Research on the Development and Prospects for High-strength Concrete Confined with High-strength Stirrup

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Abstract. It is an important direction to improve the construction level in China to vigorously promote the high strength concrete structures in civil engineering application. The research on the high strength concrete confined by the high-strength stirrup columns breaks the restricted area of the high axial pressure and high strength concrete columns in earthquake area using. Based on this situation, this paper discusses the development and prospects for high-strength concrete confined with high-strength stirrup, focusing on the constitutive model and seismic performance in order to provide some references for the relevant researchers.

Introduction

As a kind of new building material, high strength concrete is widely used in in high-rise structure, large span bridge structure as well as some special structure due to its advantages of high compressive strength, strong resistance, high density and low porosity. High strength concrete is characterized by high compressive strength, generally to 6 times the general strength of the soil mixed. It can reduce the cross-section of the component, so the most suitable for high-rise buildings. The results show that the high strength concrete frame columns have good seismic performance under the condition of a certain axial compression ratio and the appropriate coupling ratio. The column section size is reduced, the weight is reduced, the short column is avoided, and the structure is also favorable for earthquake resistance, and the economic benefit is improved. The high strength concrete material provides favorable conditions for the technology, which can be used in high strength steel and artificial control stress, thus greatly improving the bending stiffness and crack resistance of the bending members. Therefore, more and higher strength concrete structures are applied in the world, which is applied to the large span buildings and bridges. In addition, the use of high-strength concrete density characteristics can be used for the construction of the impact and blast loading of the building materials, such as atomic energy reactor foundation. High strength concrete with high permeability resistance and corrosion resistance of the characteristics of the construction of high permeability and high corrosion resistance requirements of industrial water tanks. The high strength concrete can reduce the section size, increase the use area, reduce the weight of the structure, save the material consumption, and reduce the consumption of resources and energy. In particular, the high strength concrete can be used to reduce the axial compression ratio of the component, especially for the compression member bearing large axial force in the high-rise building. But the ductility of high strength concrete is poor, and the brittleness problem becomes more significant with the increase of concrete strength. The use of high-strength stirrup in high-strength concrete can effectively increase the restriction effect of stirrups on the concrete. The brittleness of concrete can not only increase the ductility of the specimen, but also can improve the concrete peak stress and peak strain.

Constitutive Model of High-strength Concrete Confined with High-strength Stirrup

Yang Kun's paper *Study on the constitutive model of high- strength concrete confined by high-strength stirrups* explored the constitutive model.

In order to study the strength and ductility of high-strength stirrup confined high performance concrete, 31 high-strength spiral stirrups, whose high aspect ratio of the prism are there, were the axial compression test specimens. In consideration for the type of stirrups, stirrup strength, stirrup spacing, concrete strength and section size. The concrete strength is C70 ~ C80, stirrup yield strength were 411MPa, 609MPa and 952MPa, stirrup diameter is about 6.5mm and the cross section of the specimen size is 150mm * 150mm and 250mm * 250mm two. The stirrup form is divided into A B, C, D, stirrup ratio from 0.98% to 4.16% (Figure 1). The experiment was carried out on the 5000kN hydraulic testing machine of the structure and seismic Laboratory of Xi'an University of Architecture and Technology.

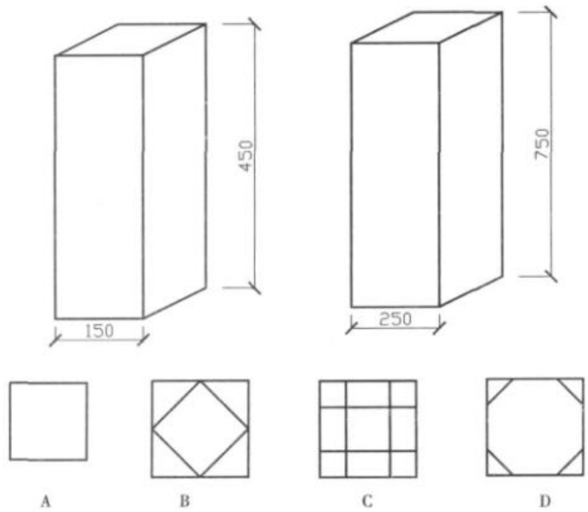

Figure 1. Geometry and tie configuration of specimen

From the test specimen in a few typical, respectively proposed model, Aoyama Hirono (Qing), Cusson model, Mander model, Saatcioglu model and Yunfang model (Zhi) was obtained with the stress-strain curve, and compared with the experimental curves, as shown in Figure 9 can be seen from the graph all of the models, the ascending curve was similar with the experimental curves, mainly reflected in the difference between the peak strain peak strength and stress-strain curve decreased. For ordinary stirrups confined high strength concrete specimens. The proposed model Mander model and Saatcioglu model curve and experimental curve was most close to the Aoyama Hirono model and Cusson model, a model of poor Yunfang. For the rest of stirrup confined high strength concrete specimens, model curve and experimental curve fitting is proposed in this paper, the Cusson model and the Aoyama Hirono model, Mander model and Saatcioglu model of the peak curve and descending branch of high Yunfang model and experimental curve fitting is poor this is due to the Mander model and the Saatcioglu model assumes that the peak values of stirrups the stress reaches the yield strength, suitable for ordinary strength stirrups, but overestimated the restraining effect of high-strength stirrup. The time of Cusson model and Aoyama Hirono model is relatively late, and there are many kinds of test results when the model is established. Therefore, the stress-strain curve of simulation of confined concrete, but the Cusson model decreased to the lower curve after about 50% of its peak intensity. Therefore, the proposed constitutive model is in good agreement with the experimental results. The comparison of stress- strain models is shown in Figure 2.

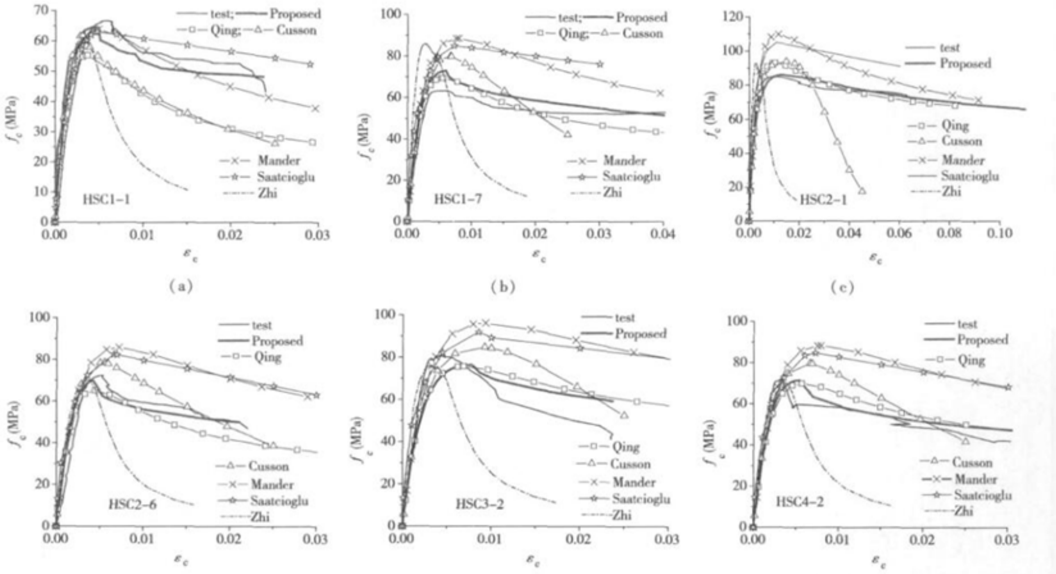

Figure 2. Comparison of stress- strain models

Seismic Performance of High-strength Concrete Confined with High-strength Stirrup

Under the action of strong earthquake, the brittle shear failure of reinforced concrete columns will severely weaken the overall seismic capacity of the structure. In recent decades, the shear bearing capacity of reinforced concrete columns or piers has developed many models, but for high strength stirrups confined high strength concrete columns is still worth exploring. Experimental study and from the point of view, a large number of experiments concentrated on the high-strength stirrup confined high strength bending failure of concrete columns, specifically for the shear strength of the study is little.

The formulation of the bearing capacity of bending shear in American ACI 318-05 standards is:

$$V_n = V_c + V_s \tag{1}$$

$$V_c = 0.17\left(1 + \frac{N_u}{14A_g}\right)\sqrt{fc}\,b_w d \tag{2}$$

$$V_s = \frac{A_v f_{yt} d}{s} \tag{3}$$

In the above formulation, V_c and V_s respectively represent the shear bearing capacity of concrete and stirrup; N_u is the axial compression load; A_g is the sectional area of the column; d is the distance between the edge of the compression zone and the center of the longitudinal reinforcement. The USCD model proposed by Priestley is as follows:

$$V = V_c + V_s + V_p \tag{4}$$

$$V_c = k\sqrt{f}A_e \tag{5}$$

In the above formulation, k is the shear capacity of concrete decreases with the increase of the ductility of the column; A_e is the effective shear area.

Based on the USCD model, Kowalsky calculated a formula of the shear strength of stirrup and concrete with anti on column was revised, proposed an improved USCD model by Martirossya and Xiao Yan (449MPa) of high strength concrete with high strength stirrups constraints (86MPa). The quasi static test results showed that the column, due to the brittleness of high strength concrete, the shear displacement increases with the rapid degradation of bearing capacity, the USCD model of the ACI318-05 specification and Priestley were overestimated the shear strength of high strength concrete columns, is unsafe, and the USCD model was a partial revision to consider characteristics of high strength concrete column on the shear strength contribution with displacement increases and rapid degradation. The test results of Bukek showed that the high strength stirrups can effectively improve the shear strength of the column, but the ACI318 specification of the shear strength of the result is unsafe. The improved UCSD model can be used to calculate the shear capacity of high-strength stirrup confined high strength concrete columns.

Due to high strength concrete curve between stress strain relations with normal strength concrete, reinforced concrete rectangular columns are widely used at home and abroad and the stress calculation formula of the shear strength of high strength concrete columns in the calculation results may not be safe or conservative, for it to be revised, so that it can be applied to high strength stirrup strength calculation of shear capacity and flexural concrete column. ACI318 formula and NZS3101 specification to ensure the ductility of reinforced concrete columns and the minimum confining stirrup dosage, cannot guarantee the seismic safety of high-strength stirrup confined high strength concrete columns, even not applicable to high strength concrete columns with high strength stirrups, should carry out special studies on its characteristics. Even in the axial compression ratio is greater than 0.6 under high axial pressure, can still be of high strength concrete columns with high strength stirrup effective restraint, and fully guarantee the high strength concrete column ductility and energy dissipation. For high strength concrete columns under axial pressure is relatively low, because of its ductility performance is easy to guarantee, does not recommend the use of constraint stirrup, high strength at the same time, the minimum spacing of stirrups were provided to ensure early buckling of longitudinal reinforcement under cyclic loading, to improve the ductility of high strength concrete column has important significance. Compared with ordinary stirrups column, column stirrup constrained peak specimen stress and peak strain are improved. Stirrup strength and reinforcement ratio have significant influence on the hysteretic curve, the same stirrup rate, with high-strength stirrup specimen loading cycle was more than the number of ordinary strength stirrup specimens, plump hysteretic curve, peak load curve decreased more slowly, the intensity of slow attenuation and deformation capacity. With high-strength stirrup confined concrete, the constraint effect is good. It can guarantee that the strength stirrup not yield in components before failure, having high security reserves.

References

[1] Sun Zhiguo, Si Bingjun, Wang Dongsheng, Yu Dehai, Engineering Mechanics, Vol. 27 (2010) No 10, p.182-189+213

[2] Pan Xiang, Structural Engineers, Vol. 31 (2015) No 5, p.141-147

[3] Ding Hongyan, Liu Yuan, Qiu Shi, Building Structure, Vol. 45 (2015) No 5, p.7-12

[4] Shi Qingxuan, Wang Nan, Tian Yuan, Wang Peng, Li Kun, Journal of Building Structures, Vol. 34 (2013) No 4, p.144-151

[5] Yang Kun, Shi Qingxuan, Zhao Junhai, Jiang Weishan, Meng He, China Civil Engineering Journal, Vol. 46 (2013) No 1, p.34-41