Comparative Study on Plane Stability of Bending Components in China and the United States

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Abstract

Chinese steel structure specificationGB50017-2003 and the American steel structure specification ANSI/AISC360-10 are chosen to study in-plane stability of the solid-web bending components.Finite element analysis of welded I-beam is carried out by general nonlinear finite element software ABAQUS under different parameters,and the finite element results are compared with calculated value according to the standard value.Finally, some suggestions are put forward for the steel structure specification in our country,which provides a reference for the domestic steel structure designers and the revision of the steel structure specifications in the future.

Keywords

Code for Chinese steel structures,American Steel Structure Specification,the solid-web bending components, in-plane stability,finite element analysis.

1. Introduction

In the field of steel structure, the United States specification has a high status in the international community with its advanced scientific and technological level, perfect theoretical system, and meticulous logical relations. [1-2] And the United States steel structure design specification has a certain reference significance. Therefore, the two steel structure specifications in China and the United States are selected to conduct a comparative study on the stability in the plane of the solid belly bending member, find out the differences in the specification and the reasons for the differences, and put forward some suggestions. Thus, designers have a deeper understanding of the norms of the two countries.

2. Basic theory

2.1 Chinese norms

GB50017-2003 still follows the calculation principle of GB50017-2003, but GB50017-2017 does not use the expression form of cross-sectional strength to calculate stability, but uses the expression form of ultimate bearing capacity. Although the expression form is different, the old and new norms The calculation essence is the same. The equivalent moment coefficient is adjusted.

$$\frac{N}{\varphi_x A}+\frac{\beta_{mx}M_x}{\gamma_x W_{1x}\left(1\text{-}0.8\frac{N}{N_{EX}^{'}}\right)}\le f$$

1) When the member is a supporting member at both ends without transverse load, $\beta_{mx}=0.65+0.35(M_1/M_2)$.
the isotropic curvature $M_1/M_2>0$;
2) When the member is a supporting member with both ends of transverse load and bending moment, the isotropic curvature β_{mx}=1.0, reverse curvature β_{mx}=0.85;
3) When the member is a two-end supporting member with only horizontal load,β_{mx}=1.0;
4) When the member is a cantilever member,β_{mx}=1.0.

2.2 American Code

In the United States, a separate section is set up for the axial compression member, the design of the bending member, and the design of the bending member. The stability design of the bending member takes into account the full section yield of the axial compression member and the formation of the plastic hinge of the bending member. The calculation formula of the bending member is based on a relative formula that calculates the values of the bending member separately and indirectly considers the stability of the bending member.

The biaxial symmetric and uniaxial symmetric cross-sectional components that are subjected to the joint action of bending moments and axial pressures are wound around the geometric axis X of the section and the axis Y is bent. When $0.1\le(I_{yc}/I_y)\le 0.9$, the following formulas(1-a) and(1-b) should be satisfied. Among them is the moment of inertia around the Y-axis of the compressed wing.

$$if\ \frac{p_r}{p_c}\ge 2.0 \qquad \frac{\mathrm{P}_r}{P_c}+\frac{8}{9}\left(\frac{M_{rx}}{M_{cx}}+\frac{M_{ry}}{M_{cy}}\right)\le 1.0 \tag{1-a}$$

$$if\ \frac{p_r}{p_c}< 2.0 \qquad \frac{\mathrm{P}_r}{2P_c}+\frac{8}{9}\left(\frac{M_{rx}}{M_{cx}}+\frac{M_{ry}}{M_{cy}}\right)\le 1.0 \tag{1-b}$$

$M_c=f_b M_n$, $P_c=\phi_c P_n$

The stability design of the bending member in the United States specification takes into account the full section yield of the axial compression member and the plastic hinge formation of the bending member. The same formula is used to calculate the bearing capacity of both bidirectional bending and one-way bending.

3. Finite element analysis

3.1 Modelling

Documentation[6] The experimental data on such eccentric bending members as welding I-shaped steel can be used as the verification of welding I-shaped steel component model in this paper and the comparison of the limit bearing capacity between Chinese and American steel structure specifications. When using the finite element software ABAQUS for numerical simulation, the flange and ventral plates of welded I-shaped steel are all modeled using the Shell(shell unit) in the ABAQUS unit library, based on the material properties of the components and the preliminary selection of model parameters. The established finite element model is shown in Figure 1. In the Mesh module, use

Grid Seeding tool sets mesh seed density, and the mesh size control for finite element analysis is 0.02. CAE provides three kinds of grid division techniques. Using structured grid division technology, the section is first divided by a segmentation tool, and the invert part of the intersection between the web and the flange is divided into separate parts. Then the model is divided into accurate hexahedral units by structured grid division technique. The numerical simulation boundary condition is articulated at both ends, and lateral constraints are applied every L/5(L is the length of the member) in the middle. One end of the rod part limits the displacement in the direction of X, Y, and Z, and the other end limits the displacement in the direction of X and Y, releasing the z-direction displacement. Using displacement loading, a certain displacement is applied to the end of the rod that releases the z-direction displacement, as shown in Figure 2. Nonlinear finite element analysis using arc length method. The sample size design uses literature[6] Test dimensions in table 1:

Table 1 Component parameters

Number	h_w/mm	t_w /mm	b_f /mm	t_f /mm	L/mm	ε	v_0	w_0
1	180	2.5	120	5	5800	3.07	4.0	1.50
2	180	2.5	120	5	5800	1.23	0	3.07
3	210	2.5	120	5	5800	0.91	-1.0	1.90
4	210	2.5	120	5	5800	2.48	1.0	2.45
5	240	2.5	120	5	5800	0.97	3.0	1.8
6	240	2.5	120	5	5800	2.35	4.0	3.12
7	270	2.5	120	5	5800	2.28	-7.5	2.87
8	270	2.5	120	5	5800	0.76	3.5	2.20
9	300	2.5	120	5	5800	2.07	2.0	3.07

Material Properties

When using ABAQUS simulation analysis in this paper, the material properties to be defined mainly include elastic modulus, Poisson ratioand yield strength. This paper takes Poisson ratio0.3, elastic modulus2.06e5MPa, and the limit value of steel strength is Q235. The material density is 7850kg/m^3.

3.2 Calculations

Reprocessing the results in the ABAQUS visualization module[8] .The selected output information can be viewed through. ODB files, including bar deformation charts, stress, strain distribution cloud charts, and can also selectively output specific values of load, stress, strain, and other variables through text, tables, etc. The limit carrying capacity value, finite element value and experimental value of China and the United States are shown in Table 2.

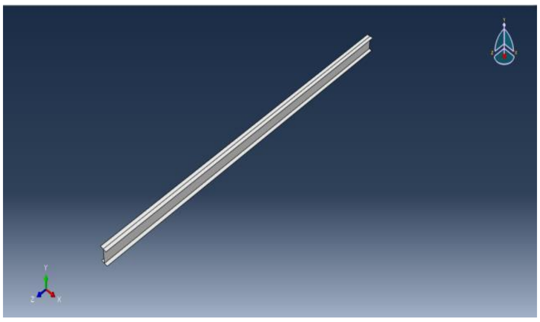

Table 1 Extreme carrying capacity

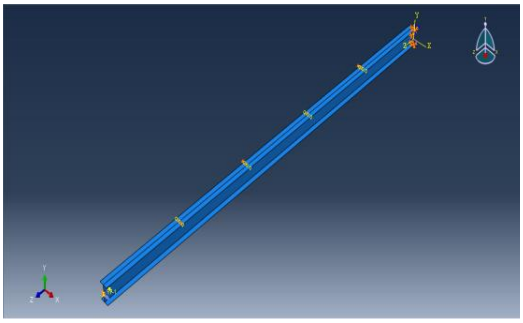

Fig. 2 Constraints for artifacts

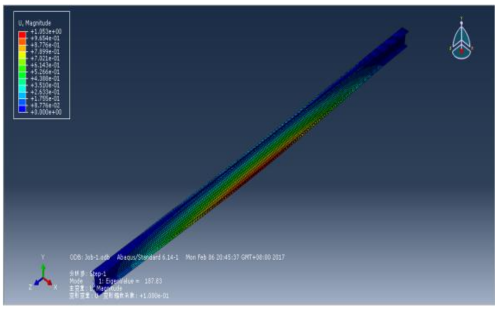

Fig. 3 Characteristic value buckling analysis

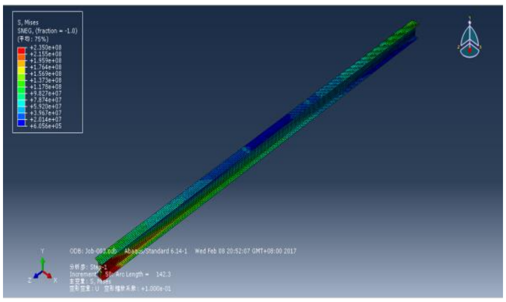

Fig. 4 Nonlinear analysis

Table 2 Extreme carrying capacity

Number	Chinese standard value/KN	American Normative Value /KN	Experimental value/KN	Finite element value/KN	$\left\|P_3-P_4\right\|/P_3$
1	77.63	91.01	96.04	96.73	0.72%
2	129.98	151.47	165.62	169.34	2.25%
3	163.76	186.45	207.76	213.17	2.60%
4	96.66	111.50	121.03	119.58	1.20%
5	172.56	194.61	203.84	219.35	7.61%
6	107.16	122.71	121.52	137.55	13.20%
7	115.96	131.93	129.36	146.22	13.03%
8	204.30	226.74	231.28	253.19	9.47%
9	131.61	129.92	147	142	3.40%

The error between the ABAQUS value calculated in table 2 and the experimental value is between 0.72 % and 13.20 %, and it can be seen that the error is acceptable.

4. Conclusion

The ultimate bearing capacity of the bending members calculated according to the Sino-US steel structure specification is less than the simulated value of the finite element and the experimental value. The reason is that the value of the initial defect of the bending member of the steel structure specification in China and the United States is relatively safe, and there is a certain safety redundancy. degree, The buckling form corresponding to the calculated value is unyielding.

The United States specification first classifies the sections and selects different calculation formulas according to the different buckling forms of different sections, which is reasonable and accurate. In our country, the various influencing factors are combined into the same formula, and some coefficients are conservative. It is suggested that the ratio of length to fineness of the components be classified into thick and short rods, non-thick and short rods, and slender rods. The correction coefficient of the second denominator in the formula for calculating the stability in the plane of the solid abdominal bending member adopts different correction coefficients for different types of rods.

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