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Research on Design and ANSYS of Joints between Steel Beams and Reinforced Concrete Columns

Xi Chen[1,a]

[1] Henan University of Science and Technology, Luoyang 471003, China

[a]chenximy2013@163.com

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Abstract. Environmentally sustainable building construction has experienced significant growth during the past 10 years. The public is becoming more aware of the benefits of green construction,and green building is leading to changes in the way of owners, designers, contractors, and approach of the design, construction. A new type of frame consisting of steel beam and reinforced concrete column (RCS) installing efficient and light heat insulation wall has been presented in composite frame. The composite frame fully develops the merits of steel and concrete, and thus is reasonable and economical from both structural and construction viewpoints. The chief aim of the present work is to establish the design procedures for RCS joints based on the existing standards in china. The research has recorded valuable experimental data using the method of the nonlinear three-dimensional ANSYS finite element.The research work introduces an amended design formula,which takes account the effect of ratio of axial compression stress to strength. Some effective design suggestions are given as a reference to the structural engineer.

Introduction

In recent years, a new composite structural system consisting of reinforced concrete columns and steel beams (RCS) has gained popularity. Compared with steel columns, reinforced concrete columns have the advantage of increased stability of structure, good durability, and fireproof property. And compared with reinforced concrete beams, steel beams have the advantage of higher strength and large rigidity, resulting in increased effective spaces and costs. This kind of frame fully develop the merits of beams and columns, and thus is reasonable and economical from both structural and construction viewpoints.

The connection region as main force transfer component is key to the research of RCS frames. However, in China many of these new joint details are not covered by the existing standards[1~3]. The establishment of design procedures for RCS joints and systems is an urgent necessity. In order to solve these problems,this thesis uses the nonlinear three-dimensional finite element method to analyse RCS beam-column joints. Based on the contrast analysis of the results of ANSYS finite element simulation , the American guidelines and chinese standards for the design of RCS frame, analysis and discussion are mentioned about the definition and estimation of the component strength of the joint.

The ANSYS finite element model

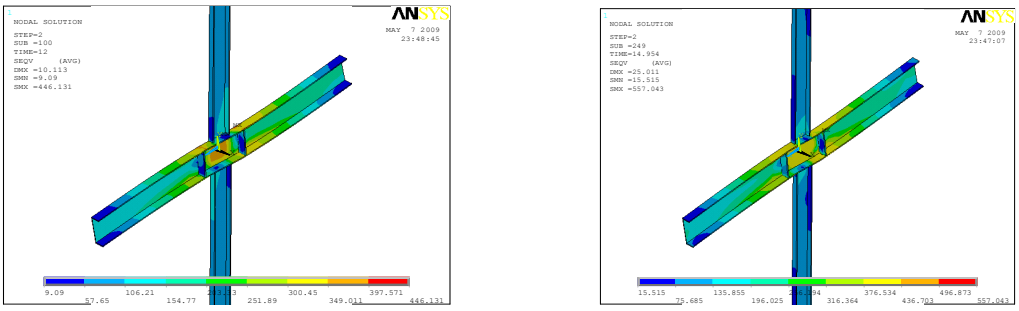
The ANSYS finite element model is a seris of specimens of the middle layer of RCS frame, which is based on the three specimens made in Chongqing University[4]. Each of the three specimens was referred to as “through-beam type”details since the steel beam ran continuous through the column. Attachments to the steel beam included face bearing plates, embedded steel columns. The length of horizontal steel beam was 2250mm. A 250×125×9×6 beam was used in this specimen. The grade of concrete was C25. Regular concrete with compressive strengths ranging from 26 MPa to 28 MPa was used in the columns of all three specimens. Q235 steel was used for steel beam, embedded steel

columns and face bearing plates. Q335 steel was utilized for longitudinal reinforcements of the columns.

The units of ANSYS finite element model were solid65, solid45 and link8. The building of the model used separating method. The concrete element model for plastic analysis was multi-linear isotropic hardening. Stress-strain equations could be calculated by Hognested method. All the elements of steel used bilinear kinematic hardening model.

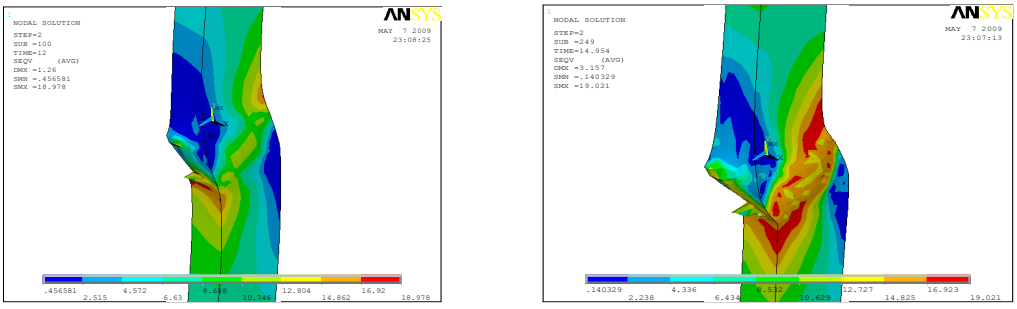
By the geometric modeling, the process of building finite element model were: (1)At first, the geometric model of steel beams, concrete columns should be established, and then the geometric model of the bearing plates would be built. (2) The geometric model of longitudinal reinforcements, stirrups and embedded steel columns was established by the method of work plane segregating the body. (3)The model was merged, compressed and meshed.

After the establishment of finite element model, the model was constrained and loaded: (1) The nodes in the symmetry plane were imposed by symmetry constraints, and the upper column was imposed by constraints in the z direction, and then the lower end of column was imposed by constraints in the x,y,z direction. (2) In the z direction, the degree of the freedom of all the nodes in the upper end of column was coupled to the plane, and in the y direction, the degree of the freedom of all the nodes in the end of the beam was coupled to the plane.(3) The type of analysis was static analysis, and the automatic time-step tracking was used. The non-linear analysis was set as force convergence criteria. After finishing all above, it was time to enter solver. Respectively, stress in steel plate and in concrete was showed in Fig.1.and Fig.2. Finite element results and comparative analysis of test results is in Table1.



(a) Stress in steel plate at limiting load (b) Stress in steel plate at yield load

Fig.1. Stress in steel plate



(a) Stress in concrete at limiting load (b) Stress in concrete at yield load

Fig.2. Stress in concrete

The design of the joint

2.1 The American design formula

According to the guidelines for American design of joints between steel beams and reinforced concrete columns[5], the design formula of the shear strength of the joint is given as follows:

$$V=V_{sn}+V_{csn}+V_{cfn} \tag{1}$$

$$V_{cfn}=0.4\sqrt{f_c'}\,b_0h+0.9A_{sh}f_{ysh}h/S_h \quad V_{sn}=0.6F_{ysp}t_{sp}jh \quad V_{csn}=1.7\sqrt{f_c'}\,b_ph \tag{2}$$

Where jh is determined by the bearing capacity in the vertical direction, and jh can be estimated as follows: $0.7h\leq jh\leq h$. h is the height of the reinforced concrete column in the direction which is parallel to the beam. F_{ysp} is specified yield strength of steel joint panel. F_{ysh} is specified yield strength of column ties. A_{sh} is cross-sectional area of reinforcement parallel to beam with spacing S_h. t_{sp} is the thickness of steel beam. b_p is the width of the internal concrete areas, and usually is equal to the width of the bearing plate. b_m is maximum effective width of joint region.

2.2 The Chinese design formula

According to the Chinese design formula of the joint between the steel-reinforced concrete column and steel beam,the shear strength of joint can be given as follows:

When the design is based on "class 1 of seismic measure":

$$Vj\leq[0.25\Phi_j\eta_jf_cb_jh_j+f_{yv}A_{sv}h/s+0.58f_at_wh_w]/\gamma_{RE} \tag{3}$$

When the design is based on "class 2 of seismic measure":

$$Vj\leq[(0.25+0.05N/f_cb_ch_c)\Phi_j\eta_jf_cb_jh_j+f_{yv}A_{sv}h/s+0.58f_at_wh_w]/\gamma_{RE} \tag{4}$$

2.3 The amended design formula

It's seen that without consideration the impact of the axial pressure the shear strength calculation of the joint according to the Chinese design formula is larger than that through the experimental values. So the shear strength of the joint through the Chinese design formula is dangerous. Although the American design formula is conservative, it has more consideration in loading mechanism of the joint. So the Chinese design formula should be amended refering to the analysis method of the American design formula.Based on the analysis of the Chinese and American design formula, the Chinese design formula can be amended as follows:

(1) The effective width of the concrete panel b_j should include the effective width of the inner concrete panel b_i and the outer concrete panel b_0, which are determined by the American design formula. So bj is given as follows: $b_j=b_i+b_0$.

(2) The confinement of the stirrup is a part of the outer concrete panel, so Vsv can be calculated according to design formula the American design formula: $V_{sv}=0.9A_{sh}F_{ysh}h/S_h$.

(3) According to the analysis of ANSYS finite element, when the ratio of axial compression stress to strength exceeds 0.5, there is a sharp decline in the shear strength of the joint. Therefore the design formula should take account of the impact of the axial pressure when the design is based on "class 2 of seismic measure".

Therefore the amended design formula for the shear strength of the joint is given as follows:

When the design is based on "class 1 of seismic measure":

$$Vj\leq[0.25\Phi_j\eta_jf_cb_jh_j+0.9f_{yv}A_{sv}h/s+0.58f_at_wh_w]/\gamma_{RE} \tag{5}$$

When the design is based on "class 2 of seismic measure":

Whenη≤0.5, Vj can be given as follows:

$$Vj\leq[(0.25+0.09N/f_cb_ch_c)\Phi_j\eta_jf_cb_jh_j+0.9f_{yv}A_{sv}h/s+0.58f_at_wh_w]/\gamma_{RE} \tag{6}$$

Whenη＞0.5, Vj can be given as follows:

$$Vj\leq[0.25\Phi_j\eta_jf_cb_jh_j+0.9f_{yv}A_{sv}h/s+0.58f_at_wh_w]/\gamma_{RE} \tag{7}$$

The value 0.09 was determined by empirical regression function.

Conclusion

To sum up, it's revealed that the American and Chinese design formula don't fit the engineering in China. The amended design formula which takes account the effect of ratio of axial compression stress to strength is based on the contrast analysis of the results of ANSYS finite element simulation, the experimental values and the American and Chinese design formula. So it is given as a reference to the structural engineer.

Acknowledgements

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References

[1] Subhash C. G. United States-Japan cooperative earthquake engineering research program on composite and hybrid structures. *Journal of Structural Engineering* 2004 ;130(2)：157 – 158.

[2] Gregory G. Deierlein ,and Hiroshi Noguchi . Overview of U.S.-Japan research on seismic design of composite reinforced concrete and steel moment frame. *Journal of Structural Engineering* 2004;130(2)：361 – 367.

[3] Parra-Montesinos, G., Weight, J.K. Modeling shear behavior of hybrid RCS beam-column connections. *Journal of Structural Engineering* 2000;126(10)：1113-1121.

[4] Yi Yong. Experimental research on seismic behavior of interior joint in the composite frame consisting of steel beams and reinforced concrete columns.Chongqing University, 2005.

[5] The ASCE Task Committee on Design Criteria for Composite Structures in Steel and Concrete. Guidelines for Design of Joints Between Steel Beam and Reinforced Concrete Columns.*Journal of Structural Engineering* 1994; 120(8)：2330-2357.