The Research for Hysteretic Behavior of Eccentrically Braced Steel Frame With Semi-Rigid Connections

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Abstract—In this paper, by using of large-scale structural analysis software ANSYS for a three-bay eccentrically braced steel frame with semi-rigid connections done nonlinear analysis. The results showed that: eccentrically braced semi-rigid steel frame have good energy dissipation capacity and some prospects.

Keywords: semi-rigid connections; eccentrically braced ; hysteretic behavior

I. INTRODUCTION

In practical engineering, when the beams and columns of steel frame structure using bolting to connection, and the joint stiffness is mostly between articulated and rigid connection and it is semi-rigid connections. Large amounts of data show that beams and columns with semi-rigid connections have good energy dissipation capacity, and can improve the ductility of structure, but the structure of the lateral stiffness is too small and lateral is too large, it is difficult to meet the regulatory requirements. Eccentrically braced lateral system technology is relatively mature and has a good energy dissipation capacity. The eccentrically braced steel frame with semi-rigid connections consisting of the eccentric braced semi-rigid steel frame system is a new type framework for supporting system, one can make up for the semi-rigid steel frame lack of stiffness problem; the other combining the two kinds of energy dissipation capacity are relatively good system, thereby enabling the structure to play a better energy performance.

II. ANALYSIS MODEL BUILDING

A. Model building

Model uses SHELL181 unit to establish steel frame, frame span of 7.8m, ceiling height 3.9m, with MPC184 unit and COMBIN39 spring unit with analog semi-rigid node connectivity features, component dimensions are in accordance with the regulatory requirements to simulate the actual works, component size as Table 1 - 1, the frame geometry shown in Figure 1-1, the frame model building in Figure 1-2, 1-3.

TABLE1 - 1 COMPONENT SIZE

Model Number	Beam size	Column size	Joint stiffness	Braced size
3R1	H450*200*8*12	H350*300*10*14	$1X10^1$KNM/rad	H250*200*8*12
3R5	H450*200*8*12	H350*300*10*14	$1X10^5$KNM/rad	H250*200*8*12
3R9	H450*200*8*12	H350*300*10*14	$1X10^9$KNM/rad	H250*200*8*12
3V5	H450*200*8*12	H350*300*10*14	$1X10^5$KNM/rad	H250*200*8*12

(No Description: The first number 3 represents three frames, the second letter R and V, respectively herringbone and V-shaped braced, third number 1,5,9 respectively node initial rotational stiffness is $1X10^1$ KNm / rad, $1X10^5$ KNm / rad, $1X10^9$KNm / rad.)

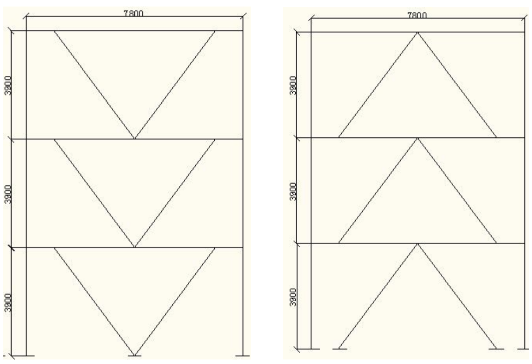


Figure 1-1 frame geometry

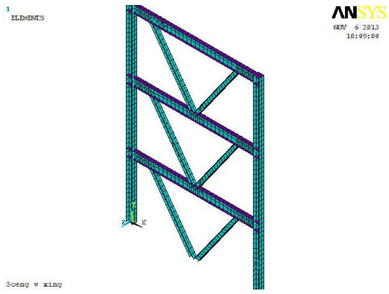


Figure 1-2 V-shaped braced model

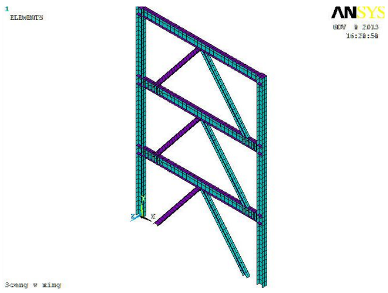


Figure 1-3 Herringbone shaped braced model

B. *Material Properties*

Steel frame are all made of Q235, steel elastic modulus, yield strength, density, tensile strength are entered in accordance with the actual situation, the Poisson's ratio of 0.3.

C. *Failure criterion*

(1) When the hysteresis curve appears dropped segment.

(2)The level maximum on a cyclic load value is less than the last level.

(3)The model appears local components buckling or loss overall stability.

(4) produce larger deformation or intensity of damage caused ANSYS can not converge.

III. RESULTS ANALYSIS

A. *The role of uniaxial loading conditions*

Loaded system: The load control loading system, each level load 200KN until the model to yield.

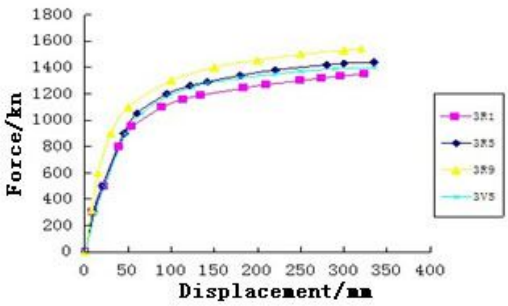


Figure 2-1 Uniaxial loading curve

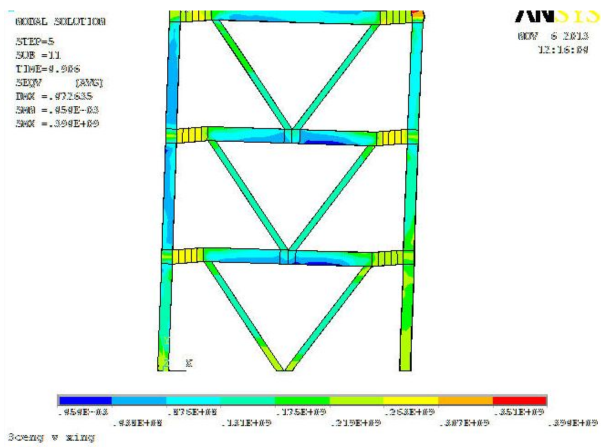
TABLE 2-1 RESULTS OF THE ANALYSIS DATA

Model Number	Yield loadPy/KN	Yield displacement Δ_y / mm	Yield displacement Δ_y / H	Elastic lateral stiffness（KN/MM）
3R1	1000.42	63	1/186	15.87
3R5	1100.55	52	1/225	21.16
3R9	1130.33	51	1/229	22.16
maximum amplitude	11.4%	23.5%	23.1%	28.3%
3V5	1100.27	52	1/225	21.159

Uniaxial loading curve of the model shown in Figure 2-1, the results of the analysis data in Table 2-1. From the Loaded curve and the data in the table can be seen:

(1)The case of the same node stiffness, herringbone and V-type eccentrically braced yield load almost the same;

(2)With the node stiffness decreases, the steel frame in elastic stage lateral stiffness decreased and yield displacement increased, but it is meet the regulatory requirements; Yield load maximum amplitude is not large, only 8.8%,while the yield displacement and lateral stiffness have large amplitude, respectively, 23.5%, 28.3%, this shows that, node stiffness have large effect on the lateral stiffness and yield displacement of the steel frame.



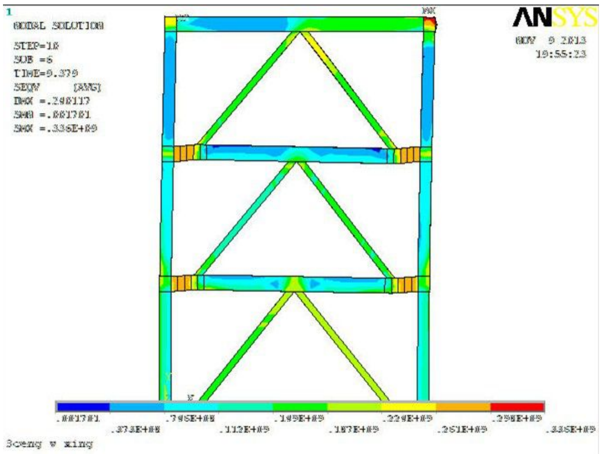


Figure 2-2Stress cloud for V-shape braced and Herringbone shaped braced

(3) The stress cloud of the model shown in Figure 2-2. By stress cloud can be seen: When the force of the model reached the limits of state, the maximum stress appears in energy beams, node domain is followed, Energy dissipation capacity and ductility of the frame rely mainly on the plastic deformation of energy beams to reflect.

B. Cyclic loading

Loaded system: The displacement control Loaded system. After by uniaxial loading calculated the yield displacement Δ_y ,according Δ_y /4 graded cyclic loading, After displacement reached Δ_y (namely after yielding), according to Δ_y continues to cyclic loading until the model destroyed.

The hysteresis curve of the model under cyclic loading shown in Figure 2-3, the cyclic loading data results in Table 2-2.

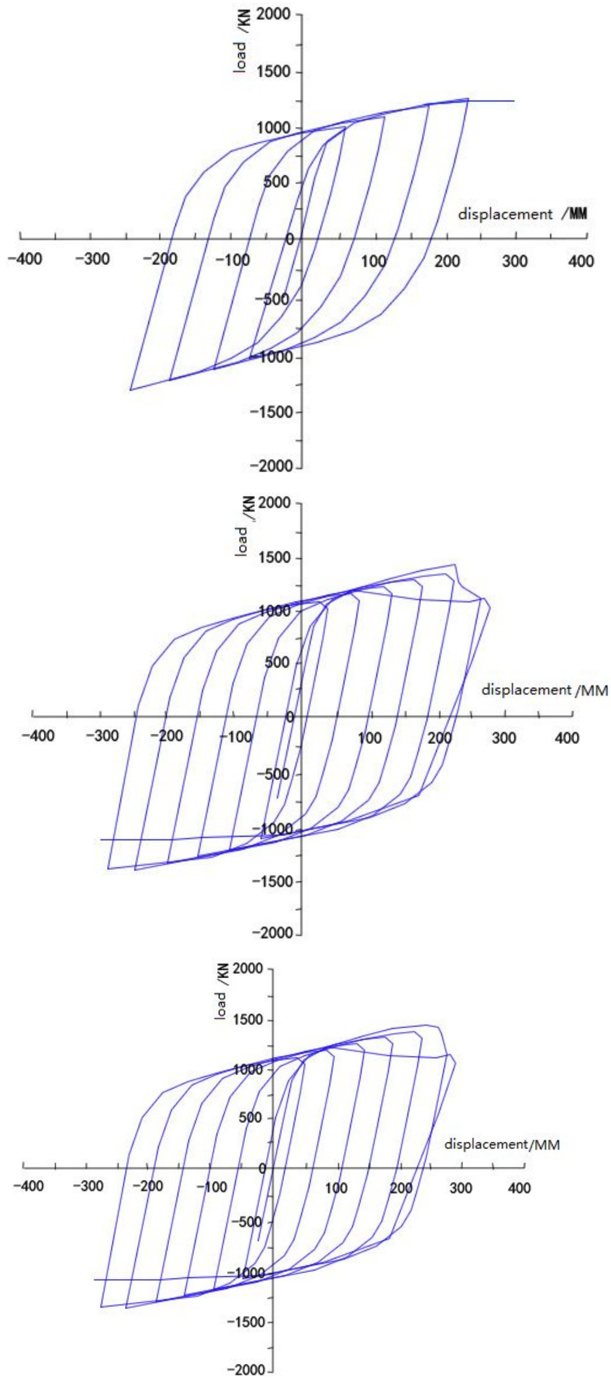


Figure 2-3 The hysteresis curve for model 3R1,3R5 and 3R9

TABLE 2-2 CYCLIC LOADING DATA RESULTS

Model Number	Limit loadPu/KN	Limit displacement		Energy dissipation factor
		Δ_u/mm	Δ_u / H	
3R1	1250.32	299	1/39	2.29
3R5	1493.51	289	1/40	2.35
3R9	1520.13	286	1/41	2.37
Maximum amplitude	21.5%	4.3%	4.87%	3.37%

By Figure and Table can be seen:

(1)Hysteresis curve under the three node stiffness are relatively plump, the energy dissipation factor are about 2.3, reflecting better hysteretic performance, the greater the joint stiffness, hysteresis curve more plump; with joint stiffness increased, energy dissipation factor showed an increasing trend.

(2) With the node stiffness increases, Ultimate Bearing Capacity of the model tended to increase; When node stiffness is $1X10^5$KNm / rad or more, the limit displacement is not great, but it is less than $1X10^5$KNm / rad, the limit displacement is obvious changes, This shows that the low node stiffness leads to insufficient lateral stiffness of the frame structure.

IV. CONCLUSION

From the above analysis can be drawn: The node stiffness of eccentrically braced steel frame with semi-rigid connections in the case of designed appropriate (this article $1X10^5$KNm / rad or more), the structure has better hysteresis properties, good seismic performance, load capacity and lateral stiffness meet the regulatory requirements. Therefore, in today's earthquake-prone society, the eccentrically braced steel frame with semi-rigid connections applied to our life can be effectively reduce the number of personal casualties and economic losses caused by natural disasters, with some prospects, more in line with the requirements of Industrial building.

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