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Research Article

Influence of Height - diameter Ratio on Bearing Capacity of GFRP - Steel Double - tube Concrete Column

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Abstract: In this paper, ANSYS finite element software is used to analyze the finite element analysis of four different members with different height-diameter ratio. The influence of height ratio on the ultimate bearing capacity of GFRP-double concrete-filled steel tubular columns is investigated. The results show that the ultimate bearing capacity of the specimen decreases with the increase of slenderness ratio, and the variation range of bearing capacity is different in different slenderness interval.
Keywords: GFRP pipe - concrete - steel pipe combination column; Height - diameter Ratio; Axial compression; Ultimate bearing capacity.

INTRODUCTION

With the research and development of FRP tube structure, in recent years, Prof. Teng Jinguang of Hong Kong Polytechnic University proposed a new type of composite structure composed of FRP outer tube, steel inner tube and concrete filled with two pipes - (FRP Tube-Concrete-Steel Double-Skin Tubular Column, referred to as DSTC), this structure has both good corrosion resistance and seismic performance, and easy to construction. The restraint efficiency of DSTC on interlayer sandwich concrete is basically the same as that of FRP-confined concrete solid pillar, so that the amount of concrete is reduced. At the same time, it satisfies the bearing capacity and durability demand, and it is an ideal new type Combination structure. Therefore, once raised, it has been widely concerned by scholars at home and abroad. GFRP pipe - concrete - steel pipe combination column has not been applied in civil engineering, although it sets a lot of advantages in one, but its theoretical research is not mature enough. In this paper, the cross-section of the component is designed. Based on the experimental study, the finite element software ANSYS is used to analyze the influence of the height-diameter ratio on the mechanical properties of the GFRP pipe-concrete-steel pipe combination. What of this can also provide reference for other engineering design.

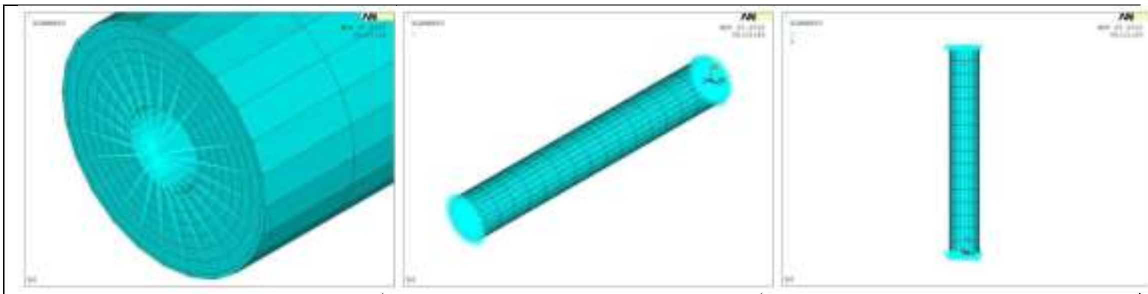
Establishment and Verification of Numerical Simulation Model

Material constitutive model

GFRP material is ideal linear elastic material, only the tensile stress in the fiber direction is considered in the force analysis, the remaining parameters are not considered. The stress-strain relationship of concrete under uniaxial compression is given by "normative" [5]. The constitutive model of steel pipe adopts double straight line model.

ANSYS model establishment

In the ANSYS simulation software, the constitutive model of the FRP unit is selected by the bilinear follow-up model (BKIN), and the solid-state model of the FRP element is selected as the solid 45 solid element. The constitutive relation model of concrete element is selected by multi - linear isotropic strengthening model (MISO), and the constitutive relation model of steel pipe unit is chosen to be the same constitutive relation as FRP unit. The established finite element model is a separate model, regardless of the slip between the materials. Considering the actual test situation, the GFRP pipe is prevented from being pressed by placing a thicker steel plate near the top of the column and the bottom of the column. The simulation test is done by adding the rigid unit MPC184 at the top of the column to connect the bearing face to the rigid unit forming a rigid rod and applying a concentrated force on the rigid element, acting on the node by force transmission. As shown in Figure 1:



(a) Rigid unit	(b) Specimen constraints	(c) Apply the load

Fig-1: Apply constraints and loads

In order to ensure that the model simulation results are similar to the results of the simulation, and to ensure that the simulation results are consistent with the actual situation, the simulation need to use the principle of assumption: between concrete and steel, ignoring the relative slip effect, assuming that concrete and steel is the deformation between the coordination of. For the GFRP pipe and concrete, only consider the assumption that the two materials between the close contact, force co-deformation. In addition, when the GFRP pipe reaches its circumferential tensile strength or the steel pipe reaches its yield strength, it is considered that the specimen is broken and the calculation is terminated.

Numerical simulation model validation

There are few experiments on the mechanical properties of GFRP pipe-concrete-tube combination long columns. Therefore, it is impossible to extract the results that can be used as reference. Therefore, we can imitate the method in [6] and by reducing the specimen height ratio, we can establish the model by reference size of the specimen used for the test in [7]. The simulation results are compared with those of the literature [7] to verify the accuracy of the numerical simulation model established by the simulation experiment. The simulation results that compared with the experimental data are show below.

Table-1: Comparison of finite element and ultimate ultimate bearing capacity

Specimen number	Document bearing capacity（kN）	This paper analog value（kN）	Error(%)
I-C30-0.48-450-4.5	1511	1375	9.8
I-C30-0.48-600-4.8	1948	1733	12.4
I-C30-0.48-750-4.0	2940	2722	8.1

It can be seen from the data in the table that the finite element model established by the simulation test can not completely represent the actual situation, but the comparison is relatively small and generally less than 15% in comparison with the test results. Therefore, the finite element model established by the simulation experiment has high accuracy.

Specimen design and simulation

Simulation test pieces design

In order to study the mechanical properties of GFRP-concrete-steel pipe composite columns with different height-diameter ratios, the design of A1, A2, A3 and A4 according to the ratio of height to diameter: 4: 1,5: 1,6: 1,7: 1Four sets of test pieces. The elastic modulus of the steel used in the simulation test is 2.06 × 105MPa, and its yield strength is 335Mpa , the flexural modulus of GFRP is 2.2 × 104Mpa, the circumferential tensile strength is 430Mpa, the elastic modulus of concrete is 3.00 × 104Mpa, and the compressive strength is 14.3 Mpa. Design of the specimen meet the geometric similarity, that is, materials are used C30 concrete, GFRP pipe wall thickness of 4mm, the specific parameters are shown in Table 2.

Table-2: Design parameters for different specimen sizes

Numbering	b×h(mm)	Steel model	Thickness of steel pipe（mm）	Concrete grade	Height - diameter Ratio	GFRP wall thickness（mm）	Hollow rate
A1	200×800	Q335	4	C30	4:1	4	0.4
A2	200×1000	Q335	4	C30	5:1	4	0.4
A3	200×1200	Q335	4	C30	6:1	4	0.4
A4	200×1400	Q335	4	C30	7:1	4	0.4

The difference of the mechanical properties between the specimens under different height-to-diameter ratios was studied by controlling the concrete strength grade, the thickness of the steel pipe, the wall thickness of the GFRP pipe, the hollow factor and so on. By analyzing the ultimate bearing capacity and ultimate load - displacement curve of the comparative specimen, the influence of the ratio of height to diameter on the mechanical properties of the specimen is obtained.

Comparison of bearing capacity

The ultimate bearing capacity of group A is shown in Table 3. Among them, the specimen length ratio calculation is shown below.

$$i = \sqrt{I/A} = \sqrt{\frac{\pi(D^4 - d^4)}{64} / \frac{\pi(D^2 - d^2)}{4}} = \frac{1}{4}\sqrt{D^2 + d^2} \quad (2\text{-}1)$$

$$l_0 = l \quad (2\text{-}2)$$

$$\lambda = l_0 / i \quad (2\text{-}3)$$

Table-3: Group A specimen ultimate bearing capacity

编号	试件长度（mm）	长细比	空心率	砼等级	钢管厚度（mm）	GFRP壁厚（mm）	极限承载力N(kN)
A1	800	14.8	0.4	C30	4	4	1580.7
A2	1000	18.5	0.4	C30	4	4	1453.5
A3	1200	22.2	0.4	C30	4	4	1362.7
A4	1400	26.1	0.4	C30	4	4	1290

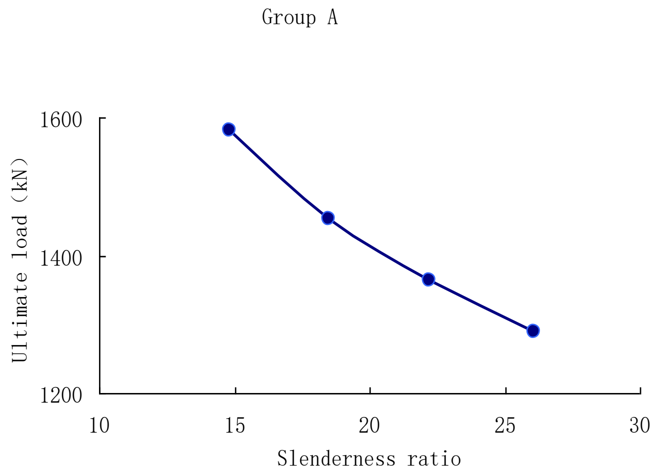


Fig-2: A group slender ratio - limit load curve

It can be seen from Table 3 and Figure 2 that the ultimate bearing capacity of the specimen in group A decreases with the increase of slenderness ratio, and the variation range of bearing capacity varies greatly in different slenderness interval The When the slenderness ratio is in the range of 14.8 ~ 18.5, the aspect ratio of A1 is 14.8, the ultimate bearing capacity is 1580.7kN; the aspect ratio of A2 is 18.5, the ultimate bearing capacity is 1453.5kN, the bearing capacity of A2 and A1 The decrease was 8.8%. When the slenderness ratio is in the range of 18.5 ~ 22.2, the aspect ratio of the specimen is further increased, the slenderness ratio of A3 is 22.2, the ultimate bearing capacity is 1362.7 kN, and the ultimate bearing capacity is 6.7% lower than that of A2. When the slenderness ratio is in the range of 22.2 ~ 26.1, the aspect ratio of the specimen is further increased, the aspect ratio of A4 is 26.1,the ultimate bearing capacity is 1290kN, and the ultimate bearing capacity is 5.6% lower than that of A3. It is shown that the ultimate bearing capacity of the specimen decreases proportionally with the aspect ratio of the specimen, and the degree of reduction is non-linear relationship with the aspect ratio. This can be seen from Fig. And from the point of view of the decrease in bearing capacity, A2 and A1 compared to the ultimate bearing capacity decreased by 8.8%, A3 and A2 decreased by

6.7% compared to A4 and A3 decreased by 5.6%, which can be seen, with the The ultimate bearing capacity of the specimen is gradually reduced, but the degree of reduction is slightly reduced, and the difference is not much worse. When the slenderness ratio of the composite column is less than or equal to 14, the stability coefficient is 1, that is to say, the composite column is the axial compression stub in the traditional sense, and the failure mode of the component is material failure.

CONCLUSION

According to the finite element analysis, it can be seen that with the increase of the aspect ratio of the specimen, the ultimate bearing capacity of the specimen decreases proportionally and the degree of reduction decreases with the aspect ratio. When the slenderness ratio increases, the ultimate bearing capacity decreases with the change of the slenderness ratio. The larger the slenderness ratio is, the lower the ultimate bearing capacity of the specimen is. The ultimate bearing capacity calculated by the simulation test is smaller than that of the short section with the same size. , The specimen occurred are destabilizing damage, rather than material damage.

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