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Sensitive behaviour of slenderness CFST filled with DCLs under axial compression

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Abstract. The demolished concrete lumps (DCLs) has been demonstrated to replacement partial coarse aggregates when casting concrete. The experimental studied involved 12 Concrete-Filled Steel Tube (CFST) columns. Each columns diameter was 159mm, the length of specimens was 2000, 2200 and 2400 mm. The Diameter-to-thickness (D/t) ratio was 79, 53 and 40. The replacement ratio of FC by DCLs was 0, 20, 40 and 60%. Test results indicated that the slenderness ratio was the most sensitive factor on the bearing capacity of slender columns under axial compression, followed by D/t ratio, and the DCLs replacement ratio was smallest factor. The ultimate bearing capacity decreased slightly with increasing DCL replacement ratio..

Keyword: DCLs CFST Axial compression

1. Introduction

Concrete-Filled Steel Tube (CFST) columns has been widely used in the civil engineering fields[1]. With the acceleration of global urbanization and the rapid development of civil engineering construction, a large number of abandoned concrete had been produced while building, rebuilding and expanding all kinds of buildings on a large scale, which seriously pollutes the environment. In addition, the rapid increase in aggregate demand had resulted in excessive development, which had led to the exhaustion of resources and the great destruction of the ecological environment, so that the contradiction between the sustainable development of concrete and aggregate demand has become increasingly prominent [4-5].

In order to reduce the cost of producing recycled aggregate (RA), The demolished concrete lumps (DCLs) had been demonstrated to replace some coarse aggregates when casting concrete. [5-8]. This method could reduce energy consumption.

However, few studies have focused on the sensitivity of factors affecting mechanical behavior of slender circular steel columns filled with DCLs and FC under axial compression. This research was carried out on the basis of Bo Wu's study. The Orthogonal design method was adopted in this experiment. This study aims to investigate the sensitivity of factors affecting mechanical behavior of slender circular steel columns filled with DCLs and FC under axial compression..

2. Experimental program

2.1. Materials and specimen details

The experimental study involved 12 CFST columns. Each column diameter was 159mm, the length of specimens was 2000, 2200 and 2400 mm. The thickness of the steel tubes was 2, 3 and 4mm, so the D/t ratio was 79, 53 and 40. The replacement ratio of FC by DCLs was 0, 20, 40 and 60%. 1Aa0, 5Bb0 and 9Cc0 were control specimens that were designed without DCLs in FC. The D/t ratio in these tests met most of the codes' requirements. According the EC4, the slenderness ratio (λ=4L/D) was obtained. The slenderness ratio was 50, 55 and 60. Strain gauge was placed in the mid-height of specimens to measure the strain. The details of the specimens are shown in Table 1.

Table 1. Detail of the test specimens Formatting sections

Specimen	L / mm	D / mm	t / mm	D / t / %	λ	η / %	N / kN
1Aa0	2 000	159	2	79	50	0	890
2Aa1	2 000	159	2	79	50	20	890
3Ac2	2 000	159	4	40	50	40	1 266
4Ab3	2 000	159	3	53	50	60	1 081
5Bb0	2 200	159	3	53	55	0	1 042
6Bb1	2 200	159	3	53	55	20	1 042
7Ba2	2 200	159	2	79	55	40	857
8Bc3	2 200	159	4	40	55	60	1 220
9Cc0	2 400	159	4	40	60	0	1 178
10Cc1	2 400	159	4	40	60	20	1 178
11Cb2	2 400	159	3	53	60	40	1 006
12Ca3	2 400	159	2	79	60	60	827

Note: L, D and t are respectively the length, diameter and thickness of the specimens. λ and η are respectively the slenderness ratio of specimens and the replacement ratio of DCLs.

2.2. Material properties

For the steel tube, the yield strength, the ultimate strength , and the elastic modulus are shown in Table 2. To measure the displacement of the columns, three LVDTs were placed on the specimens. Through the hydraulic testing machine, the jack act on the top of the column to load step by step. Load grade was directly controlled by hydraulic testing machine. The geometric center of the specimen before loading coincided with the connection of the geometric center of the upper and lower loading plates of the testing machine. Loading can be divided into two stages: preloading and formal loading. In the pre-loading stage, the applied load value was about 1/20 of the ultimate load. The purpose was to test whether the data collected by strain gauges and displacement meters were accurate and effective, and to make the specimen in good contact with the loading device, and then entered the formal loading stage.

In the elastic range, the loading value of each stage was 1/10 of the design ultimate load; when the applied load was about 70% of the design ultimate load, then the loading value of each stage was 1/20 of the design ultimate load, and the loading time of each stage was about 5 minutes. When the applied load was about 95% of the design ultimate load, the lateral deflection at mid-height of the column increased by 1 mm as the control index, and the lateral deflection at mid-height of the column increased gradually until the specimen was destroyed. The data in the test process were collected automatically by the instrument.

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2.3. The relationship between slenderness and bearing capacity

Fig.1 shows the influence of slenderness ratio on the bearing capacity of slender columns. it could be concluded that the bearing capacity of slender CFST columns filled with DCLs decreased with the increased of slenderness ratio.

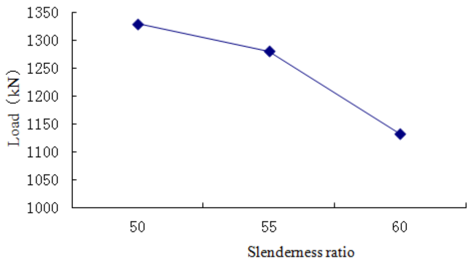

Fig.1. Relationship between slenderness ratio and bearing capacity of specimens

When slenderness ratio increased from 50 to 55, the bearing capacity of the column decreased by about 4%, the slope of the section was about 9.8, and when slenderness ratio increased from 55 to 60, the bearing capacity of the column decreased by about 12%, and the slope of the section was about 29.6. Through comparative analysis, the following basic rules were obtained: the bearing capacity decreased greatly with the increased of slenderness ratio, but the relationship was not linearly. It also illustrated that the elastic-plastic instability failure did not converge with the increase of slenderness ratio.

The bearing capacity decreased greatly with the increased of slenderness ratio. The reason was that the column's deflection did not change significantly at the beginning of loading, and the slender column was in the stage of elastic working. When the load continued to be applied, the lateral deflection began to appear in the mid-height of the slender column. The eccentricity of the specimen occurred, which result in the bending moment and reduced the bearing capacity of the column. When approaching the ultimate load, the column's deflection increased obviously, the eccentricity continued to increased, and the bending moment also increased significantly. At a certain moment, even if the load did not increase, the lateral deflection of the slender column would continue to increase.

2.4. The relationship between D/t ratio and bearing capacity

The relationship between D / t ratio and bearing capacity of specimens is shown in Fig.2.The ultimate bearing capacity increased by about 6%, with the D / t increased from 40% to 53%, the slope of this section was about 22.7%, and the ultimate bearing capacity increased by about 7% with the steel content increased from 53% to 49%, and the slope of this section was about 27.7. Through comparative analysis, the following basic rules were obtained: with the increased of D/t ratio, the increased range of bearing capacity became larger.

The hoop coefficient ($\xi = A_s f_y / A_c f_c$) affected the bearing capacity of the column. The hoop coefficient was introduced to reflect the constraint of steel tube on core concrete. The larger the hoop coefficient was, the stronger the constraint of steel tube on concrete was, the higher the bearing capacity of the column was. D / t ratio indirectly affected the hoop coefficient. For concrete with the same steel and axial compressive strength, the D / t ratio had a linear relationship with the hoop coefficient ($\xi = A_s f_y / A_c f_c$). When the D / t ratio increased, the hoop coefficient increased, the restraint effect of steel tube on core concrete increased, and the bearing capacity of columns increased.

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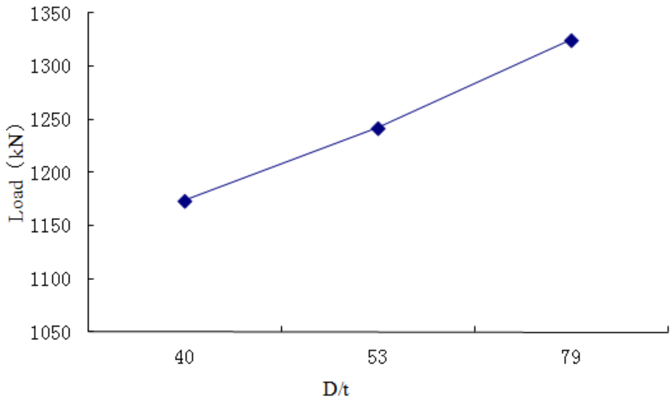

Fig.2. Relationship between D / t ratio and bearing capacity of specimens

2.5. The relationship between DCLs replacement ratio and bearing capacity

The relationship between DCLs replacement ratio and bearing capacity of specimens is shown in Fig.3. The ultimate bearing capacity of long columns decreased by 7% wit hthe replacement ratio of DCLs increased from 20% to 40%, the slope of this section was about 4.6, and the ultimate bearing capacity of slender columns decreased by 3% with the replacement ratio of DCLs increased from 40% to 60%, and the slope of this section was about 1.2. Through comparative analysis, the following basic rules were obtained: the column's bearing capacity slightly decreased with the increased of DCLs replacement rate.

The reason why the DCLs reduced the bearing capacity was that when concrete was poured, because of the small cross-sectional area of the steel tube, there were voids between the DCLs and the steel tube in the process of casting, the concrete was not as dense as expected. In addition, the DCLs were placed unevenly, which reduced the bearing capacity compared with the specimens without DCLs.

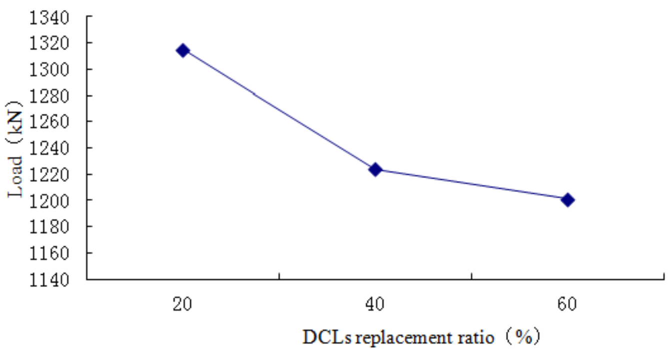

Fig.3. Relationship between DCLs replacement ratio and bearing capacity of specimens

3. Conclusion

The mechanical behavior of CFST filled with DCLs under axial compression was presented. The following conclusions are drawn from the test results:

(1) The influence of slenderness ratio, D / t ratio and DCLs replacement ratio on ultimate bearing capacity and sensitivity of specimens were analyzed by orthogonal test results. The slenderness ratio was the most sensitive factor on the bearing capacity of slender CFST columns, followed by D / t ratio, and the smallest was DCLs replacement ratio.

(2) The bearing capacity decreased by 12% with slenderness ratio increased from 55 to 60,

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the bearing capacity increased by 7% with D / t ratio increased from 8% to 11%, , and the effect was not obvious. The bearing capacity decreased by 7% with DCLs replacement ratio increased from 20% to 40%, , and the effect was not obvious. Through the orthogonal test, the influence of various parameters on the bearing capacity was analyzed. The column bearing capacity slightly decreased with the increased of DCLs replacement rate. The column bearing capacity increased with the increased of D / t ratio. The column bearing capacity decreased with the increased of slenderness ratio.

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