

Research on the Influence of Size Effect for the mechanical Performance of GFRP tube concrete steel tube composite column under axial compression

Li Wen, Wang Tong, Na Yu

School of Civil Engineering and Architecture, Northeast Petroleum University, Daqing, Heilongjiang 163000, China

E-mail: 997843450@qq.com

Abstract. FRP tube-concrete-steel tube composite column (DSTC) was a new type of composite structures. The column consists of FRP outer tube and steel tube and concrete. Concrete was filled between FRP outer tube and steel tube. This column has the character of light and high strength and corrosion resistance. In this paper, properties of DSTC axial compression were studied in depth. The properties were studied by two groups DSTC short columns under axial compression performance experiment. The different size of DSTC short columns was importantly considered. According to results of the experiment, we can conclude that with the size of the column increases the ability of it to resist deformation drops. On the other hand, the size effect influences on properties of different concrete strength DSTC was different. The influence of size effect on high concrete strength was less than that of low concrete.

1. Introduction

Since 1940s, foreign scholars have begun to study various aspects of FRP composite columns. However, in these research, the mechanical properties of FRP reinforced concrete columns were mostly studied. As a new type of structure, DSTC has many advantages. But theoretical research of DSTC is still immature. Meanwhile, there is no corresponding specification for it. So the application of DSTC to civil engineering was limited by these factors. Hence, it is of great theoretical and engineering significance to study its mechanical properties.

The influence of size effect on the mechanical properties of DSTC under axial compression was mainly researched in this paper. The mechanical properties of a material vary with size was called size effect. Because of the destabilizing effects of size effect on the engineering structure, it is of great significance to study it.

2. Experimental situation

2.1 material properties

The steel tubes used in this paper are hot-rolled seamless steel tubes, steel elastic modulus $E=200\text{GPa}$, yield strength $f_y=235\text{MPa}$. In order to meet the requirements of the experiment, The steel pipe is cut into the same height as the GFRP tube in the experiment.

In this paper, the GFRP tube material was used in the experiment. Eight pipes of the GFRP were purchased. They are different length and different diameter. Parameters of tubes were provided by the manufacturer.



Combined with the needs of the experiment, meanwhile, taking into account the actual effect of the experiment, two kinds of common strength grade concrete (C30 and C40) were selected in this experiment.

2.2 design and manufacture of test pieces

DSTC parameters of the specimens are shown in table 1-2. The ratio of hollow is the ratio of the outer diameter of the GFRP pipe to the inner diameter of steel pipe.

Table 1. Concrete mix ratio.

Concrete strength grade	Concrete mix proportion			
	water(kg/m ³)	cement(kg/m ³)	sand(kg/m ³)	stone(kg/m ³)
C30	175	461	512	1252
C40	205	500	593	1152

Table 2. Component parameter design.

sample number	height diameter ratio	hollow ratio	column height	concrete strength grade	GFRP tube wall thickness	GFRP tube diameter
C30-1	3:1	0.46	300mm	C30	4.1mm	100mm
C30-2	3:1	0.48	450mm	C30	4.5mm	150mm
C30-3	3:1	0.50	600mm	C30	4.8mm	200mm
C30-4	3:1	0.46	750mm	C30	4.0mm	250mm
C40-1	3:1	0.46	300mm	C40	4.1mm	100mm
C40-2	3:1	0.48	450mm	C40	4.5mm	150mm
C40-3	3:1	0.50	600mm	C40	4.8mm	200mm
C40-4	3:1	0.46	750mm	C40	4.0mm	250mm



Figure 1. concrete mixing and casting

The production process of DSTC composite column as follows:

1, the internal steel pipe processing

The steel pipe was machined by sand wheel. Two ends of the steel pipe were parallel to each other and perpendicular to the axis.

2, the steel pipe internal strain chip paste

In order to observe the stress of steel tube and GFRP tube in the loading process, four circumferential and axial strain gauges are installed on the outer wall of the steel tube and the FRP tube. Because of the tube roughness surface, the steel pipe is firstly burnished by the grinder, and then polished with sandpaper and fine sandpaper grinding, grinding after wipe with acetone, after these four steps, and finally to paste the strain gauge; between the steel pipe and GFRP pipe should be filled with concrete, the strain gauge on the pipe end of the internal, after pasting strain gauge is completed and welding wire, the external use of AB glue to prevent strain moisture affect the data accuracy. After applying AB glue protection, the resistance of the corresponding chip is needed to be measured in order to prevent the corresponding chip from being damaged, and all the wires connected with the strain gauges on the steel tube are led out from the groove reserved in the top end plate.

3, concentric positioning

The position of the cross section of the steel pipe and the external GFRP pipe must be concentric circle. The following methods are used to locate the GFRP pipe and steel pipe. The position of the steel pipe is arranged on the bottom end plate, then the Steel nail is fixed around the steel pipe, and the position of the GFRP pipe is set out according to the distance between the GFRP tube and steel pipe.

4, pouring concrete

Pouring concrete is mainly divided into the following steps: according to the ratio of sand, gravel, cement, water to take the amount of concrete mixing; concrete pouring; vibrating rod vibration, the top mortar leveling.

2.3 measuring points arrangement

The measuring points are arranged in the middle, upper and lower parts of the tube body, the GFRP pipe body is divided into four equal parts, and 4 measuring points are arranged along the axial direction and the circumferential direction of the 3 dividing lines, and a total of 24 measuring points are arranged; in order to facilitate the subsequent analysis of the results of the analysis convenience, the measurement of the cross section of the section 1-1, section 2-2, section 3-3 instead of the following is not to repeat.

The arrangement of measuring point is shown in Figure 2, figure (a), H represents the direction of the ring, Z represents the longitudinal, figure 2 (b) for the measurement of the layout of the elevation.

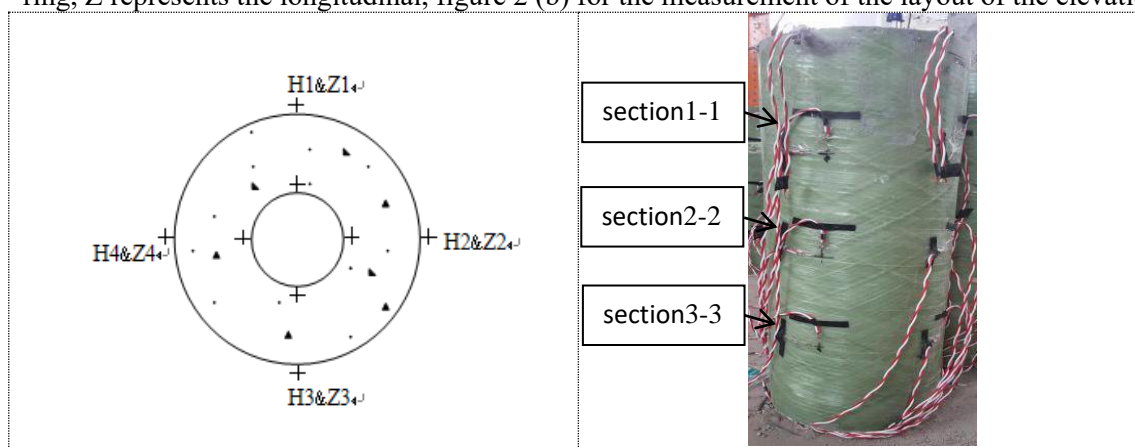


Figure 2. arrangement of measuring points

2.4 measurement arrangement

When the specimen is compressed, in order to test can produce the maximum axial and circumferential deformation, displacement generated for test of axial compression in the specimen is arranged on the dial indicator, two specimens are placed at the bottom of the specimen to determine the axial

displacement, two specimens were placed in the middle of the specimen to determine the circumferential displacement.

For the data collection of strain gauges in the test piece, the static strain data measuring instrument are used to carry out the data acquisition instrument. The data acquisition instrument is DH3818 static resistance strain gauge.

The strain gauge connecting terminal is connected with the collector wire, and the sheet of temperature compensation is connected to conduct the experiment, in the experiment, the value of the strain gauge can be collected in real time by the measuring instrument.

2.5 experimental loading

Loading equipment for YAW-5000 microcomputer control electro-hydraulic servo pressure testing machine, the maximum range of the test machine is 5000kN. According to the estimated value of 20% load, each load is about 90s, and record the test data, when the specimen failure, the data was over, then the experiment was stopped.

3 .test analysis

3.1 test phenomenon

In the experiment, C30-1 is taken as an example. In the initial stage of the experiment, the specimen is preloading , and the pre load value is 1/10, which is 63.3kN. At the same time, the plate and the test machine are combined with the specimen. When the load is stable, start to load formally .In loading process, when loaded to 63.3kN, 126.6kN, 189.9kN, 253.2kN and 316.5kN, and on the occurrence of specimens observed phenomenon and strain resistance and a dial indicator, strain and displacement of steady growth, pressure testing machine display load growth rate stable, no significant fluctuations, indicates that the specimen in the normal work state. When loaded to 379.8kN, the specimen appeared slight noise, steel No. 1 strain gauge disappeared, No. 7 strain 1-1 reading disappears; Loaded to 569kN, the specimen at the load when the instability, the specimen appeared large noise, and in the observation of the specimen was found on the FRP pipe has a slight white edge. Loading to 601kN, concrete slight drop phenomenon, but the duration is longer, the load curve of the load pressure testing machine collected from high to low final stable steel No. 5 strain gauge readings disappeared, the measured strain readings have a great change on each strain resistance box. After the 601kN has finished reading, continue loading until the specimen is damaged. Finally, the failure load of the specimen is measured as 626kN.

The mode of failure of the specimen is the tensile failure of the upper part of the FRP tube, the failure of the concrete is crushed, and the specimen is loaded and destroyed as shown in figure 3.

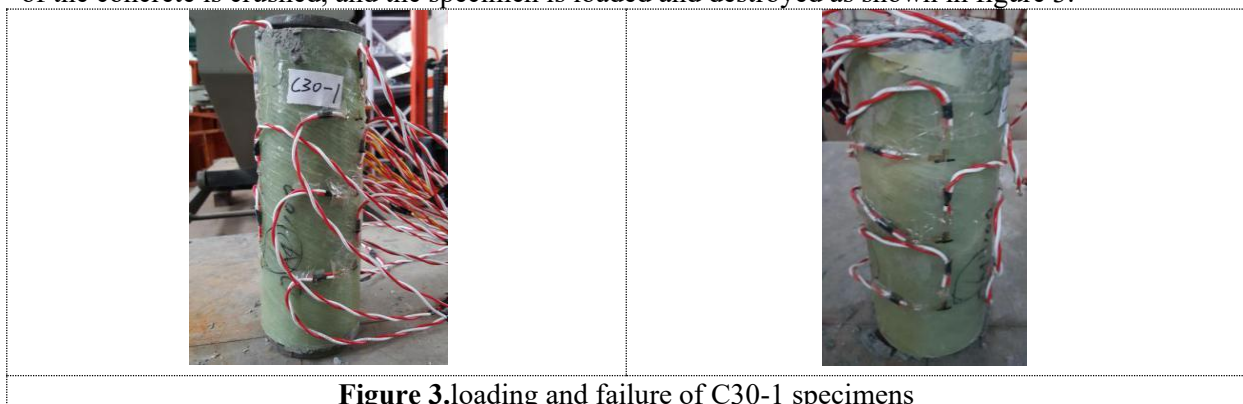
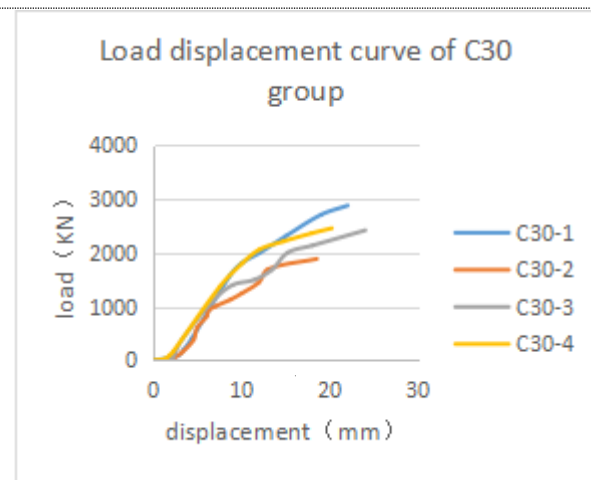
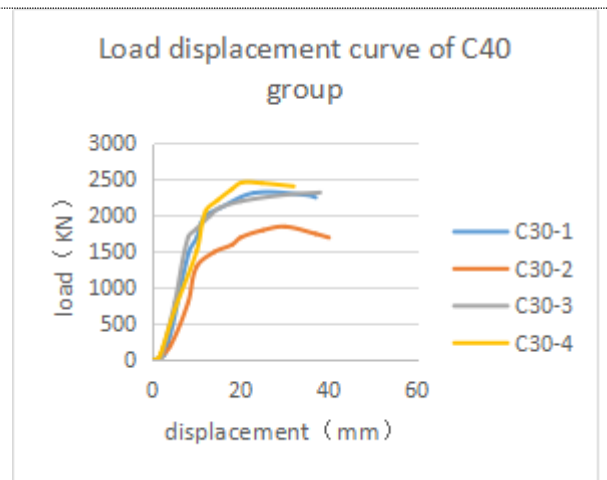


Figure 3.loading and failure of C30-1 specimens

3.2 load displacement curve analysis

**Figure 4.** load displacement curve of C30 group**Figure 5.** load displacement curve of C40 group

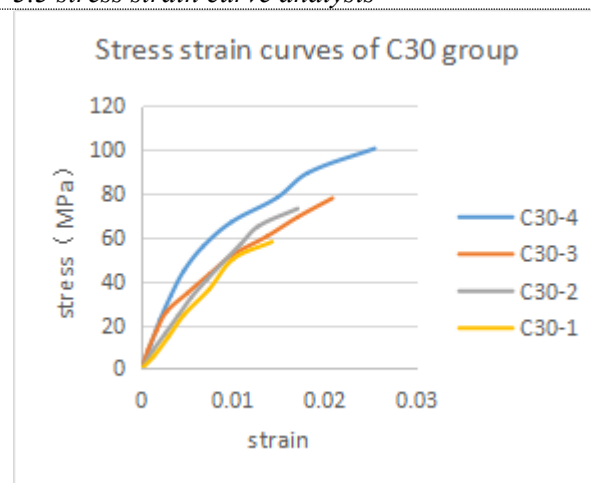
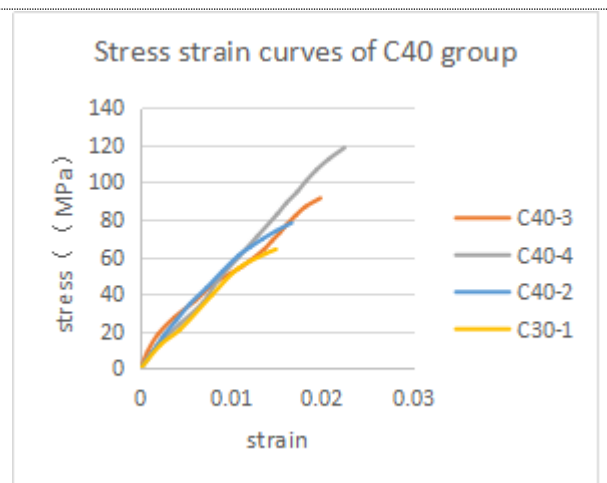
Through the load displacement curve of 8 DSTC short columns, we can see that each specimen in the early stage has a certain period of adjustment. The adjustment period after GFRP tube concrete filled in steel tube composite column in the axial compression process. The process can be approximately divided into the following three stages:

1, the elastic stage: when GFRP tube-steel-concrete composite columns in this phase, load displacement curve is a straight line of slope. It shows that the GFRP tube, concrete and steel pipe among the three kinds of materials with good bonding properties. It can work very well together and bear the axial load. In this stage, concrete and steel tube bear a large part of the load. The GFRP tube has little effect on the core concrete. The specimen's appearance has no obvious change.

2, the elastic-plastic stage: when the load applied to a certain extent, load displacement curve showed irregular curve. GFRP tube and concrete and steel pipe can still work together at this stage. But the ability to work effectively with respect to the elastic stage has decreased significantly.

3, strengthening phase: When GFRP tube-concrete-steel tube composite column in this phase, load displacement curve is linear. But the slope is small, during the stage of strengthening, deformation is mainly due to the continuous development of the plastic deformation of the component, so the displacement ratio in the elastic stage of the displacement many, the stiffness of the composite short columns is decreased, and the GFRP tube plays an important role in the binding of the concrete.

3.3 stress strain curve analysis

**Figure 6.** C30 stress strain curve**Figure 7.** C40 stress strain curve

From the figure 6-7, it can be seen intuitively that there are some differences between the curves of DSTC specimens. From the trend of the curve, the size effect between the specimen and the second specimen is obvious. Compared with the C30 group, the trend of growth the curve of the C40 group is more convergent, the difference between the curves is smaller, which means that the influence of the specimen size effect is weaker.

4. conclusion

Based on the geometric similarity, this paper studied the 8 DSTC axial compressive test. The data extracted and the load strain curve and load displacement curve and stress-strain curve were plotted, the conclusions are as follows:

1, through the load displacement curve of 8 DSTC short columns, we can see that each specimen in the early stage has a certain period of adjustment. The adjustment period after GFRP tube-concrete-steel tube composite column in the axial compression process can be approximately divided into three stages as follows: elastic stage elastic-plastic stage and strengthening stage.

2, from the stress-strain curve, compared with the C30 group, the trend according to the stress-strain curve, compared with the C30 group, the trend of the curve of the C40 group is more convergent. The difference between the curves is smaller, which shows that the influence of the specimen size effect is weak of the curve of the C40 group is more convergent, and the difference between the curves is smaller, which shows that the influence of the specimen size effect is weak.

References

- [1] Teng,J.G.And Lam,L.Behavior and modeling of fiber reinforced polymer-confined Concrete[J].Journal of Structural Engineering, 2004, 130(11): 1713~1723.
- [2] Lorenzis,D.L, and Tepfers, R.Comparative study of models on confinement of concrete cylinders with fiber-reinforced polymer composites[J].Journal of Composites for Construction, 2003, 7(3):219~237.
- [3] Green M. F, Bisby L A, Fam A.Z,et al.FRP confined concrete columns:behavior under extreme conditions[J].Cement and Concrete Composites,2006, 28(10):928-937.
- [4] TengJ G, Yu T,Wong Y L, et al. Hybrid FRP-concrete-steel tubular columns: Concept and behavior[J].Construction and Building Materials.2007, 21(4): 846-854.
- [5] Tao Zhong, Gao Xian, et al.Stress strain relationship of FRP confined concrete[J].Engineering mechanics,2005,22(4): 187-195.
- [6] Qian Jin, Liu Mingxue,FRP- concrete steel double skin tubular long columns under axial compression test[J].Concrete,2006, (9):31-34.
- [7] Wang Qingxiang, Ruan Bingfeng et al.Experimental study on axial compressive behavior of reinforced concrete short columns with GFRP casing[J].Journal of building structures, 2009,30(6):123-127.
- [8] Wu Ping, Yu Feng,Study on stress-strain relationship of FRP confined concrete filled steel tubular columns[J].Building structure, 2013,43 (8): 90-91.