

Comparison and Analysis of Steel Frame Based on High Strength Column and Normal Strength Column

Taiyu Liu¹, Yuwei An²

¹School of Civil Engineering, Bowen College of Management Guilin University of Technology, Guilin 541006, China.

²DUOWEI United group co. LTD, Beijing 102445, China

*Corresponding author e-mail:hyun.bin.2008@163.com.

Abstracts. The anti-seismic performance of high strength steel has restricted its industrialization in civil buildings. In order to study the influence of high strength steel column on frame structure, three models are designed through MIDAS/GEN finite element software. By comparing the seismic performance and economic performance of the three models, the three different structures are comprehensively evaluated to provide some references for the development of high strength steel in steel structure.

1. Introduction

High strength steel (the yield strength standard value is greater than 460MPa) has been successfully applied to many steel structures due to its good mechanical properties. The application of high strength steel has promoted the development of civil steel structure building, reduced construction cost and brought significant economic and social benefits. It is the inevitable trend of the future development of steel structure engineering [1-2]. At present, the research on high strength steel in China focuses on the properties of high-strength steel materials, the performance of components [3-4] and the nodes [5], but the research on the relevant system of high-strength steel is lacking. Therefore, the study of high strength steel application technology and seismic performance of civil steel structure construction has become the key technical issue that restricts the industrialization of civil steel structure [8]. In this paper, three frame models are established. Model 1: The frame column is designed with Q345 steel. Model 2: The frame column is designed with Q460 steel. Model 3: The lower three-layer frame column adopts Q460 steel, and the upper third layer adopts Q345. Based on the comparison of three models in earthquake response, the seismic performance of each model is analysed.

2. Model parameters

The six-layer steel frame structure, the plane drawing and the elevation diagram are shown in figure 1 and figure 2, The frame length is 19.8 m, 10.8m wide and 3m high, The cross section of the beam and column is H type, which is connected by welding, The frame column is connected to the base by a rigid connection. The permanent load on the floor is 5.0KPa (including self - weight), the variable load is 2.0KPa; The permanent load on the roof is 5.0KPa (including self - weight), the variable load is 0.5KPa, the wall load is 4kN/m; The site category is class two; The design of seismic grouping is based on the first group, and the seismic fortification intensity is 8 degrees.

Model 1: the frame column is designed with Q345 steel.



Model 2: the frame column is designed with Q460 steel.

Model 3: the lower three-layer frame column adopts Q460 steel, and the upper third layer adopts Q345.

In the same frame structure, both beams and columns are used in the same section, and the frame beams of the three models are all in Q345 steel. The model is calculated using MIDAS/GEN finite element software, and the strength, stiffness and stability of the structure are checked. The maximum (axial ratio) of the three frame corresponding components is controlled at the same level. The dimensions of the three frame beam columns are shown in table 1 and table 2.

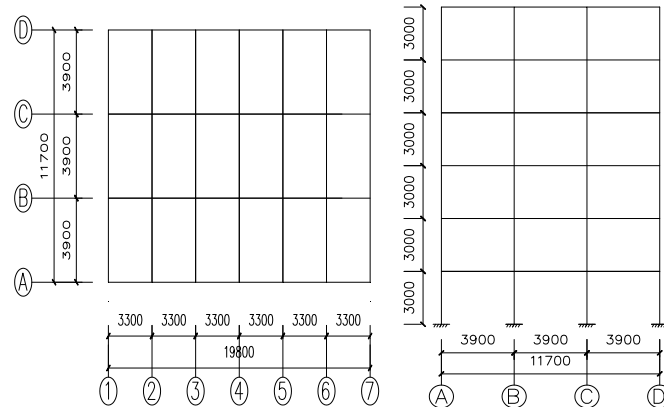


Fig. 1 Plane diagram

Fig. 2 Elevation

Table 1. Dimensions of frame beam (mm)

| Name | Height section | Width of section | Thickness web | Flange thickness |
|------------|-------------------|------------------|------------------|------------------|
| Frame Beam | 300 | 150 | 6.5 | 9 |

Table 2. Dimensions of frame column (mm)

| Name | Height section | Width section | Thickness web | Flange thickness | Axial compression ratio |
|---------|-------------------|------------------|------------------|---------------------|-------------------------------|
| Model 1 | 300 | 300 | 10 | 15 | 0.20 |
| Model 2 | 260 | 260 | 10 | 15 | 0.20 |
| Model 3 | 265 | 265 | 10 | 15 | 0.20 |

3. The comparison of elastic analysis of three models under the action of frequent earthquake

3.1. Contrast of earthquake action

Through MIDAS/GEN software, the first six modes of the structure were selected to analyze the modal analysis of the three frame structures. The framework self-oscillation cycles are shown in table 3. The force of X in frequent earthquake action is shown in table 4. When the first six modes of the structure were selected, the combined quality of each mode was over 90%. The first mode of the three models is the x-oriented, the second mode is the same as Y, the third is torsional, and the torsion ratio meets the specification requirement. At the same time, the torsional vibration cycle is closer to the translational period, indicating that the structure torsional mode is more obvious.

Table 3 and table 4 show that the self-oscillation period of model 2 and 3 is larger than that of the model 1. This is because the frame column adopts the high strength steel, the column section decreases, the lateral stiffness weakens, resulting in the increase of the self-vibration period, the smaller the earthquake influence coefficient, the smaller the earthquake effect. Therefore, the framework of high

strength steel is good for earthquake resistance, and the period of model 2 and 3 is relatively close to the earthquake force, and the seismic performance is better.

Table 3. Self-oscillation period of each model (S)

| Numbers of formation | Model 1 | Model 2 | Model 3 |
|----------------------|---------|---------|---------|
| 1 | 1.3088 | 1.4676 | 1.4438 |
| 2 | 1.1757 | 1.2680 | 1.2552 |
| 3 | 1.0848 | 1.1815 | 1.1677 |
| 4 | 0.4272 | 0.4846 | 0.4760 |
| 5 | 0.3627 | 0.4005 | 0.3954 |
| 6 | 0.3395 | 0.3773 | 0.3720 |
| Ratio of torsion | 0.83 | 0.81 | 0.81 |

Table 4. X earthquake force of each frame (kN)

| Floors | Model 1 | Model 2 | Model 3 |
|----------------------------|----------------|----------------|----------------|
| 6 | 181.13 | 159.16 | 162.03 |
| 5 | 240.05 | 214.80 | 218.20 |
| 4 | 184.34 | 164.72 | 167.34 |
| 3 | 221.04 | 193.88 | 197.43 |
| 2 | 220.87 | 196.48 | 199.74 |
| 1 | 118.57 | 110.23 | 111.43 |
| Total seismic force | 1166.00 | 1039.27 | 1056.17 |

3.2. The contrast between lateral displacement and interlayer displacement Angle

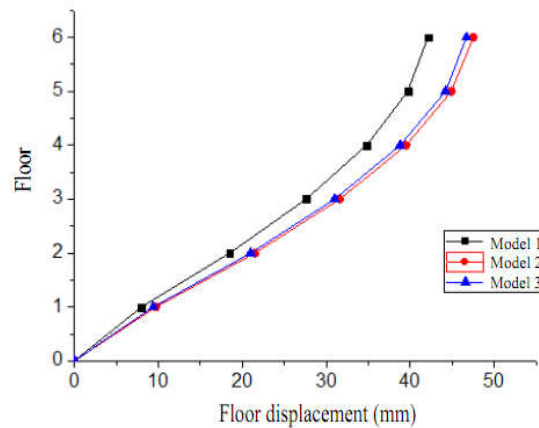
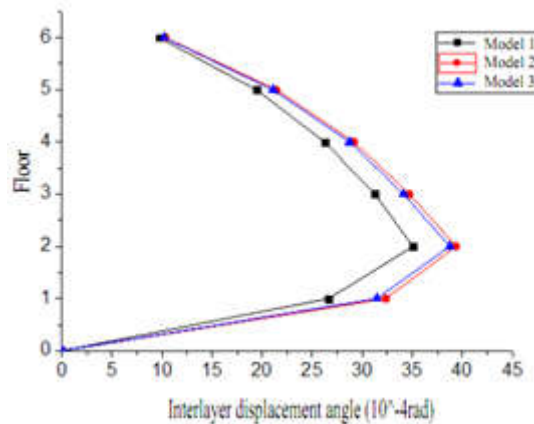
The lateral displacement and inter-layer displacement Angle of the three structural models are presented in table 5 and table 6. The curve comparison is shown in FIG. 3 and FIG. 4. The maximum interlayer displacement Angle appears on the second layer, which is 1/285, 1/254, 1/258. Both are less than the standard limit of 1/250. The weak layer is located in the lower layer of the structure, and the deformation conforms to the pattern of shear deformation of frame structure. Due to the increase of steel strength, the elastic modulus is unchanged, and the column section size is reduced, so the lateral stiffness of model 2 and 3 decreases, and the displacement and interlayer displacement Angle are larger. Compared with model 3, model 2 shows that the displacement and interlayer displacement are relatively close, and the stiffness is not much changed.

Table. 5 Floor displacement (mm) under frequent earthquake action

| Floors | Model 1 | Model 2 | Model 3 |
|--------|---------|---------|---------|
| 6 | 42.1 | 47.5 | 46.7 |
| 5 | 39.7 | 44.9 | 44.2 |
| 4 | 34.8 | 39.5 | 38.8 |
| 3 | 27.6 | 31.6 | 31.0 |
| 2 | 18.5 | 21.5 | 21.0 |
| 1 | 8.0 | 9.7 | 9.4 |

Tab. 6 Interlayer displacement Angle under the action of frequent earthquake(10-4rad)

| Floors | Model 1 | Model 2 | Model 2 |
|--------|---------|---------|---------|
| 6 | 1/1030 | 1/969 | 1/979 |
| 5 | 1/515 | 1/467 | 1/474 |
| 4 | 1/381 | 1/343 | 1/348 |
| 3 | 1/320 | 1/288 | 1/293 |
| 2 | 1/285 | 1/254 | 1/258 |
| 1 | 1/375 | 1/309 | 1/318 |

**Fig. 3** Floor displacement (mm) under frequent earthquake action**Fig. 4** Interlayer displacement Angle under the action of frequent earthquake(10-4rad)

4. Comparison of elastoplastic analysis under the rare earthquake

Using the MIDAS/GEN structure finite element software, the static elastoplastic analysis of three steel frame structures is analysed. The loading mode is a first-order mode loading, and the procedure B method in the atc-40 is adopted to solve the structural performance point. The study shows that, under the action of the earthquake, the interlaminar displacement of the structural performance points is 1/86, 1/82 and 1/83, respectively, which is not exceeding the standard limit of 1/50. FIG. 5 shows that the plastic hinge also basically appears in the floor 1-3 layer, which is the weak layer of structure.

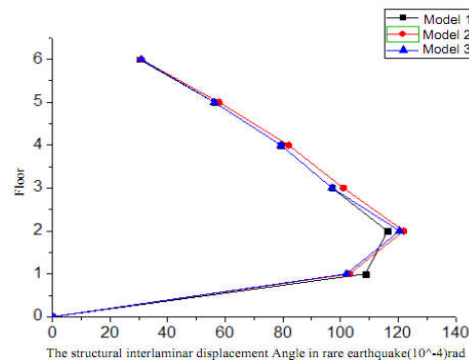


Fig. 5 The structural interlaminar displacement Angle in rare earthquake(10^{-4} rad)

5. Economic comparison

The steel consumption and comprehensive cost of the three structures are shown in table 7 and table 8. It can be seen from the table that the two structures used in high strength steel are lower than normal strength steel structure in terms of steel usage and cost.

Table 7. Steel consumption (t)

| | Q345 | Q460 | Total | Comparison |
|---------|-------|-------|-------|------------|
| Model 1 | 83.18 | — | 83.18 | — |
| Model 2 | 35.51 | 39.99 | 75.5 | -9.2% |
| Model 3 | 55.91 | 20.39 | 76.3 | -8.3% |

Table 8. Construction cost (yuan)

| | Total cost | Comparison |
|---------|------------|------------|
| Model 1 | 307766 | — |
| Model 2 | 295346 | -4.0% |
| Model 3 | 290466 | -5.6% |

6. Conclusion

1. Through comparative analysis, it is found that the frame column adopts high strength steel, which can reduce the size of the column section, reduce the amount of steel used, reduce the cost and also have the larger building space.

2. The use of high strength steel in frame structure, can decrease the size of cross section, reduce weight, structural stiffness decreases, and natural vibration period increased, the earthquake effect significantly reduced, but the floor displacement and displacement Angle between the layers are increased, so the floor displacement and interlayer displacement Angle of structure design is the main controlling factors.

3. By comparing the model 2 and 3, found that under the seismic action, all column using high strength steel and the lower column using high strength steel of the steel frame of floor displacement and interlayer displacement Angle close to, seismic performance is good, high strength steel on seismic performance of frame structure upper column use increase is not big. Although the model 3 is slightly larger than the model 2, the overall cost of the model 3 is lower and the comprehensive economic performance is better.

4. Steel frame structure of the weak layer located in the central part of the overall structure and lower, model 2 and model 3 seismic performance and comprehensive cost comparison shows that the

use of high strength steel in the structural weak layer can make full use of the advantages of high strength steel

References

- [1] Shi Gang, Ban Hui-yong, Shi Yong-jiu, Wang Yuan-qing. The engineering application and research progress of High strength steel structure [J]. Industrial building 2012. 42 ;
- [2] Shi Gang, Ban Hui-yong, Shi Yong-jiu, Wang Yuan-qing. Research progress of high strength steel structure[J]. Engineering mechanics 2013.30 (1) 1-13;
- [3] SHI Gang, LIU Zhao, ZHANG Yong. The finite element analysis of local stability of high strength steel axial compression member [J] . Journal of shenyang architectural university: Natural science edition 2011.26(6):1046 — 1051;
- [4] JIANG Xue-yi, XU Yong-lei, SHI Gang, SUN Ya-xin. High strength steel welded i-section section compression member finite element analysis[J]. Steel structure 2014.29[3]:7-11;
- [5] .DAI Yue, ZHANG Yuan-xin, LI Bu-hui,Q460 high strength steel pipe - beam bearing capacity test and analysis[J].Journal of nanjing university of technology 2014.36(2).