

Research Advances on Overall Stability of Q460 High Strength Steel Members under Axial Compression

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Abstract. In recent years, with the continuous rapidly development of the productivity and the production processing, the performance of steel has been continuously improved. High-strength performance steel has been used widely in long-span structures and tall buildings. The mechanical properties and the overall stability of axial compression members with Q460 high strength were summarized in the domestic and foreign in this paper. The differences between Q460 high strength and ordinary steel on the overall stability of axial compression members due to the differences in the mechanical properties of materials and the values and distribution of residual stress were analysed. It can provide reference for the study on the overall stability of axial compression members with high-strength performance.

1. Study on Mechanical Properties of Q460 Steel

With the emergence of long-span structures and tall buildings, high strength steel has been widely used. And the mechanical properties of Q460 high strength steel need to be further study. Compared with ordinary steel, the constitutive relations of high strength steel has been different because of the change of processing. Therefore, for studying the impact of this improvement on the overall stability behavior of Q460 steel members under axial compression, a comprehensive review of mechanical properties on Q460 steel has been given in this paper.

1.1. Study on Stress-strain Curves of Q460 Steel

The steel stress-strain curves have been often used to illustrate its mechanical properties. The material test results were obtained and the tensile stress-strain curves of Q460C were given by Shi Gang [1] through test. By comparing of the stress-strain curve of Q460C steel with the curve of ordinary steel, it is easy to see that the yield plateau of the steel with high-strength performance are shorter than its of steel with normal performance.. And terminal of yield platform corresponding to the strain value is also reduced to about 2%.

1.2. Study on the yield-strength ratio of Q460 steel

The yield-strength ratio is also an important indicator of the mechanical properties. By comparing the yield-strength ratio of Q460 steel with that of ordinary steel, the yield-strength ratio of Q460 steel has greatly improved because of different material. The mechanical properties of S460 (the yield strength is 460MPa) of European structural steel were summarized by Langenberg [2]. The results reflected that the yield ratio of S460 steel had a great increase. The yield-strength ratio of Q460 steel can reach about 0.8. The yield-strength ratio of Q460C was also given by Shi Gang [1]. It is found that the yield-strength ratio of Q460 steel was around 0.78. It is a quite consistent with the conclusion of Langenberg.



1.3. Study on ductility of Q460 steel

The elongation and the percentage reduction of steel are usually regarded as the mechanical property to evaluate the ductility of the steel. The mechanical property of Q460 steel was reviewed by Langenberg [2]. It is found that the elongation decreases by increasing the strength performance. It also can be showed that it is difficult to use in earthquake resistance system due to the low ductility. There are some varies between the high-strength performance steel and the common steel in the aspects of failure modes and property, particularly in aseismatic performance

2. Study on Welding Residual Stresses of Q460 Steel

Mechanical properties of steel members

The mechanical performances of steel members are great affected by the sectional residual stress, in the aspect of buckling capacity of members caused by yielding prematurely and the damage of stiffness under the condition of pressure particularly. As the main mechanical defects of the axial compression members, the effect of residual stress on the buckling performance is also changing with the strength increase of the steel. Therefore, it is essential to study the welding residual stresses of the high-strength performance steel in different types. Thus, the study of steel with various shapes referred before was summarized in this paper.

There was a little experimental study on the residual stress of 460MPa grade steel in the foreign. And the measurement data was imperfect. Besides, the thickness of the specimen was too thin, so the representation of the engineering was not well [3]. The residual stress test on I-section composed by welding of the SM570 steel (the nominal yield strength is 460 MPa) was conducted by Iwatsubo [4]. The residual stress values of two welded sections were obtained. And its distribution on closed section of 460MPa steel was studied through using sectioning method by Usami [5]. It was found that the residual tensile stress around the weld region was about 80% of the yield strength.

In domestic study, the residual stress on 6 closed and 8 I-section specimens of 460MPa domestic steel were measured through using sectioning method by Shi Gang [3]. The influence of plate thickness, the width-thickness ratio of plate, weld form and other factors are analyzed comprehensively. The models which have distributed residual stress and the formula which have considered the influence of section size of residual tensile stress are put forward. In 2012, the residual stress in Q460 steel welded closed section was measured by Li Guo qiang [6]. The residual stresses formula was put forward and its distributed region was given. In 2015, the longitudinal residual stress of two Q460GJ steel welded thin-walled H-shape members was measured through cutting method by Luo Bin [7]. In 2016, the residual stress of Q460 welded closed section with thick plate was measured through cutting method by Duan Tao [8]. The residual stress distribution was obtained. At the same time, the residual stress distribution model and the corresponding suggested formula which has considered the thickness of the section were put forward.

3. Study on the overall stability capacity of Q460 steel under axial compression

In 1984, the test about the overall stability performance of 3 SM58 welded closed sections columns was conducted by Usami[5]. The results showed that the overall stability coefficients for the closed section columns composed of high strength steels were higher than the corresponding design codes in ANSI/AISC 360-10. In 2000, the overall stability tests for SM570 (the yield strength is 460MPa) I-section columns was conducted by Kaname [9]. It can obtain from the test that the overall stability coefficient was obviously high, however, the correlation design curve was lower than the former.

In the domestic study, the overall stability of members in different strength grades were analyzed by means of using the finite element program ANSYS by Zhang yin long in 2010 [10]. A calculation formula of overall stability behavior was put forward which considered the yield strength and the slenderness as the parameter. In 2012, the overall stability of 7 welded I-section and 5 welded closed section of domestic Q460C high-strength steel have been examined under axial compression by Shi Gang [3]. The influences of the residual stress, initial geometric imperfection were fully considered in the test. The experimental results were compared with the design methods in ANSI/AISC 360-10, Eurocode3 and GB 50017-2003. It could be seen from the comparison that, data of the correlation design curve was lower than the test data in a great number in China and European, but generally

lower than the design standard in ANSI/AISC 360-10. In order to analyze the overall stability of the domestic Q460MPa steel axial compression members with welded section and obtain the calculation formula of the overall stability of the steel columns with different geometrical parameters, they made further finite element numerical analysis. The bearing capacity of 860 axial compression members with welded sections (closed section and I-section) with a total of 4 different steel grades including 235, 460, 690, 960 MPa was calculated by them, and a large number of column curves was obtained. By comparing the column curves with the national standard of the steel structures, they suggested that the axial compression columns of both Q460 welded I shapes and closed section can still be designed according to Chinese or European standard of the b-type curve. There are another accurate method that it can be solved by using nonlinear curve fitting which has been put forward the imperfect factors based on curves of columns in Chinese Code GB 50017-2003

In 2012, the overall stability performance of Q460 welded closed columns (7 specimens) was examined by means of axial compression experiments and numerical simulations by Li Guo qiang [6]. The results showed that the current design stability curve (c-type curve of GB 50017-2003) was much safe for these columns. The mechanical behaviors of Q460 welded H section steel columns under the axial compression were studied by Wang Yanbo [11]. By changing the slenderness, the experimental results showed that the high-strength performance columns with yielding stresses of 460MPa could be designed according to c-type curve of GB 50017-2003. Because there were a little test data, the conclusion needs to be further verified. In 2016, the axial compression test for 6 H section columns made of Q460 high strength steels were conducted by Liu Min [12]. The results showed that the column curve of the Chinese steel structures standard was not applicable with such columns, these standards need to be modified to include high strength steel.

For proving the correctness of theories, the overall stability behavior of axially compression steel-angle made from Q460 high strength with four different sections and varied slenderness were studied by Tuo Yanyan [13] in 2009. The experimental were compared with the design methods in GB50017-2003, ASCE10-1997. The results showed that there were some difference between Code GB50017-2003 and Code ASCE10-1997 in the aspect of ultimate bearing capacity, the former were much conservative, however the latter were much accurate. The test has been carried by Fan Jinkai [14], who tested single equal leg angle Q460 steel under axial compression. The conclusion was obtained that its ultimate load capacity was higher than the common steel by contrasting the failure modes. The finite element method was used to analysis, based on the nonlinearity of both geometric and material. The stability coefficient calculation formula was put forward for future design after the research on test and the analysis of the finite element method.

4. Conclusion

After so many years of research, the high-strength steel stability performance of members has been extensively studied from the material properties and residual stress measurement in China. These studies not only provide important theoretical basis for the new codes or revision of existing steel structure design code, but also further promote the development of high-strength steel structure.

Acknowledgements

This work described in this paper was supported by National Science Found of China (51108279) and Natural Science Foundation of Liaoning Province (201602636), their supports are gratefully acknowledged.

References

- [1] Ban Hui-yong, Shi Gang, Shi Yong-jiu, Wang Yuan-qing. Research advances on mechanical properties of high strength structural steels [J]. Journal of Building Structures, 2013(02): 88-94. (in Chinese)
- [2] Langenberg p. Relation between design safety and Y/T ratio in application of welded high strength structural steels[C]. Proceedings of International Symposium on Applications of High

- Strength Steels in Modern Constructions and Bridges—Relationship of Design Specifications, Safety and Y/T Ratio. Beijing, 2008: 28-46.
- [3] Ban Hui-yong. Research on the overall buckling behavior and design method of high strength steel columns [D]. Beijing, Tsinghua University, 2012. (in Chinese)
- [4] Iwatsubo K, Yamao T. An experimental study on the ultimate strength and behavior of members made of high strength steel with low-yield ratio [J]. Mm FacEng Kumamoto Univ, 2000, 45(1):1-13.
- [5] Usami T, Fukumoto Y. Welded box compression members. Journal of Structural Engineering, 1984, 110(10):2457-2470.
- [6] Li Guo-Qiang, Wang Yan-Bo, Chen Su-wen. Experimental study on ultimate bearing capacity of axially compressed high strength steel columns [J]. Journal of Building Structures. 2012, 33(3): 8-14. (in Chinese)
- [7] Luo Bin-li, Bao Zi-ran, You Ze-zheng, Dai Guo-xin, Xiong Gang. Study on longitudinal residual stress of Q460 high-strength steel welded H-section [J]. National Symposium on Modern Structural Engineering, 2015. (in Chinese)
- [8] Duan Tao. Study on residual stresses in welded moderate and heavy plat box sections made of Q460GJ steel [D]. Chongqing: Chongqing University, 2016. (in Chinese)
- [9] Kaname I, Toshitaka Y. An experimental study on the ultimate strength and behavior of members made of high strength steel with low-yield ratio [R]. The minutes of the department of labor and education of Kumamoto University, 2001, 45(1): 1-13.
- [10] Zhang Yin-long. Research on overall stability of axially compressed member of high strength steel [J]. Steel Construction, 2010, 06. (in Chinese)
- [11] Wang Yan-bo, Li Guo-qiang, Chen Su-wen, Sun Fei-fei. Experimental study on the ultimate bearing capacity of axially compressed high strength steel of H-section columns [J]. China Civil Engineering Journal, 2012(6): 58-64. (in Chinese)
- [12] Liu Min. Research on the overall buckling behavior of axially compressed welded H-section columns made of Q460 high strength steel [D]. Xi'an: Xi'an university of architecture and technology, 2016. (in Chinese)
- [13] Tuo Yan-yan. Theoretical and experimental study on integral stability of high strength (Q460) angle bars to axial compression [D]. Xi'an: Xi'an university of architecture and technology, 2009. (in Chinese)
- [14] Fan Jin-kai. Theoretical and experimental study on Q460 single equal leg angle axial compression members [D]. Xi'an: Xi'an University of architecture and technology, 2009. (in Chinese)