COMPARISON OF CHINESE WITH NORTH AMERICAN CODE OF COLD-FORMED STEEL STRUCTURAL MEMBERS

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ABSTRACT There are some differences between Chinese and North American code of cold-formed steel structural members, such as course of development, serviceable range, design method and calculation method of effective width and strain hardening, which are mainly presented and some advice are put forward in this paper. **KEY WORDS** Cold-formed steel, Calculation method, Design code, Effective width, Direct strength method

1 Introduction

Cold moulding profile steel components made from steel plate through the cold-rolled forming process. Relative to hot-rolled profile steel, wider and thicker plate pieces can be processed into various forms of economic cross-section; satisfied suitable strength-weight ratio to achieve the purpose of optimizing the cross-section, the design of cross-section can be exempted from the existing forms of restriction to meet different design requirements. For the design of cold moulding profile steel components, the current regulations in China are Structural Technical Specifications of Cold-formed Thin Wall Profile Steel (GB50018-2002) (hereinafter referred to as the Chinese norms). The United States, Canada, Mexico, the United Kingdom, Australia, Europe, South Africa and other countries have their own design specifications for cold roll forming steel structure. These specifications are essentially based on the North American Design Specifications for Cold Forming Steel (North American Specification for the Design of Cold-Formed Steel Structural Members, 2001) (hereinafter referred to as the North American norms). Although both China and the United States are using the effective width as the design method to consider the post-buckling strength, there are some differences in use range as well as consideration factors etc. In order to enable designers to understand and use the two norms better, the paper introduce the differences between the two norms and give an explanation through the calculation of effective width of pure bending component example.

2 Comparisons of Norms between China and US

Although the Chinese norms in some respects use for reference from the North American norms, such as when to consider post-buckling strength are both using the methods of effective breadth, there are also some differences in the course of development and usage scope, as well as the use of calculation methods of effective width and cold forming strengthen effect etc.. The following is the detailed specification of the differences between China and the United States.

2.1 The Course of Development

Since the fifties last century, China began to study cold-formed thin-walled steel structure and issued the first draft of "Technical Specifications of Bending Thin-walled Steel Structure" in 1969. The draft amended in 1975 as a trial of Thin-walled Steel Structure Technical Specifications (TJl8 - 75). In 1987, the national standard was promulgated as Cold-formed Steel Structure Technical Specifications (GBJl8-87). In 2002, the national standard of Cold-formed Steel Structure Technical Specifications (GB500l8-2002) was promulgated.

The foreign calculation theory research of cold-formed thin-walled profile steel began in the United States. In 1939, American Iron and Steel Institute (AISI) funded in the Cornell University (Cornell University) for the research of the design theory of cold-formed thin-walled steel structure held by George (George Winter), Professor and done a lot of tests. On this basis, the world's first Admit Stress Design Specification of the Cold-formed Thin-walled Profile Steel Components (ASD) is published in 1946. In 1991, the first edition of the Load Resistance Factor Design (LRFD) specification was issued by the AISI. In 1996, AISI incorporated ASD norms and LRFD norms into one norm. In 1999, AISI has released the supplement of 1996 edition of AISI Specification. In 2001, the United States , Canada and Mexico, the three countries combined the previous version of the United States AISI specifications and Canada S136 specifications together to form the current Cold-formed Steel Structural Component Design Specifications of the North American.

2.2 Application Range

The Chinese Design Specifications for Cold Forming Profile Steel Structure is only suitable to apply to the design and construction of cold-formed thin-walled steel structure by cold-bending (or cold-pressing) formed of industrial and civilian houses and the general build. The wall thickness of component is inadvisable more than 6mm, or less than 1.5mm (except pressure plate). The wall thickness of the main load-bearing structural components is not less than 2mm, which not suitable to be the load-bearing structure applied to bear a direct bearing dynamic load. For strip steel and steel plate of cold-formed thin-walled used in load-bearing structure, is limited only to use the steel in line with existing norms, the “Carbon Structural Steel" GB/T700 provisions of Q235 steel and "High-strength Low-alloy Structural Steel" GB/T1591 provisions of Q345 steel. Only when have reliable basis and in accordance with the corresponding state standards, the other brands of steel can be used. The limit value of width and thickness ratio of non-stiffened plate pieces, partial-stiffened plate panels and stiffened plate panels is as the following: Q235 steel were 45,60,250, Q345 steel is 35,50,200 respectively, the limit value of slenderness ratio of main compression member is 150, other components and support is 200.

The Design Specifications of North American Cold Forming Steel Structure is suitable for carbon or low carbon steel sheet, strip, plate, profile steel etc cold formed structural components design with the thickness of no more than 1 in (25.4mm). If properly taken into account the dynamic effects, except applied in construction, the cold-forming components can be used on other structures. The norms regulates 15 kinds of steel products can be used, including not only the A36 (Q235) and A588 (Q345) steel, but also more higher strength steel, such as A875, A1003 and A1011. The limit value of width and thickness ratio of non-stiffened plate pieces, partial-stiffened plate panels and stiffened plate panels pieces is 60, 60, 500 respectively. The limit value of slenderness ratio of press components is 200.

2.3 Design Methods and Forms of Expression

The Chinese design specification of cold forming steel structures regulated to use limit state design methods based on probability theory, calculated by the subentry coefficient expressions, design formula by expression form of stress, which is similar to the load and resistance coefficient design (LRFD) of North American Cold Forming Profile Steel Design Specifications.

The design specifications of North American cold forming steel structure combined the traditional method of Allowed Stress Design (ASD) and Load Resistance Factor Design (LRFD) as well as Limit State Design (LSD) into one, in which the Limit State Design (LSD) is limited to Canada, and Load Resistance Factor Design (LRFD), Allowed Stress Design (ASD) are limited to the United States and Mexico. The LRFD and LSD design method achieved by the appropriate resistance coefficient, and the ASD design method achieved by the appropriate safety factor. The design formula adopt the expression form of power.

2.4 The Calculation Method of Cold Work Hardening

The norms of China set the intensity design value of cold work hardening effect of of cold-formed thin-walled steel can be calculated by he following equation:

$$f' = \left[1 + \frac{\eta t(12\gamma - 10)}{l} \sum_{i=1}^{N} \frac{\theta_i}{2\pi}\right] f$$

In this formula: η- coefficient of molding manner. For cold-formed high-frequency welding (circular variable) square, rectangular tubes, value = 1.7; for round pipe and other means of formed square, rectangular pipes and placket profiled steel, value = 1.0;
γ- F_u / F_y, the ratio value of yield strength and tensile strength of steel, for Q235 steel, value = 1.58, for Q345 steel value = 1.48;
n - the number of pointness contained in steel cross-section;
θi - the circumferential angle corresponding to the no.*i* pointness of steel cross-section, with radian as a unit;
l - the length of the centerline of steel cross-section, which can adopt the ratio of cross-sectional area of steel and the thickness. The formula is the simplified formula deduced by Jin Changchen in theory. Considering the type of molding, impact of F_u / F_y, and R / t. Greater F_u / F_y or less R / t, greater the yield strength after cold forming. Vice

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Versa, the method of calculation takes into account the effect of molding yield strength after different molding form. Time after time the yield strength will be improved. In North American norms, considering the entire cross-section tensile yield strength influenced by the mechanical properties of cold rolled steel can be calculated by the following equation:

$F_{ya} = CF_{yc} + (1 - C)F_{yf}$

$$F_{yc} = B_c F_y / (R / t)^m$$

$$B (/0.819/3.69 2yuyuc-=FFFF)-1.79m =0.192F_u / F_y - 0.068$$

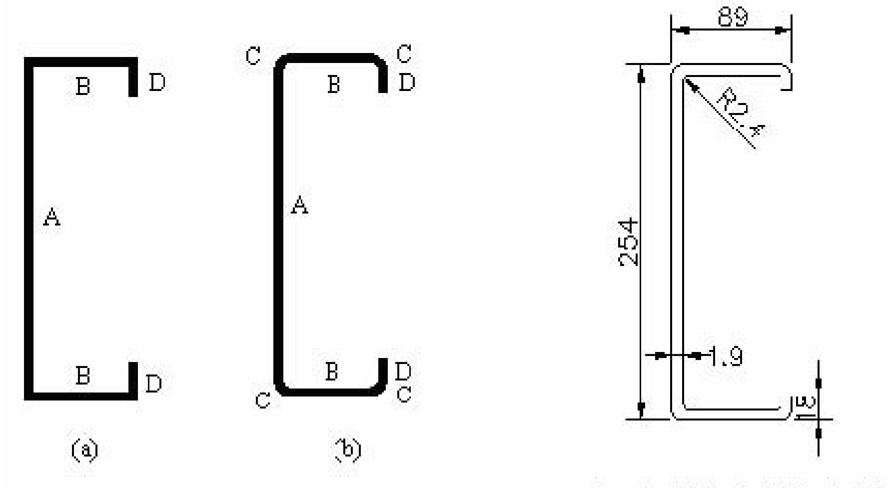
In this formula: F_{ya} - tensile yield strength of the entire cross-section; F_{yc} - average tensile yield strength of corner; F_{yf} - the average tensile yield strength of flat plate part; C - ratio of bend angle area and total cross-sectional area.

This formula is provided by Kahn (Karren) according to the hot-rolled steel to bring out the calculation formula of yield strength under the cold forming effect for considering the cold roll forming steel. The formula takes into account the effect of F_u / F_y, and R / t for cold forming mechanical properties of cross-section. The formula does not apply to $F_u / F_y < 1.2$, $R / > 7$, and the cross-section of maximum angle over 120 º. The analysis results in literature [4] show that the norms in China are somewhat conservative, but taking into account the domestic cold into inadequate research and testing in the theory of thick-walled cold roll forming steel, it is necessary of somewhat conservative values. And the formula is more rigorous in theory, avoid of the shortcomings of the North American norms. In the accuracy, reliability and versatility, the Chinese norms have been improved, easy for application. While the North America norms did not consider the end yield zone and its contribution to the yield strength in existence of the forming process, there will be a result under the yield strength of mother material at the condition of greater *R/t.* At the same time, as a result of using the regression of digital solution within the limited range as well as expression skills etc. a reasons in theoretical analysis, makes the physical meaning of the formula not clear enough and the accuracy, reliability and versatility not so good.

2.5 The Calculation Method of Effective Width

In the calculation of effective width, the calculating formula for the effective width-thickness ratio of the compressed plate pieces in the Chinese norms of design of cold forming is based on plate group (rather than veneer) as analysis unit, considering the limit influence of the adjacent plates to calculated plates. First to consider the impact of plates group effect and the part of bending angle is not considered separately but only take the whole cross-section width as flat and straight part, such as Figure 1 (a) below. Consider the restriction of flange B to web A, but no longer consider the impact of angle part C.

Moreover, the North American norms consider the bending angle parts solely, as Figure 1 (b) indicated that all the bending part C are effective parts, and then calculate the effective width of straight section of cross-section, and do not consider the impact of flange B to web A.



Give the following pure bending C shape steel component as an example: the upper flange pressed equally, web plate pressed unequally, the cross-section dimensions shown as in Figure 2, Fy = 345MPa. As per the calculation of effective cross-section width, the result is shown in table 1. The results of analysis show that the normative calculation project in China is simple, the results are somewhat conservative, and considered the effect of plate group. The North American norms have more complicated calculation, not to consider the effect of plate group.

Table 1 Computation Firm of Effective Width of Cross-section (Unit: ：mm^2)

Chinese norms				North America norms			
Plate Pcs	Effective Width	Q'ty	Aggregate	Plate Pcs	Effective Width	Q'ty	Aggregate
Compressed Web	380.8	1	352.3	Compressed Web	447.4	1	447.4
Compressed Flange	84.7	1	84.7	Compressed Flange	107.6	1	107.6
Compressed Crimping	21.5	1	21.5	Compressed Crimping	5.5	1	5.5
Compressed Angle	—	—	—	Compressed Angle	19.9	2	39.8
Tensile Flange	169.1	1	169.1	Tensile Flange	152.6	1	152.6
Tensile Crimping	34.2	1	34.2	Tensile Crimping	26.6	1	26.6
tensile Bend Angle	—	—	—	tensile Bend Angle	19.9	2	39.8
Effective Width of Cross-Section			690.3	Effective Width of Cross-Section			819.3

3. Conclusion

Through the above analysis, the following conclusions can be drawn:

1) The restriction of wall thickness is 6mm in Chinese norms, and only limited to use Q235 and Q345 steel. For the ratio of width and thickness of board pieces and ratio of length and thin of components have much stricter restrictions. But the North America norms can use a higher strength of steel, with more loose restrictions of thickness and ratio of width and thickness and the ratio of length and thin of components.

2) Chinese norms only adopt the expression form of design method of probability limit state, but the North America norms adopt the Allowed Stress Design (ASD) and Load Resistance Factor Design (LRFD), as well as Limit State Design (LSD) the three forms, with broader scope of application.

3) The Chinese norms adopt the design expression form of stress, which the concept was not clear in stability calculation, easy to mix up the concepts of intensity and stabilization. But the North America norm adopt the design expression form of powder, with clear concept.

4) The Chinese norms are biased conservative in the calculation method of cold working hardening effect. At the accuracy, reliability and versatility etc. aspects, there have been improvement. But in the theoretical analysis of the North American norms, by using the regression and expression skills of limited range of digital solutions etc reason make the physical meaning of its calculation formula is not clear enough. The accuracy, reliability and versatility are not so good.

5) In China norms, there is no special consideration of bending corner parts in the calculation of the effective width, only considering the entire cross-section width as flat and straight parts and the effect of plate group, which results somewhat conservative. But the North American norms consider a bending corner parts separately, acceptance of its full force and effect, and then calculating the effective cross-section width of flat and straight section, with clear concept. The effective width of the plate pieces under the no uniform stress need iterations in calculation.

6) The Chinese norms have regulation of the roof, frame and component production, installation and preservative content. But the North America norms have not involved this. They have the stipulation in special circumstances test and the cold steel fatigue design.

7) For bending components, the North American norms regulated separately the ratio limit of high-thickness, and detailed regulated the web crumple problem when bearing concentrated load, which China norms have not made specific provisions.

8) The supplementary provisions of 2004 version of North American norms, the the design of using direct intension method of cold steel components has allowed. Although our country have been researched on this, but the norms have not been involved. In short, the two norms have their own advantages and disadvantages. The Chinese norms have relatively narrow scope and no clearly enough concept of design expression of

stress, firstly considering the effect of plate group, with somewhat conservative result. While the United States norms have broader scope, more detailed regulations, more clearly design expression of the concept of powder.

4 Recommendations

By comparing the two specifications can be found clearly that the Chinese norms still exist a number of shortcomings, which can be improved in the following areas:
1) With the improvement of production of cold roll forming steel and the growing production capacity, China has already produced the cold steel components with wall thickness 12.5mm (some manufacturers up to 22mm) . It is available to consider to relax the restrictions on the thickness for the wall, provided the necessary basis for the cold rolled design of thick steel greater than 6mm.
2) Due to some cold formed steel components may also be directly under dynamic load, which can learn from North American norms and combine with our engineering practice and the accumulated information to increase in the regulation of cold steel into fatigue design provisions.
3) Learn from North American norms and combine with engineering practice, to make Chinese norms more detailed, full considering all kinds of influencing factors so that the design becomes more economical and reasonable.
4) With the computer technology developing rapidly, the direct strength design procedures by using of numerical analysis program for the overall analysis of the components, it is easier compared with the effective width design method. China should strengthen the theoretical and experimental research at it, to introduce the direct strength design way in the norms, easy for engineer to better design cold roll forming steel.

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