Research progress of steel tube rubber concrete

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Abstract. As a new form of concrete-filled steel tube, this paper focuses on the experimental research of the axial pressure performance of steel tube rubber concrete members in recent years, explains and summarizes related research results of hysteretic behaviors and seismic performance. Then further work to be carried out is listed. Finally, the possibility and development trend of its application in practical engineering is discussed.

1. Introduction

With the acceleration of urbanization construction, the consumption of building materials has increased significantly. The environmental pollution and resource waste caused by over-exploitation of natural aggregates have received more and more attention. Based on traditional ordinary steel tube concrete structures, some new types of concrete-filled steel tube structures have been investigated and applied at home and abroad. The rubber powder from the broken tires is added to the concrete in a definite volume, and the rubber concrete is poured into the steel pipe to form a new type of steel pipe rubber concrete composite member.

Owing to the presence of rubber particles in the interior of the concrete, this tiny group of stretchable particles will constrain the microscopic cracks in the concrete. The compression performance and bending strength of concrete decrease sharply with the increase of rubber content [1]. This is a major reason for limiting the application of rubber concrete in civil engineering. However, rubber concrete effectively prevents its radial deformation ability under the constraints of steel pipes, so that it is located in a relatively stable three-way compression state [2]. At the same time, core rubber concrete can reduce the local buckling sensitivity of the steel tube.

The application of steel tube rubber concrete in engineering practice can recycle used rubber, minimize the amount of natural aggregate, and at the same time improve the bearing capacity and seismic performance of concrete-filled steel tubular members utilizing the joint force of steel pipe and rubber concrete, and then waste rubber. The use of building materials provides an effective way.

2. Research status

Research on steel tube rubber concrete has attracted the attention of scholars at home and abroad. Certain experiments and theoretical research have been conducted. The research on steel tube rubber concrete members started late and has only been more than 20 years old. So far, research on steel-reinforced concrete has been limited to short columns, and most of them have studied axial compression properties. The research parameters are limited to the influence of the type and particle size of the rubber powder on the bearing capacity, and the disclosed limitations are considerable. The current research status is summarized as follows.
2.1. Axial pressure performance

Yang [3] restrained the axial compression tests of 27 specimens of ordinary strength concrete, high strength concrete and rubber modified concrete short column by 9 different materials. The axial compression load of diverse material confined concrete short columns was studied. Under the action of deformation and failure process, the relationship between axial force and longitudinal strain, macroscopic deformation characteristics and failure mode were investigated. The ultimate bearing capacity of these 27 kinds of confining concrete columns is obtained. The influence of different material wrapping on the bearing capacity of confined concrete columns is analyzed. The advantages and disadvantages of the performance of these 27 confined concrete columns are compared, and the performance cost analysis is carried out. Engineering applications provide a technical reference.

Liu et al. [4-6] used the parameters of rubber powder volume substitution rate and rubber powder particle size to study the static mechanical properties of square, rectangular and circular steel tube rubber concrete, and explored the failure mode and limit of the specimen. Bearing capacity, stiffness, ductility, etc., and based on the finite element software ABAQUS, the practical calculation formulas for the bearing capacity of the axial compression strength of steel tube rubber concrete short columns are proposed respectively.

Wu [7] designed more than 30 steel pipe rubber concrete short columns with a steel content and rubber content as control parameters (the slenderness ratio was controlled at about 3) and carried out the axial load of the steel tube rubber concrete short columns. The next test studied the failure characteristics of steel-reinforced concrete short columns, the constitutive relationship of core rubber concrete, and the axial compression performance.

Wang [8] through the glass-reinforced concrete short-column test, axial force bearing capacity theory analysis and simulation with finite element software ABAQUS, the alkali-silicic acid expansion reaction on the concrete bearing capacity of glass steel tube concrete the improvement has a beneficial effect. The waste rubber is applied to the concrete-filled steel tube. The steel pipe provides the tightening force for the core concrete, which improves the problem of poor compatibility between the rubber particles and the cement paste. At the same time, due to the good deformation property of the rubber particles, the concrete-filled with the concrete tube performance is improved.

Cha et al. [9] carried out axial compression tests on 15 solid circular steel tube rubber concrete short columns and found that the ferrule action of the steel tube on the core concrete affects the bearing capacity. Depending on the finite element numerical simulation results, the regression is corrected. The unified theoretical calculation formula for the axial bearing capacity of steel tube rubber concrete is preliminaries confirmed that the application of waste rubber to solid steel tube concrete is feasible.

Liang et al. [10-12] completed the axial compression test of 16 steel tube rubber concrete columns. Considering the replacement coefficient of recycled rubber and the particle size of recycled rubber as the various parameters, a static test was carried out. The test shows that the final failure mode of the test piece is damaged by the waist drum oblique shear pressure; the rubber is mixed to increase the ductility of the test piece; with the increase of the rubber replacement rate, the bearing capacity of the rubber concrete column is continuously reduced; Large, steel tube rubber concrete columns have lower bearing capacity.

Duarte et al. [13-14] proposed that when the rubber powder content is 5%, the cycle of the rubber-plastic concrete short column is only reduced by 5%, but the plastic property is improved by 52%, further confirming that the steel-reinforced concrete has better earthquake resistance performance. Besides, the influence of parameters such as section form and steel pipe grade on the mechanical properties of steel-reinforced concrete short columns is also thought to be.

Xu et al. [15] designed 12 steel pipe rubber concrete short column specimens and carried out the axial compression test, further confirming that the increase of the steel content will increase the bearing capacity.

Gao et al. [16] designed four thin-walled square steel tube rubber concrete short columns axial compression test, and found that the rubber content is the same, the smaller the rubber particle size, the
greater the compression performance of rubber concrete. The rubber particles replace the sand with an equal volume of 20%, and the compression performance of the steel tube rubber concrete is greatly increased compared to the reference concrete. The displacement ductility coefficient of the steel tube rubber concrete short column increases due to the incorporation of rubber particles.

2.2. Hysteresis behaviors
Liu et al. [17] used the method of finite element analysis to calculate the load-displacement hysteresis curve of steel-reinforced concrete columns, and systematically analyzed the parameters of the steel tube section and rubber powder substitution rate on the hysteresis curve skeleton line and bearing capacity. The effects of degradation curves and stiffness degradation curve. The results show that the finite element calculation results are in good agreement with the test results, and the steel tube rubber concrete has excellent hysteresis performance.

Li and Song [18] used the ABAQUS concrete plastic damage model to calculate the hysteresis behavior of ordinary CFST columns and steel tube rubber concrete under different slenderness ratio control parameters. The research results show that although the rubber-filled-steel concrete column has good deformation performance, the energy consumption performance of the rubber-filled-steel concrete column is less than that of the ordinary steel-concrete concrete column due to the significant decrease of the bearing capacity.

2.3. Seismic performance
Zhang et al. [19] analyzed the damping ratio and seismic performance of the 4 steel tube rubber concrete columns by controlling the rubber content and the axial compression ratio. The results demonstrate that the damping ratio increases most when the rubber content is 20%. The increase of the damping ratio of the yielding column can effectively improve the seismic safety of the structure.

Xing et al. [20] carried out low-cycle repeated horizontal load tests on 8 round steel tube rubber concrete short columns. In addition to considering the rubber content and axial compression ratio, the design of steel content and slenderness ratio was increased. The increase in the amount, the axial pressure ratio, and the slenderness ratio will reduce the bearing capacity, but the increase in the steel content will increase the bearing capacity.

Gao et al. [21-22] established the finite element model of the steel-reinforced concrete arch bridge to change the rubber content to analyze the model and nonlinear dynamic time history of the arch bridge. It is possible to conclude that the seismic performance of the arch bridge is better when the rubber powder content is 5%.

3. Development trends and discussions
Steel tube rubber concrete retains the series of advantages of the high concrete-bearing capacity of CFST and good ductility of concrete. It has good ductility and seismic performance and has potential application value in engineering applications. However, due to the relatively low level of relevant research at home and abroad, the relevant theory is not mature, and no specific application has been seen in practical engineering. It needs further theoretical analysis and experimental verification. The author believes that further research should be conducted on the following aspects.

3.1. Node problem
One of the key points in the promotion of steel tube rubber concrete members is to study the form of nodes with good mechanical properties, reasonable force transmission, convenient construction material saving. At present, the research theory of nodes is not mature enough. Experimental research lacks systematically. The calculation model of nodes is not clear. A complete set of computational theory and design methods has not yet been formed.

3.2. Fire resistance
Whether steel tube rubber concrete components can maintain good overall performance in the event of
a fire, the fire resistance limit has yet to be further studied. On the one hand, it is necessary to consider the fire resistance of the component itself, and on the other hand, the repair work after the fire is also the focus of research.

3.3. Concrete
When steel tube rubber concrete member is constructed, the rubber concrete is wrapped by the outer steel tube, which increases the difficulty of casting quality control. Therefore, it is necessary to fully consider the strength and compactness of concrete. How to improve the strength of rubber concrete by modification method, so that it can have good ductility and high strength, is also an important issue to promote the application of rubber concrete.

4. Conclusion
In summary, research on steel tube rubber concrete is restricted to short columns, the research on the influence of rubber powder replacement rate and particle size on the test results has limitations, and the research on seismic performance is less involved. However, steel tube rubber concrete provides an effective way for the use of waste rubber in building materials. Applying steel tube rubber concrete to engineering practice can not only solve the characteristics of the insufficient anti-seismic capacity of concrete-filled steel tube but also effectively recycle and utilize waste rubber to minimize the amount of natural aggregate. The application of steel tube rubber concrete has a broad space for development. To meet the requirements of industrialization of modern construction technology, to achieve labor cost savings, reduce the engineering cost, and speed up construction, it requires repeated trials and theoretical verification.

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