Mechanical properties of GFRP tube confined recycled concrete under axial compression

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Abstract. This article outlines the recycled aggregate replacement rate and thick-diameter rate of GFRP tube confined in recycled concrete, which has an important impact on the material's compressive strength. Overall, under the same conditions of using recycled concrete, the bearing capacity of short concrete columns can be improved by using broader GFRP tubes. There is a four-fold increase in the bearing capacity of short concrete columns compared to the short column without the restriction of a GFRP tube. The bearing capacity of a short column crafted by recycled coarse aggregate is much lower (about 30%). than those made by common concrete column Additionally, the bearing capacity of short columns made by recycled fine aggregates is also lower than those made by common concrete (approximately 20%). Finally, we find that there is no significant difference between experimental and theoretical data.

1. Introduction

GFRP (short glass fiber reinforced plastic) is characterized by having a high strength, strong corrosion resistance, and thermal expansion coefficient of concrete material; its winding mold made of GFRP tube at a certain angle, and pouring concrete in it can form the GFRP pipe concrete column [1]. So, the GFRP tube can reduce the influence of environment on the concrete, improving the durability of the structure, but also greatly improves the carrying capacity of the concrete column. Also, it can be applied as a template, and pouring concrete in concrete pouring is completed. Meanwhile, concrete is the modern civil engineering material, and it is difficult for people to handle a social problem such as the waste of it. Recycled concrete can easily solve the current problem, and concrete can be used responsibly again. As a result of these arguments, recycled concrete has become more popular in modern civil engineering [2].

2. The experiment

2.1. Specimen preparation

This study was conducted by a30 GFRP tube recycled concrete short column test; the specimen diameter is at 150 mm, height is 300 mm, and short columns are made from ordinary Portland cement, C32.5. GFRP tube is provided by Shanghai Ning Trading Company, while recycled concrete material is crushed by the test of C25 concrete beam, after crushing screening to the experimenter. The

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thickness of the GFRP tube in the coarse aggregate replacement ratio and the fine aggregate content is 3 mm, and the thickness diameter ratio on the recycled concrete axial compression performance is recorded at 3 mm, 6 mm, 9 mm respectively. The data from this study can be seen in table 1.

Table 1. Test parameters.

Specimen number	Wall thickness (mm)	Replace rate of recycled coarse aggregate Ñ (%)	Replace rate of recycled fine aggregate P (%)	f_c (Mpa)
1	3	0	100	76.40
2	3	50	100	61.15
3	3	100	100	52.6
4	3	100	0	66.1
5	3	100	50	58.9
6	3	100	100	54.2
7	0	100	100	12.9
8	3	100	100	53.7
9	6	100	100	70.4
10	9	100	100	118.1

The specimen of GFRP tube and the short concrete column height are the same; in the GFRP tube strain gauge and tile, according to the figure 1, below.

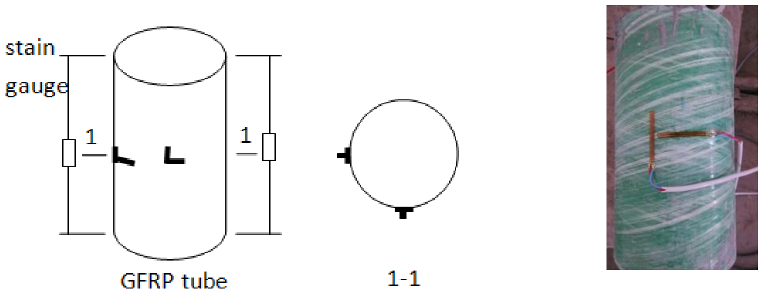

Figure 1. Strain gauge arrangement.

2.2. Test methods

In the middle of the test piece and GFRP pipeline flank placed on horizontal and vertical strain gauges then connect the static resistance strain gauges, measure test concrete short column in the process of each phase of the transverse and longitudinal strain. Specimens were loaded on 300 KN pressure machine, and the loading speed is recorded at 0.5 Mpa/s slow continuous loading, until the specimen damaged.

Specimen loaded figure as showed in figure 2.

Figure 2. The loading diagram and experimental process diagram.

3. The thickness-diameter ratio of GFRP tube on the axial compression bearing capacity of recycled concrete

The thickness to diameter ratio on the influence of the axial compression bearing capacity of recycled concrete short column is reflected in the ultimate compressive strength of GFRP tube and GFRP tube binding of recycled concrete short columns.

According to the loading characteristics of the GFRP tube's recycled concrete short column, there are six basic assumptions:

- The radial restraint stress of the recycled concrete is evenly distributed;
- Regardless of the slippage between recycled concrete and GFRP tube;
- Concrete is non-linear elastic isotropic material;
- By the radial stress of the GFRP tube is far less than its axial and hoop stress, it can be ignored. Consider with thin GFRP tube [3];
- Consider the GFRP pipe is thin, we think axial stress and hoop stress is evenly distributed along the thickness direction;
- Considering the short column is shorter, we do not consider the stability coefficient.

By the force balance of the GFRP tube recycled concrete column analysis reveals the vertical axis pressure by the core of recycled concrete compression and the compression of GFRP tube share to occur at the same time because of the short column inferior height, therefore we don't consider the effect of the stability coefficient, axial compression bearing capacity of GFRP tube recycled concrete column by the static equilibrium condition analysis, the design equation of the axial compressive strength of recycled concrete with the constraint, the compressive strength of GFRP tube, and GFRP tube for the core of the recycled concrete constraint.

Therefore, we apply the equation:

$$N_{\mathrm{u}} = N_0 = f_{cc}A_c + f_{fy}A_f \tag{1}$$

In the equation, N_0 is the core of the GFRP tube recycled concrete ring to restraint stress, A_c and A_f is the recycled concrete, and the cross sectional area of the GFRP tube; f_{fy} is the compressive strength of GFRP tube; f_{cc} is restrained by GFRP tube of the compressive strength of recycled concrete.

f_{cc} derivation equation [3]:

$$f_{\mathrm{cc}} = f_{ck} + \zeta_{cf} f_{fy} \tag{2}$$

In the equation, f_{cc} is constrained axial compressive strength of recycled concrete, f_{ck} is the ultimate compressive strength of GFRP tube, and ζ_{cf} is the GFRP pipe ring enhancement coefficient to constraints.

Enhancement coefficient of GFRP pipe ring [4] to the constraints ζ_{cf}:

$$\zeta_{cf} = \frac{f_{hl}}{f_{ck}} \tag{3}$$

$$f_{hl} = \frac{2 f_{hf} t}{d} \tag{4}$$

In the equation, f_{hl} is the core of GFRP tube's recycled concrete ring to restraint stress. f_{hf} is the GFRP materials used to attain the tensile strength, while t and d are the GFRP tube wall thickness and diameter, respectively.

The ultimate compressive strength of GFRP tube is represented by f_{fy} [4]:

$$f_{fy} = \frac{(1+\mu_f \nu_{f\theta_x})E_f \varepsilon_{\theta_u}}{(1-\nu_{f\theta_x}\nu_f)\mu_f} \tag{5}$$

In the equation: $\nu_{f\theta_x}$ is ring of GFRP tube to the Poisson ratio, ν_f is GFRP tube axial poisson's ratio, μ_f is GFRP tube axial compression poisson's ratio of concrete reinforcement phase, ε_{θ_u} is GFRP tube to tensile strain limit cycles, E_f is the GFRP tube axial compressive modulus of elasticity.

Upon examination, we utilize the following equation: $N_u = f_{cc}A_c + f_{fy}A_f$.

The theoretical equation for calculating the bearing capacity calculation of the theoretical equation is consistent with the experimental data. Specific data are shown in table 2.

Table 2. Comparison table theoretical values and the measured values.

Specimen number	Wall thickness (mm)	f_c (Mpa)	N (Kn)	N_u (Kn)	N_u/N
8	3	53.7	1136.69	1230	1.08
9	6	70.4	1599.51	1575	0.98
10	9	118.1	2086.58	2190	1.04

4. The parameter analysis

During the experiments, we continued the study of the recycled concrete short column GFRP tube's mechanical properties. According to the test data, we analyse the whole loading process of short column, and in analysing we adopt the following basic assumptions [5]:

- There is no relative slip between GFRP and recycled concrete;
- During the process of the stress of the short column, a deformation compatibility condition is met, is=ε_f ; is recycled concrete strain, and GFRP tubes area strain.

We analysed recycled coarse aggregate content, the recycled fine aggregate super test with a testing program, then drew the corresponding strain-time curve chart.

4.1. Coarse aggregate replacement ratio effect on strain - time curve [6]

In the study, we analysed the recycled coarse aggregate content, which was found to be at 0%, 50%, and 100%; three cases of strain - time curve, it can be seen that the ultimate bearing capacity of the short column decreased as the recycled coarse aggregate content increased, but the short column of ultimate compressive strain did not decrease with the rise of recycled coarse aggregate content. However, when the recycled coarse aggregate replacement ratio is 50% (the results were shown in figures 3 and 4), the ultimate tensile strain is a larger aggregate. There is the recycled coarse aggregate and mortar between old and recycled coarse aggregates, which form the relatively weak section of the

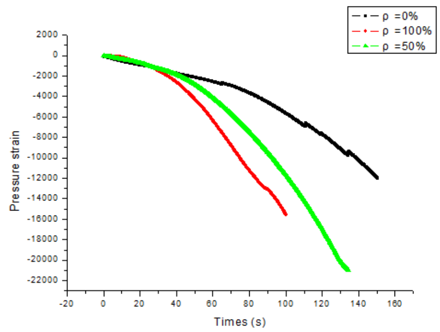

Figure 3. Strain coarse aggregate content - time curve.

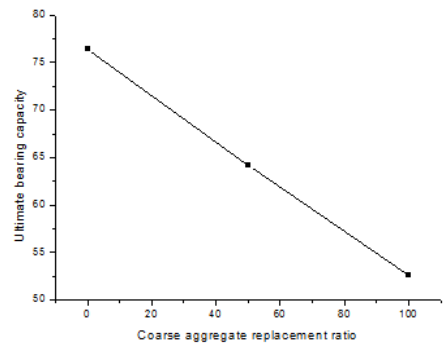

Figure 4. The ultimate bearing capacity in elation to the coarse aggregate content.

transition between the new mortar strains as a result of the increase being too large.

4.2. Fine aggregate replacement ratio effect on strain - time curve

We analyzed the rho recycled fine aggregate, which was found to be at 0%, 50%, 100%, three cases of strain - time curve, it can be seen that the ultimate bearing capacity of the short column decreased with increasing of recycled fine aggregate. When the recycled coarse aggregate replacement ratio is 50％, the overall strain is more significant than the fine aggregate to replace at a rate of 0% and 100% recycled coarse aggregate content (the results were shown in figures 5 and 6). Similarly, the ultimate 50% strain of this group of components is greater than the concrete with the aggregate replacement ratio of recycled concrete.

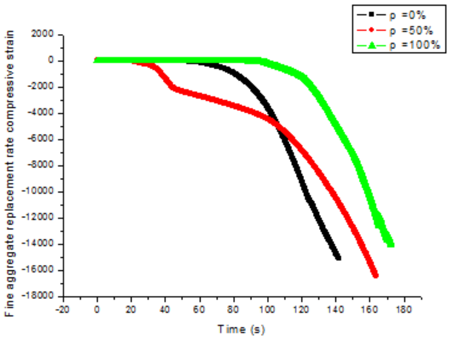

Figure 5. Strain fine aggregate content - time curve.

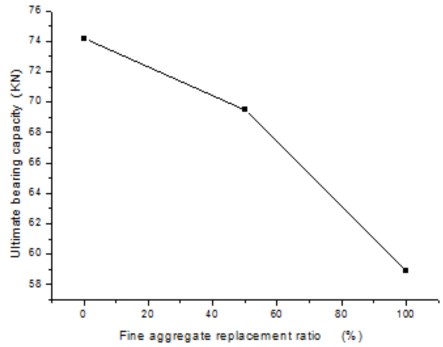

Figure 6. The ultimate bearing capacity in relation to the fine aggregate content.

Based on these results, we can initiate a hypothesis stating that when components both have new and recycled aggregates, new and old concrete of components of the new and old mortar gelation and the development of micro cracks are caused by the results. Therefore, these components' deformation is better than that of concrete with aggregate replacement ratio of recycled concrete.

5. Conclusion

- Based on the influence of GFRP tube recycled concrete short columns, axial compression performance analysis shows that based on GFRP tube recycled concrete short column constraints, recycled concrete short column's axial compression performance can enhanced. Additionally, the thick diameter ratio on the bearing capacity of the axial compression short column has obvious promotional qualities, however due to the limited number of specimens, more tests are needed in order to represent the overall truth.
- The replacement ratio of recycled concrete has a profound effect on short column's axial bearing capacity. Compared with natural coarse aggregates, recycled aggregates contain more old mortar, therefore the strength is lower than a natural coarse aggregate. With the increase of aggregates, the bearing capacity has fallen dramatically; but when the component is contained in the new and old aggregate, the deformation of such components is better than that of concrete with an aggregate replacement ratio of recycled concrete.
- In this experiment, a single source of recycled aggregates, strength grade is C30, the replace rate type is less, however in advanced engineering, the source of the recycled aggregates and their replace rate is more complex. Additionally, the performance is vastly different, so the recycled aggregates still need supplementary study.

Acknowledgments

This work was financially supported by National Nature Science Foundation (51308340), the College Students Scientific and Technological Innovation Programs of Zhejiang Province (2013R426013), and Nation (201310349014)

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