 span point and 2/3 span point. The load applied on the member is either uniform bending moment (load pattern 3 in Tab. 1) or uniformly distributed load (load pattern 1 in Tab. 1).

The comparisons on the buckling stress, effective cross-sectional modulus, nominal flexural strength and the element effective width for each member calculated in accordance with the two standards are presented in Tab. 3 to Tab. 5. From Tab. 3, it can be seen the difference of the buckling stresses between the two standards for member C

is considerably different from that for members A and B. The difference of the buckling stresses between the two standards for members A and B is practically negligible; whereas for member C, however, the difference is associated with the applied load pattern. When member C is subjected to uniform bending moment, there is no significant difference of the buckling stresses between the two standards. But when the uniformly distributed load is applied, buckling stresses calculated based on GB 50018—2002 are 39.4% and 22.8% greater than those of CSA S136-07 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively.

The larger values of buckling stresses associated with GB 50018—2002 for member C are primarily resulted from the larger value of bending coefficient  $\zeta_1$ . When the member is subjected to uniformly distributed load and the weak axis of the member is supported by two equally spaced bracings, the value of  $\zeta_1$  defined in GB 50018—2002 is 35.1% greater than  $C_b$  calculated in accordance with CSA S136-07 as shown in Tab. 1. However, since  $C_b$  and  $\zeta_1$  affect the lateral-torsional buckling stress only, they have no influence on members which are not governed by lateral-torsional buckling. For members A and B, because the flanges are adequate to resist the lateral-torsional buckling, the buckling stresses of members A and B are almost identical which are slightly less than the yield stress. Therefore, in this case, the difference between bending coefficients  $C_b$  and  $\zeta_1$  has a trivial influence on the difference of buckling stresses between the two standards.

The difference of the nominal flexural strength between the two standards for member C is also considerably different from that for members

Tab. 2 Constructions of Members  
表 2 构件构造

Member	Section Dimension/mm									Section Modulus/ 10 <sup>3</sup> mm <sup>3</sup>	Length/m	Bracing
	$h_0$	$b_0$	$D$	$t$	$R$	$r$	$d$	$w_f$	$w_w$			
A	254	76.2	25.4	1.44	2.16	2.88	21.8	69.0	246.8	48.6	6	2
B	305	76.2	25.4	1.44	2.16	2.88	21.8	69.0	348.8	62.4	6	2
C	254	41.3	12.7	2.58	3.87	5.16	6.25	28.4	241.1	55.6	6	2

Tab. 3 Comparison of Nominal Flexural Strength

表 3 名义抗弯强度比较

Load Pattern	Member	Standards	$f_y=345\text{ MPa}$			$f_y=235\text{ MPa}$		
			Buckling Stress/MPa	Effective Section Modulus/ $10^3\text{ mm}^3$	Nominal Flexural Strength/ ( $\text{kN}\cdot\text{m}$ )	Buckling Stress/MPa	Effective Section Modulus/ $10^3\text{ mm}^3$	Nominal Flexural Strength/ ( $\text{kN}\cdot\text{m}$ )
UM	A	CSA S136-07	323.59	37.94	12.28	233.39	43.54	10.16
		GB 50018—2002	324.07	26.92	8.72	232.11	30.89	7.17
		Difference/%	0.1	−29.0	−28.9	−0.5	−29.1	−29.4
	B	CSA S136-07	321.87	43.65	14.05	232.59	48.48	11.28
		GB 50018—2002	322.56	32.93	10.62	231.41	38.47	8.90
		Difference/%	0.2	−24.6	−24.4	−0.5	−20.6	−21.0
	C	CSA S136-07	152.28	55.56	8.46	149.18	55.56	8.29
		GB 50018—2002	154.98	55.56	8.61	154.98	55.56	8.61
		Difference/%	1.8	0.0	1.8	3.9	0.0	3.9
UDL	A	CSA S136-07	323.59	37.94	12.28	233.77	43.51	10.17
		GB 50018—2002	338.21	26.47	8.95	235.00	30.73	7.22
		Difference/%	4.5	−30.2	−27.1	0.5	−29.4	−29.0
	B	CSA S136-07	321.87	45.44	14.63	232.99	48.45	11.29
		GB 50018—2002	337.10	32.28	10.88	235.00	38.21	8.98
		Difference/%	4.7	−29.0	−25.6	0.9	−21.1	−20.4
	C	CSA S136-07	152.28	55.56	8.46	150.73	55.56	8.37
		GB 50018—2002	212.33	55.56	11.80	185.12	55.56	10.28
		Difference/%	39.4	0.0	39.4	22.8	0.0	22.8

**Note:** UM means uniform bending moment; UDL means uniformly distributed load; and Buckling Stress is  $f_c$  in CSA S136-07 or  $\varphi_b f_y$  in GB 50018—2002.

A and B. From Tab. 2 to Tab. 5, it can be seen the web, flange and stiffener of member C are all fully effective for the both load patterns. When member C is subjected to the uniform bending moment, as there is no significant difference between the buckling stresses, consequently, no significant difference is found in the nominal flexural strengths of the two standards. For the case when the uniformly distributed load is applied for member C, because the buckling stresses evaluated based on GB 50018—2002 are greater than those of CSA S136-07, the nominal flexural strengths evaluated based on GB 50018—2002 are 39.4% and 22.8% greater than those of CSA S136-07 for  $f_y=345\text{ MPa}$  and  $f_y=235\text{ MPa}$  steel, respectively. As the difference of the nominal flexural strength are the same as that of the buckling stresses, therefore, in this case the difference of the nominal flexural strengths for member C is entirely resulted from the difference of the buckling stresses.

However, for members A and B, the difference of the nominal flexural strengths between the two standards is primarily resulted from the difference of the effective cross-sectional modulus, as there is no significant difference on the buckling stresses between the two standards. Since load pattern has little influence on the effective cross-sectional modulus for members A and B as shown in Tab. 3, the following discussions on effective cross-sectional modulus and nominal flexural strength for members A and B is only limited to the case of the uniform bending moment.

(1) Member A

The nominal flexural strength of member A evaluated based on GB 50018—2002 are 28.9% and 29.4% less than those of CSA S136-07 for  $f_y=345\text{ MPa}$  and  $f_y=235\text{ MPa}$  steel, respectively, as shown in Tab. 3. The smaller values of nominal flexural strength associated with GB 50018—2002 are primarily resulted from the smaller values

Tab. 4 Comparison of Effective Width when  $f_y=345$  MPa  
表 4  $f_y=345$  MPa 时有效宽度的比较

Member	Element		Actual Width $wt^{-1}$	$b_e t^{-1}$			$\Psi_w$		CSA S136-07		GB 50018—2002	
				CSA S 136-07	GB 50018 —2002	Difference/%	CSA S136-07	GB 50018 —2002	$k$	$R_l$	$k$	$k_1$
A	Web	$b_{e1} t^{-1}$	171.39	24.10	21.40	−11.1	0.84	−0.59	19.32	N/A	14.91	0.81
		$b_{e2} t^{-1}$		45.80	32.10	−29.9						
		$b_t t^{-1}$		76.30	63.60	−16.7						
		$b_e t^{-1}$		146.20	117.10	−19.9						
	Flange		47.92	47.92	21.40	−39.0			3.41	1.00	0.98	1.03
	Stiffener		15.14	15.14	7.60	−40.5			0.49	1.00	0.39	0.31
B	Web	$b_{e1} t^{-1}$	206.81	24.21	23.99	−0.9	0.71	−0.57	18.17	N/A	14.53	1.01
		$b_{e2} t^{-1}$		28.37	35.98	26.8						
		$b_t t^{-1}$		85.63	74.91	−12.5						
		$b_e t^{-1}$		138.20	134.90	−2.4						
	Flange		47.92	47.92	19.86	−43.5			3.41	1.00	0.98	0.88
	Stiffener		15.14	15.14	7.57	−40.0			0.48	1.00	0.39	0.31
C	Web	$b_{e1} t^{-1}$	93.45	23.40	18.69	−20.0	1.00	−1.00	24.00	N/A	23.87	1.09
		$b_{e2} t^{-1}$		23.40	28.03	20.0						
		$b_t t^{-1}$		46.70	46.72	0.0						
		$b_e t^{-1}$		93.40	93.45	0.0						
	Flange		11.01	11.01	11.01	0.0			N/A	1.00	0.98	0.41
	Stiffener		2.42	2.42	2.42	0.0			0.45	1.00	0.41	0.16

Note: N/A means not applicable.

Tab. 5 Comparison of Effective Width when  $f_y=235$  MPa  
表 5  $f_y=235$  MPa 时有效宽度的比较

Member	Element		Actual Width $wt^{-1}$	$b_e t^{-1}$			$\Psi_w$		CSA S136-07		GB 50018—2002	
				CSA S136 −07	GB 50018 —2002	Difference/%	CSA S136 −07	GB 50018 —2002	$k$	$R_l$	$k$	$k_1$
A	Web	$b_{e1} t^{-1}$	171.39	28.15	24.48	−13.0	0.91	−0.67	21.81	N/A	16.38	0.74
		$b_{e2} t^{-1}$		55.06	36.72	−33.3						
		$b_t t^{-1}$		81.76	68.68	−16.0						
		$b_e t^{-1}$		164.97	129.88	−21.3						
	Flange		47.92	39.47	25.56	−35.2			3.41	1.00	0.98	1.05
	Stiffener		15.14	14.17	9.06	−36.1			0.49	1.00	0.39	0.31
B	Web	$b_{e1} t^{-1}$	206.81	28.30	28.14	−0.6	0.78	−0.65	18.78	N/A	16.09	0.98
		$b_{e2} t^{-1}$		31.85	42.20	32.5						
		$b_t t^{-1}$		90.44	81.73	−9.6						
		$b_e t^{-1}$		150.59	152.07	1.0						
	Flange		47.92	39.51	24.40	−38.2			3.41	1.00	0.98	0.96
	Stiffener		15.14	14.03	9.02	−35.7			0.48	1.00	0.39	0.31
C	Web	$b_{e1} t^{-1}$	93.45	23.36	18.69	−20.0	1.00	−1.00	24.00	N/A	23.87	0.16
		$b_{e2} t^{-1}$		23.36	28.03	20.0						
		$b_t t^{-1}$		46.72	46.72	0.0						
		$b_e t^{-1}$		93.45	93.45	0.0						
	Flange		11.01	11.01	11.01	0.0			N/A	1.00	0.98	1.09
	Stiffener		2.42	2.42	2.42	0.0			0.45	1.00	0.41	0.41

of flange, stiffener and web effective widths. As presented in Tab. 4 and Tab. 5, the effective

widths of flange calculated using GB 50018—2002 are 39.0% and 35.2% less than those calculated using CSA S136-07 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively. Similarly, the effective widths of stiffener evaluated based on GB 50018—2002 are 40.5% and 36.1% less than those calculated by CSA S136-07 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively. Since the effective widths of the flange and the stiffener calculated using GB 50018—2002 are both considerably less than those calculated using CSA S136-07, the resulted distance between the centroid to the neutral axis  $y_0$  evaluated based on GB 50018—2002 is greater than that of CSA S136-07. In this case,  $y_0$  of member A calculated in accordance with GB 50018—2002 are 31.83 mm and 24.51 mm, while that of CSA S136-07 are only 13.52 mm and 5.67 mm for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively. Since the value of  $y_0$  in GB 50018—2002 is greater than that of CSA S136-07, from Eqs. (14), (16) and Fig. 3, it can be obtained that  $\Psi_w$  evaluated based on GB 50018—2002 is less than that of CSA S136-07, as shown in Tab. 4 and Tab. 5.

From the relations between the stress ratio  $\Psi_w$  and the buckling coefficient  $k_w$  as shown in Fig. 6, it can be seen that in GB 50018—2002 a smaller value of  $\Psi_w$  yields to a smaller web buckling coefficient  $k_w$  as observed in Tab. 4 and Tab. 5, which subsequently leads to a smaller value of web local reduction factor  $\rho_w$ . Meanwhile, the smaller value of  $\Psi_w$  also would lead to larger ratios  $b_{e1}/(\rho_w w_w)$  and  $b_{e2}/(\rho_w w_w)$  as shown in Fig. 9. Therefore, as a result of the decreasing of  $\rho_w$  and increasing of ratios  $b_{e1}/(\rho_w w_w)$  and  $b_{e2}/(\rho_w w_w)$ , the decrease of  $\Psi_w$  would not yield to significant changes in web effective width ratios  $b_{e1}/t$  and  $b_{e2}/t$ . Consequently, the difference of web effective width between the two standards would also not be significantly influenced by a difference of  $\Psi_w$  between the two standards. The conclusions discussed in section 3.3.3 which are obtained by the assumption that the two standards have the same web stress ratio  $\Psi_w$ , are still applicable. The investigation shows that the web

effective width ratios  $b_{e1}/t$  calculated by GB 50018—2002 are 11.1% and 13% less than those calculated by CSA S136-07 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively. Meanwhile, for  $h_0/b_0=3.3$ , web ratios  $b_{e2}/t$  of member A calculated by GB 50018—2002 are 29.9% and 33.3% less than those of CSA S136-07 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively.

## (2) Member B

The difference of the flange and web effective widths between the two standards for member B is similar to that for member A because the flange and stiffener are identical. In addition, the buckling stresses of the two members are almost the same as that shown in Tab. 3. However, the difference of the web effective widths for member B is considerably different from that for member A. Comparing to member A, member B has a larger web, therefore, the ratios  $w_w/w_f$  and  $h_0/b_0$  for member B are both greater than those for member A, as shown in Tab. 2. Since the ratio  $h_0/b_0=4.003>4$  for member B, the ratio  $b_{e2}/t$  calculated based on GB 50018—2002 for member B is considerably greater than that of CSA S136-07, being 26.8% and 32.5% for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively, as stated in section 3.3. Meanwhile, due to the increase of  $w_w/w_f$ , the difference of ratio  $b_{e1}/t$  between the two standards for member B also decreases comparing to that of member A. The ratios  $b_{e1}/t$  of member B calculated by GB 50018—2002 are only 0.9% and 0.6% less than those evaluated based on CSA S136-07 for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively.

Although the difference of the web effective width between the two standards for member B is considerably different from that for member A, the difference of the nominal flexural strength between the two standards for member B is still similar to that for member A. The nominal flexural strengths of member B evaluated based on GB 50018—2002 are still less than those of CSA S136-07, with the difference being -24.4% and -21% for  $f_y=345$  MPa and  $f_y=235$  MPa steel, respectively, as

shown in Tab. 3. Comparing with member A, the difference of the nominal flexural strength for member B only decreases slightly. Therefore, difference of the nominal flexural strength between the two standards for member B is essentially resulted from the difference of the flange effective widths, whereas the difference of the web effective widths has little influence on the nominal flexural strength in this case. As flange is the element located at the farthest distance to the neutral axis of C-section as shown in Fig. 3, increasing the flange effective width is far more efficient than enlarging the web effective width to amplify the nominal strength.

From the foregoing analysis, it can be concluded the difference of the nominal flexural strength between the two standards is influenced by both the cross-sectional dimension and the load pattern, whereas the yield stress almost has no influence on the difference. Generally, the following discussions are observed from the investigation:

(1) If the flange of the C-section is not adequate to resist lateral-buckling, then the strength of the member is governed by the lateral-torsional buckling and local buckling would not occur. The difference of the nominal flexural strength is primarily influenced by the difference of  $C_b$  defined in CSA S136-07 and  $\zeta_1$  stipulated in GB 50018—2002. The difference of  $C_b$  and  $\zeta_1$  is related to the applied load pattern as presented in Tab. 1. However, no matter what load pattern is applied,  $\zeta_1$  is not less than  $C_b$ . Therefore, the nominal flexural strength calculated by GB 50018—2002 is not less than that of CSA S136-07.

(2) If the flange of the C-section is adequate to resist lateral-torsional buckling, the difference of the nominal flexural strength is primarily affected by the difference of the flange effective width between the two standards. Since the flange effective width calculated by GB 50018—2002 is normally much less than that of CSA S136-07, the nominal moment evaluated using GB 50018—2002 is also considerably less than that of CSA S136-07.

In order to quantify the influence of the flange

depth and the applied load pattern on the difference of the nominal flexural strength between the two standards, comparisons of nominal flexural strength evaluated based on the two standards are carried out for typical C-section joists with the web depth ranging from 203 mm to 305 mm. The 35 typical C-sections listed in Tab. 6–Tab. 9 are selected from the *Handbook of Steel Construction*<sup>[10]</sup>. The length of the joist member is still assumed to be 6 m and the weak axis of the member is braced at the 1/3 point and 2/3 point. In addition, load patterns with uniform bending moment and uniformly distributed load, are considered in the investigation. Furthermore, as the yield stress doesn't have significant influence on the difference of the nominal flexural strength, comparisons are only carried out for  $f_y=345$  MPa steel.

The differences of the nominal flexural strength between the two standards are listed in Tab. 6–Tab. 9 with the following observations:

(1) For C-sections with flange width being 41.3 mm (Tab. 6), the nominal flexural strength is primarily controlled by the lateral-torsional buckling not the local buckling. Therefore, the difference of the nominal flexural strength is dominated by the applied load pattern. The nominal flexural strength calculated by GB 50018—2002 is greater than that of CSA S136-07 if the member is subjected to uniformly distributed load, with the maximum magnitude being 39.6%; whereas there is almost no difference on the nominal flexural strength if the applied load is uniform bending moment.

(2) However, for the C-sections with flange width being either 63.4 mm or 76.2 mm (Tab. 7 or Tab. 8), the load pattern almost has no influence on the difference of the nominal flexural strength, as shown in Fig. 11(a). The difference of the nominal flexural strength between the two standards is primarily influenced by the difference of the flange effective widths related to local buckling. The flange effective width evaluated by GB 50018—2002 is less than that of CSA S136-07, which leads to the nominal flexural strength associated with GB



Tab. 6 Comparison of Nominal Flexural Strength when  $b_0=41.3\text{ mm}$ ,  $D=12.7\text{ mm}$

表 6  $b_0=41.3\text{ mm}$ ,  $D=12.7\text{ mm}$  时名义抗弯强度的比较

No.	$h_0/\text{mm}$	$t/\text{mm}$	$R/\text{mm}$	$w_{\text{f}}t^{-1}$	$w_{\text{w}}w_{\text{f}}^{-1}$	Load Pattern	Buckling Stress/MPa		Effective Section Modulus/ $10^3\text{ mm}^3$		Nominal Flexural Strength/( $\text{kN}\cdot\text{m}$ )		Difference of Nominal Flexural Strength/%
							CSA S136-07	GB 50018—2002	CSA S136-07	GB 50018—2002	CSA S136-07	GB 50018—2002	
1	203	2.58	3.87	11.0	6.7	UM	165.7	168.9	39.8	39.8	6.6	6.7	1.9
						UDL	165.7	231.4	39.8	39.8	6.6	9.2	39.6
2	203	1.81	2.72	17.8	6.0	UM	163.7	166.4	29.0	29.0	4.8	4.8	1.6
						UDL	163.7	227.9	29.0	27.9	4.8	6.4	33.8
3	203	1.44	2.16	23.7	5.7	UM	163.6	166.1	22.7	21.8	3.7	3.6	−2.5
						UDL	163.6	227.6	22.7	20.2	3.7	4.6	23.8
4	254	2.58	3.87	11.0	8.5	UM	152.3	155.0	55.6	55.6	8.5	8.6	1.8
						UDL	152.3	212.3	55.6	55.6	8.5	11.8	39.4
5	254	1.81	2.72	17.8	7.6	UM	152.9	155.3	39.1	39.1	6.0	6.1	1.4
						UDL	152.9	212.8	39.1	36.5	6.0	7.8	29.7
6	254	1.44	2.16	23.7	7.2	UM	152.0	156.2	29.7	28.3	4.6	4.4	−3.4
						UDL	154.0	214.1	29.7	26.3	4.6	5.6	23.0
7	305	2.58	3.87	11.0	10.3	UM	141.3	143.7	73.6	73.6	10.4	10.6	1.7
						UDL	141.3	196.8	73.6	73.6	10.4	14.5	39.3
8	305	1.81	2.72	17.8	9.2	UM	143.7	145.9	49.3	49.2	7.1	7.2	1.2
						UDL	143.7	199.9	49.3	45.9	7.1	9.2	29.5
9	305	1.44	2.16	23.7	8.7	UM	145.5	147.6	37.1	35.6	5.4	5.3	−2.6
						UDL	145.5	202.2	37.1	33.2	5.4	6.7	24.3

50018—2002 being less than that of CSA S136-07. In addition, it can be seen from Fig. 11(a) that the difference increases with the increase of flange width-to-thickness ratio  $w_{\text{f}}/t$ . When  $w_{\text{f}}/t=47.9$ , the difference can be as large as  $-30.2\%$ .

(3) As shown in Tab. 9, for C-sections with flange width being 50.8 mm, the difference of the nominal flexural strength is not only influenced by the flange width-to-thickness ratio  $w_{\text{f}}/t$ , but also influenced by the applied load pattern. Based on Fig. 11(b), for members under uniform bending moment and uniformly distributed load and if the ratios  $w_{\text{f}}/t$  are not greater than 14.7 and 23.1, respectively, the nominal flexural strengths evaluated by GB 50018—2002 are greater than that of CSA S136-07, and vice versa.

Other factors, such as the ratio  $w_{\text{w}}/w_{\text{f}}$  and the stiffener depth, also have certain influence on the difference of the nominal flexural strength between the two standards. However, from Tab. 6 to Tab. 9, it can be seen their influences on evaluating the nominal flexural strength are not as significant

as that of load pattern and flange width.

5 Conclusions

The differences on evaluating the nominal flexural strength of cold-formed steel C-section based on the North American standard CSA S136-07 and the Chinese standard GB 50018—2002 are investigated. The investigation unveils that the differences are not only resulted from the differences in computing effective sectional properties, but also resulted from the differences in evaluating buckling stresses. More specifically, the differences are normally resulted from differences in element buckling coefficients, the maximum stresses and the effective widths. The maximum stress  $\sigma_{\text{max}}$  employed in GB 50018—2002 is approximately 87% of that utilized in CSA S136-07 even if for the case that the bending coefficients  $C_{\text{b}}$  and  $\zeta_1$  defined in the two standards are identical. In the case that the coefficients  $C_{\text{b}}$  and  $\zeta_1$  are not identical, the difference of  $C_{\text{b}}$  and  $\zeta_1$  would result in the difference in the nominal flexural strength. The follow-

Tab. 7 Comparison of Nominal Flexural Strength when  $b_0=63.4\text{ mm}$ ,  $D=19.1\text{ mm}$

表 7  $b_0=63.4\text{ mm}$ ,  $D=19.1\text{ mm}$  时名义抗弯强度的比较

No.	$h_0/\text{mm}$	$t/\text{mm}$	$R/\text{mm}$	$w_{\text{f}}t^{-1}$	$w_{\text{w}}w_{\text{f}}^{-1}$	Load Pattern	Buckling Stress/MPa		Effective Section Modulus/ $10^3\text{ mm}^3$		Nominal Flexural Strength/( $\text{kN}\cdot\text{m}$ )		Difference of Nominal Flexural Strength/%
							CSA S136	GB 50018	CSA S136	GB 50018	CSA S136	GB 50018	
							-07	—2002	-07	—2002	-07	—2002	
1	203	2.58	3.87	19.5	3.8	UM	293.4	297.8	53.5	50.1	15.7	14.9	−5.0
						UDL	293.4	319.0	53.5	49.4	15.7	15.7	0.3
2	203	1.81	2.72	30.0	3.6	UM	293.6	297.9	37.2	30.3	10.9	9.0	−17.3
						UDL	293.6	319.1	37.2	29.9	10.9	9.5	−12.8
3	203	1.44	2.16	39.1	3.5	UM	293.9	298.1	28.7	21.2	8.4	6.3	−25.4
						UDL	293.9	319.2	28.7	20.6	8.4	6.6	−22.2
4	203	1.15	1.81	50.2	3.4	UM	294.2	298.4	20.3	14.0	6.0	4.2	−30.2
						UDL	294.2	319.5	20.3	13.6	6.0	4.3	−27.2
5	254	2.58	3.87	19.5	4.8	UM	289.3	294.2	72.0	67.3	20.8	19.8	−5.0
						UDL	289.3	316.4	72.0	66.3	20.8	21.0	0.6
6	254	1.81	2.72	30.0	4.5	UM	290.2	294.9	46.2	40.7	13.4	12.0	−10.6
						UDL	290.2	316.9	46.2	40.0	13.4	12.7	−5.5
7	254	1.44	2.16	39.1	4.4	UM	290.8	295.4	33.5	27.9	9.7	8.2	−15.3
						UDL	290.8	317.3	33.5	27.1	9.7	8.6	−11.7
8	305	2.58	3.87	19.6	5.8	UM	285.7	291.0	89.9	84.0	25.7	24.4	−4.8
						UDL	285.7	314.1	89.9	82.5	25.7	25.9	0.9
9	305	1.81	2.72	30.1	5.4	UM	287.2	292.2	56.9	49.6	16.3	14.5	−11.3
						UDL	287.2	314.9	56.9	48.4	16.3	15.2	−6.7
10	305	1.44	2.16	39.1	5.3	UM	288.0	292.9	41.0	32.4	11.8	9.5	−19.5
						UDL	288.0	315.4	41.0	31.4	11.8	9.9	−16.1

Tab. 8 Comparison of Nominal Flexural Strength when  $b_0=76.2\text{ mm}$ ,  $D=25.4\text{ mm}$

表 8  $b_0=76.2\text{ mm}$ ,  $D=25.4\text{ mm}$  时名义抗弯强度的比较

No.	$h_0/\text{mm}$	$t/\text{mm}$	$R/\text{mm}$	$w_{\text{f}}t^{-1}$	$w_{\text{w}}w_{\text{f}}^{-1}$	Load Pattern	Buckling Stress/MPa		Effective Section Modulus/ $10^3\text{ mm}^3$		Nominal Flexural Strength/( $\text{kN}\cdot\text{m}$ )		Difference of Nominal Flexural Strength/%
							CSA S136	GB 50018	CSA S136	GB 50018	CSA S136	GB 50018	
							-07	—2002	-07	—2002	-07	—2002	
1	305	2.58	3.87	24.5	4.6	UM	320.7	321.6	108.3	89.2	34.7	28.7	−17.4
						UDL	320.7	336.4	108.3	88.4	34.7	29.7	−14.4
2	305	1.81	2.72	37.1	4.4	UM	321.5	322.2	68.1	51.4	21.9	16.6	−24.3
						UDL	321.5	336.8	68.1	50.5	21.9	17.0	−22.4
3	305	1.44	2.16	47.9	4.3	UM	321.9	322.6	43.7	32.9	14.1	10.6	−24.4
						UDL	321.9	337.1	45.4	32.3	14.6	10.9	−25.6
4	254	2.58	3.87	24.5	3.8	UM	322.7	323.4	84.1	70.1	27.1	22.7	−16.4
						UDL	322.7	337.7	84.1	69.5	27.1	23.5	−13.5
5	254	1.81	2.72	37.1	3.7	UM	323.3	323.8	56.8	41.0	18.4	13.3	−27.7
						UDL	323.3	338.0	56.8	40.3	18.4	13.6	−25.8
6	254	1.44	2.16	48.0	3.6	UM	323.6	324.1	37.9	26.9	12.3	8.7	−28.9
						UDL	323.6	338.2	37.8	26.5	12.3	9.0	−27.1

ing conclusions are obtained from this investigation;

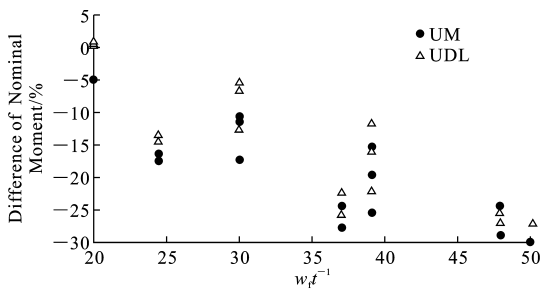
(1) The differences between the two standards on evaluating the stiffener effective width for

C-section members subjected to flexural bending are similar to those for the compressive member<sup>[7]</sup>. That is when the stiffener is small, the stiffener effective width calculated as CSA S136-07 may

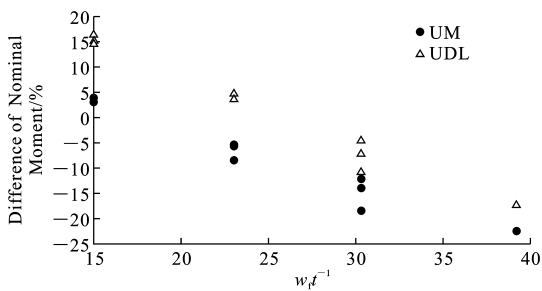
Tab. 9 Comparison of Nominal Flexural Strength when  $b_0=50.8\text{ mm}$ ,  $D=19.1\text{ mm}$

表 9  $b_0=50.8\text{ mm}$ ,  $D=19.1\text{ mm}$  时名义抗弯强度的比较

No.	$h_0/\text{mm}$	$t/\text{mm}$	$R/\text{mm}$	$w_{\text{f}}t^{-1}$	$w_{\text{w}}w_{\text{f}}^{-1}$	Load Pattern	Buckling Stress/MPa		Effective Section Modulus/ $10^3\text{ mm}^3$		Nominal Flexural Strength/( $\text{kN}\cdot\text{m}$ )		Difference of Nominal Flexural Strength/%
							CSA S136	GB 50018	CSA S136	GB 50018	CSA S136	GB 50018	
							-07	—2002	-07	—2002	-07	—2002	
1	203	2.58	3.87	14.7	5.0	UM	251.4	261.2	47.0	47.0	11.8	12.3	3.9
						UDL	251.4	292.3	47.0	47.0	11.8	13.8	16.3
2	203	1.81	2.72	23.1	4.7	UM	251.1	260.7	34.2	30.1	8.6	7.8	−8.5
						UDL	251.1	292.0	34.2	29.4	8.6	8.6	0.0
3	203	1.44	2.16	30.3	4.5	UM	251.4	260.9	27.6	21.7	6.9	5.7	−18.4
						UDL	251.4	292.1	27.6	21.1	6.9	6.2	−10.9
4	203	1.15	1.81	39.2	4.4	UM	251.9	261.3	20.5	15.3	5.2	4.0	−22.4
						UDL	251.9	292.4	20.5	14.6	5.2	4.3	−17.3
5	254	2.58	3.87	14.7	6.4	UM	242.7	253.5	64.9	64.4	15.8	16.3	3.6
						UDL	242.7	286.7	64.9	63.2	15.8	18.1	15.0
6	254	1.81	2.72	23.1	5.9	UM	243.9	254.4	43.5	39.3	10.6	10.0	−5.6
						UDL	243.9	287.3	43.5	38.2	10.6	11.0	3.5
7	254	1.44	2.16	30.3	5.7	UM	244.8	255.1	33.1	27.9	8.1	7.1	−12.1
						UDL	244.8	287.9	33.1	26.8	8.1	7.7	−4.6
8	305	2.58	3.87	14.7	7.7	UM	234.7	246.5	82.0	80.5	19.2	19.8	3.1
						UDL	234.7	281.6	82.0	78.2	19.2	22.0	14.5
9	305	1.81	2.72	23.1	7.1	UM	237.1	248.4	53.8	48.6	12.7	12.1	−5.3
						UDL	237.1	283.0	53.8	47.1	12.7	13.3	4.6
10	305	1.44	2.16	30.3	6.8	UM	238.4	249.5	40.7	33.5	9.7	8.3	−13.9
						UDL	238.4	283.8	40.7	31.7	9.7	9.0	−7.2



(a)  $w_{\text{f}}=63.4\text{ mm}$  or  $w_{\text{f}}=76.2\text{ mm}$



(b)  $w_{\text{f}}=50.8\text{ mm}$

Fig. 11 Comparisons of Nominal Flexural Strength when  $w_{\text{f}}=50.8, 63.4, 76.2\text{ mm}$

图 11  $w_{\text{f}}=50.8, 63.4, 76.2\text{ mm}$  时名义抗弯强度的比较

generally be less than that of GB 50018—2002,

whereas if the size of stiffener is large, the effective width associated with CSA S136-07 can be greater than that of GB 50018—2002.

(2) Similar to that of the compressive members, the flange effective width of C-section flexural member calculated based on GB 50018—2002 is considerably less than that of CSA S136-07.

(3) The differences of web effective widths  $b_{\text{e1}}$  and  $b_{\text{e2}}$  between the two standards are greatly influenced by the ratio  $w_{\text{w}}/w_{\text{f}}$  of GB 50018—2002 (or ratio  $h_0/b_0$  in CSA S136-07). When  $w_{\text{w}}/w_{\text{f}}=3$ , the ratio  $b_{\text{e1}}/t$  evaluated based on GB 50018—2002 is less than that of CSA S136-07. However, as the increase of  $w_{\text{w}}/w_{\text{f}}$ , the ratio  $b_{\text{e1}}/t$  of GB 50018—2002 increases whereas that of CSA S136-07 remains as a constant. Thus, the ratio  $b_{\text{e1}}/t$  calculated in accordance with GB 50018—2002 may become greater than that of CSA S136-07 when  $w_{\text{w}}/w_{\text{f}}$  further increases.

For the ratio  $b_{\text{e2}}/t$ , when  $h_0/b_0>4$ , the ratio

$b_{e2}/t$  calculated using GB 50018—2002 is considerably greater than that of CSA S136-07, and vice versa.

(4) The difference between the two standards on the nominal flexural strength is influenced by both the cross-sectional dimension and applied load pattern. If the flange of the C-section is not adequate to resist the lateral-torsional buckling and local buckling does not occur, the nominal flexural strength calculated by GB 50018—2002 is not less than that of CSA S136-07 and the magnitude of the difference between the two standards relies upon the applied load pattern.

If the flange of the C-section is adequate to resist the lateral-torsional buckling, the difference of the nominal flexural strength is then primarily influenced by the difference of the flange effective width between the two standards. Since the flange effective width calculated by GB 50018—2002 is normally much less than that of CSA S136-07, the nominal flexural strength evaluated using GB 50018—2002 can be significantly less than that of CSA S136-07.

To quantify the influences of the flange depth and the applied load pattern on the difference of the nominal flexural strength between the two standards, cold-formed steel joists with typical C-sections subjected to the uniformly distributed load and uniform bending moment are investigated. The results show that when the flange width is small ( $b_0=41.3$  mm), the difference of the nominal flexural strength is primarily resulted from the lateral-torsional buckling stress. In this case, the nominal flexural strength calculated by GB 50018—2002 is greater than that of CSA S136-07 if the member is subjected to uniformly distributed load, with the maximum magnitude being 39.6%. However, there is almost no difference in the nominal flexural strengths if the member is subjected to uniform bending moment. For cases that  $b_0=63.4$  mm and  $b_0=76.2$  mm, the differences of the nominal flex-

ural strengths are primarily affected by flange effective width and the nominal flexural strength associated with GB 50018—2002 is less than that of CSA S136-07, with the maximum magnitude being 30.2%. Finally, when  $b_0=50.8$  mm, the difference of the strength is influenced by both the flange width-to-thickness ratio  $w_t/t$  and the applied load pattern. In this case if ratio  $w_t/t$  is not greater than 14.7 and 23.1 for the uniform bending moment and uniformly distributed load, respectively, the nominal flexural strength evaluated by GB 50018—2002 is greater than that of CSA S136-07, and vice versa.

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