Study on Seismic Performance of Variable Section Columns Based on Increasing Section Method

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Abstract. In order to improve the seismic performance of variable section columns, nine finite element models of variable section columns reinforced by increasing section method were established by using finite element software ABAQUS to study the influence of different reinforcement grades and section areas on the seismic performance of variable section columns. The study shows that the increase of reinforcement grade and diameter improves the ductility and seismic performance of the columns. The reinforced variable section columns have good axial compressive load capacity with high seismic performance. The cross sectional area of the reinforcement is the main factor affecting the performance of this member.

Keywords: increased section method, seismic performance, reinforcement, variable section columns

1 Introduction

Nowadays, there are fewer studies on the axial pressure and seismic aspects of variable section columns [1]. In 2019, Keun-hyeok[2] study proposes a novel section-expanding reinforcement technique to enhance the performance of non-seismic or deteriorated columns by introducing V-ties in the conduit frame section as an auxiliary transverse reinforcement. The effectiveness and limitations of the technique were assessed by performing axial load tests on nine full-size columns. Abdulridha[3] study investigates the response of carbon fibre reinforced plastic (CFRP)-reinforced reinforced concrete (RC) framed basement columns under seismic action by means of computer simulation and finite element analysis. The results of the study show that CFRP reinforcement significantly improves the seismic capacity of the RC structure, which is mainly reflected in the reduction of maximum and residual displacements. Molan P and others[4] study investigated the composite effect of cross-shaped steel reinforced square columns constrained by fibre-reinforced polymer (FRP) tubes to form new hybrid columns, and it was found that FCCSCs with wide steel flanges showed higher axial load carrying capacity and deflection. Slender FCCSCs, on the other hand, showed lower axial load carrying capacity and higher lateral deflection. The study also proposes a calculation method for the compressive load carrying capacity of slender FCCSC. Therefore, in

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this paper, by investigating the use of ABAQUS finite element software to establish a variable cross-section column model, combined with the comparison of numerical simulation and similar experimental results

2 Finite Element Modelling and Validation

2.1 Selection of the Principal Structure

In this paper, a concrete material model based on plastic damage theory is selected, and the corresponding tensile and compressive intrinsic model is established according to the uniaxial stress-strain relationship proposed by GB50010-2015 as the research object. The expansion angle is 30., the eccentricity is 0.1, fb0 /fc0 =1.16, the viscosity parameter is 0.005, and the stiffness is 0.667. Since the reinforcing bar and the steel take into account the Bauschinger effect and the strain-hardening effect so that the bi-folding intrinsic model is used, Young's modulus is taken as 200000 GPa, and the Poisson's ratio of the reinforcing bar is 0.2.

2.2 Model Validation

In this paper, a finite element model is established according to the test in Wang Zuohu [5] et al. Wang Zhixin [6], and the model column is calculated and analysed in ABAQUS software, and the test results are compared with the results of the finite element model analysis, which is used to verify the accuracy of the finite element model. The comparison results are shown in Figure 1 and Table 1.

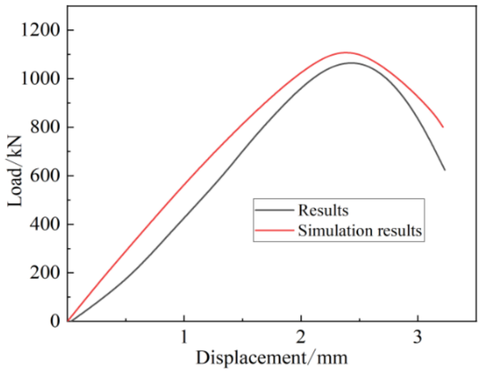


Fig. 1. Comparison between finite element simulation and test

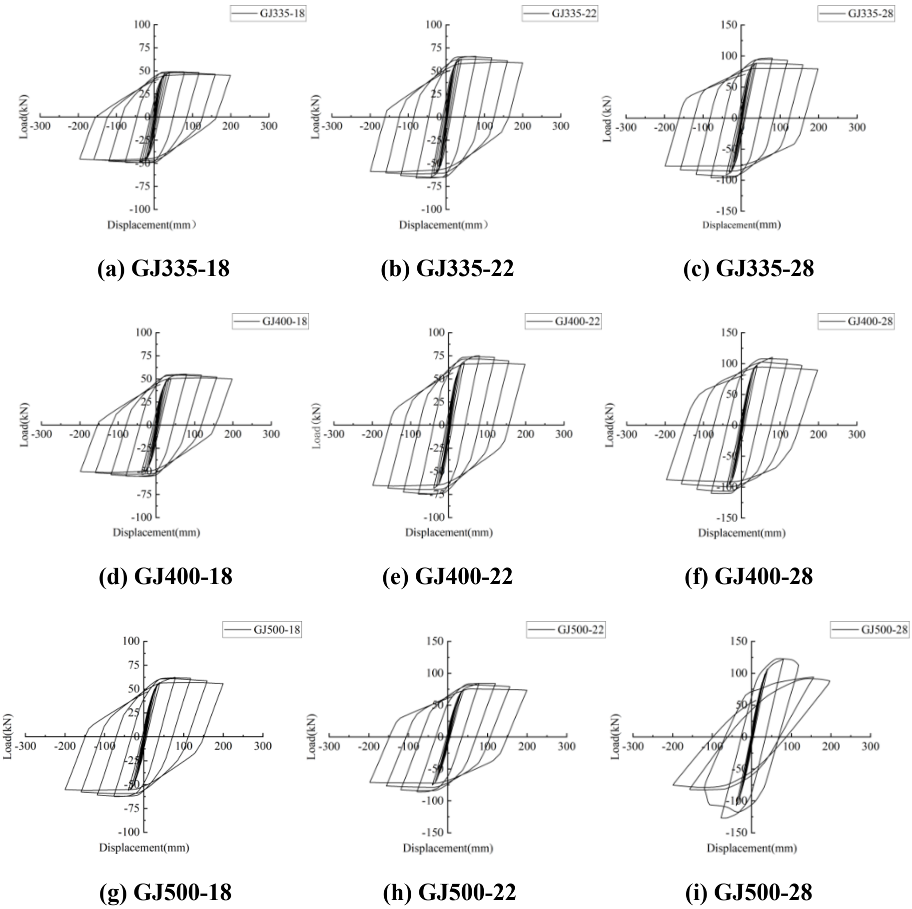
Table 1. Comparison of values

Specimen number	Experimental value/KN	Analogue value/KN	Error/%
Z1	1081.67	1151.32	6.4

Load-displacement (P-Δ) curves obtained by finite element method and comparison with experimental results: The load-displacement curves of the finite element are slightly fuller than the experimental curves, but the overall trend of change is consistent, and the difference between the two is basically within 10%, so the established finite element model has a high accuracy and can be used for subsequent analysis.

3 Analysis of the Effect of Different Reinforcement Grades and Cross Sectional Areas on Seismic Performance

3.1 Hysteresis Curves



(a) GJ335-18 (b) GJ335-22 (c) GJ335-28

(d) GJ400-18 (e) GJ400-22 (f) GJ400-28

(g) GJ500-18 (h) GJ500-22 (i) GJ500-28

Fig. 2. Hysteresis curve

The hysteresis curves under different reinforcement grade members are shown in Fig.2. As can be seen from the figure, the hysteresis loop area of the members is larger, and the hysteresis curves present full characteristics, showing good energy dissipation performance. With the increase of reinforcement grade and cross sectional area, the shape of the hysteresis curve of the members is similar, and their peak load carrying capacity and the load carrying capacity of each cyclic displacement amplitude are also similar. The observation of pike-shaped hysteresis band curves shows a more uniform deformation and stress distribution. This implies that the forces and deformations of the structure are relatively uniform without much concentration under repeated ground shaking. This is important for improving the overall performance and stability of the structure.

This uniformity results from the reinforcement effect of the increased section method. In addition, the energy dissipation capacity of this column is increased when the reinforcement grade is 335, 400 section area is 18mm^2, 22mm^2. There is a degrading effect on the seismic performance of the members when the reinforcement grade is 500 and the cross sectional area is 22mm^2, 28mm^2. The reason for this is the localised over-strength of the enlarged section portion of the upper column, which leads to the unreinforced portion of the column being more susceptible to damage, thus inducing the seismic effect of the cycle.

3.2 Skeleton Curve

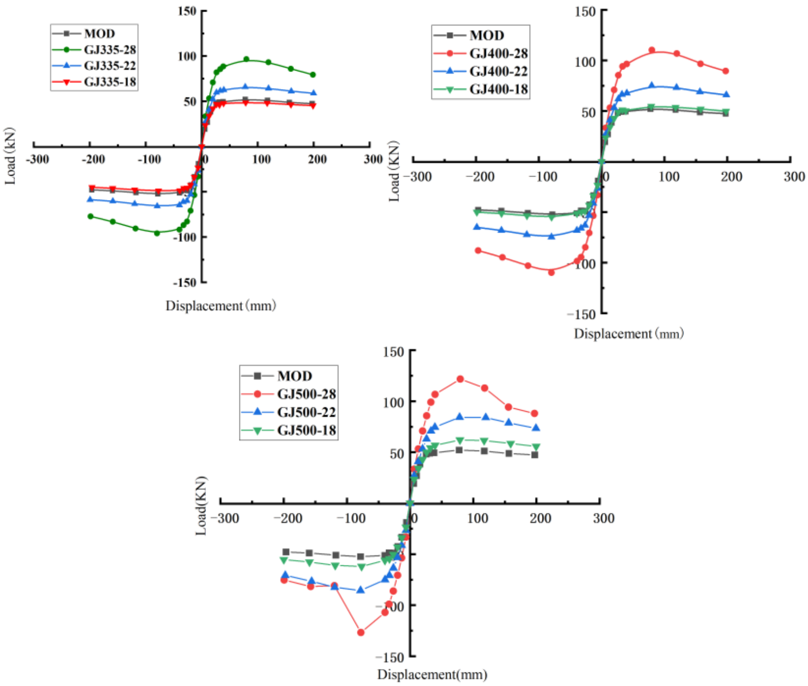


Fig. 3. Skeleton curves

The skeleton curves for different reinforcement grades and cross-sectional areas in Fig.3, the skeleton curves show S-shape, it can be seen that with the increase of reinforcement grade and cross-sectional area, the stiffness is not much affected in the initial elasticity stage, and the maximum load carrying capacity of the member increases with it, and the maximum magnitude of the member increases is 1.34%, and the minimum magnitude of the member increases is 0.05%. The curve in the falling section tends to be stable. The results show that the effect of improving the seismic performance capacity of variable section members by increasing the cross-section method is not related to the grade of reinforcement but to the cross-section area of reinforcement.

The results show that the seismic performance of the concrete structure with HRB335 and 18 mm² is worse than the original unreinforced concrete column. However, when the reinforcement grade is upgraded to 18mm², HRB400 and above, the seismic capacity has equalled or even exceeded that of the original variable section members.

3.3 Energy Consumption Performance

Table 2. Energy dissipation coefficients for components

displacement/mm	MOD	GJ335-18	GJ400-18	GJ500-18	GJ335-22	GJ400-22	GJ500-22	GJ3335-28	GJ400-28	GJ500-28
	E	E	E	E	E	E	E	E	E	E
6	0.51	0.60	0.60	0.60	0.52	0.52	0.52	0.40	0.40	0.40
13	0.36	0.39	0.39	0.39	0.31	0.31	0.31	0.23	0.23	0.23
20	0.28	0.35	0.30	0.28	0.25	0.22	0.22	0.17	0.16	0.16
26	0.42	0.49	0.35	0.27	0.38	0.26	0.19	0.28	0.18	0.15
33	0.74	0.79	0.55	0.33	0.69	0.42	0.25	0.57	0.30	0.17
40	1.02	1.04	0.79	0.49	0.92	0.70	0.35	0.77	0.55	0.25
80	2.11	2.18	1.94	1.53	2.09	1.79	1.39	2.01	1.65	1.27
120	2.50	2.54	2.40	2.16	2.54	2.35	2.11	2.51	2.31	2.01
160	2.62	2.61	2.52	2.40	2.65	2.56	2.40	2.76	2.57	1.54
200	2.60	2.57	2.54	2.48	2.63	2.63	2.60	2.87	2.72	1.60

According to Table 2, it is observed that when the specimens are at very small horizontal displacements, their energy dissipation coefficients do not differ much and belong to the elastic phase. In this process, the energy dissipation coefficient of the variable section column gradually increases and is dominated by energy dissipation at this stage. Increasing the cross-section form has little effect on its energy dissipation, especially when the cross-section size is less than 28 mm², its energy dissipation capacity will be weakened. When using the increased section method of reinforcement, different forms of reinforcement and different cross sectional areas also have little effect on the energy dissipation factor. The maximum energy dissipation factor increased by 11 per cent compared to the unreinforced condition.

4 Conclusion

As the grade of reinforcement increases, it increases the stiffness and load-bearing capacity of the upper columns. This allows the upper column to disperse and dissipate stresses more quickly, thus changing the stress distribution throughout the structure. Under equal loading conditions, the area of plastic damage to the lower column of a variable-section column may increase due to the increased cross-sectional area of reinforcement in the reinforced portion of the upper column, thus affecting the performance of that column.

The hysteresis curves of the members are basically similar as the reinforcement grade and cross sectional area increases. With the increase in reinforcement grade and cross sectional area, the ultimate load carrying capacity of the members increases and the maximum increase is 2.34 times the maximum energy dissipation factor increases by 11%. It shows that the increased section method reinforcement has improved the seismic performance of variable section columns and improved the energy dissipation capacity, and the skeleton curves of different reinforcement grades and section areas show better ductility. There is a degrading effect on the seismic performance of the members when the reinforcement grade is HRB500 and the cross sectional area is 28 mm2. The initial stiffness, stiffness degradation rate, and post-degradation stiffness values of the members with larger reinforcement grade and cross sectional area are larger.

As the grade of reinforcement and the cross-sectional area increase, the ultimate bearing capacity of the variable section column is higher and the ductility is gradually increased. The maximum ultimate bearing capacity can be increased to 137.1% of the original column, and the peak load is increased to 37% of the original. Since the reinforcement effect does not change significantly when the reinforcement grade is HRB500 or above, it is recommended to use the columns with the reinforcement grade of HRB400 and the cross-sectional area of 22mm2 in the actual working condition to ensure the good structural load bearing capacity and at the same time more economical and save the material, and at the same time, it is necessary to pay special attention to and deal with the back half of the column's bottom end.

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