Journal of Engineering Research and Reports

Volume 26, Issue 4, Page 85-91, 2024; Article no.JERR.114458
ISSN: 2582-2926

Overview of the Current Research Status of Concrete-Filled Steel Tube

Yang Hao [a*]

[a] School of Civil Engineering and Ttransportation, North China University of Water Resources and Electric Power, Zhengzhou 450011, China.

Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JERR/2024/v26i41116

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/114458

Review Article

Received: 12/01/2024
Accepted: 16/03/2024
Published: 21/03/2024

ABSTRACT

Steel tube concrete refers to a composite structure formed by filling concrete in a steel tube, and the steel tube and its core concrete can jointly bear external loads. The seismic performance of composite structures largely depends on the strength and ductility of the columns. In the structure, columns are the main vertical load-bearing components due to their high strength and good ductility. However, under seismic action, steel tube concrete columns may experience end steel tube wall buckling, and the concrete inside the pipes may be crushed and lose its load-bearing capacity, causing the overall structure to collapse. In order to better utilize the performance of steel tube concrete, this study analyzes the research of scholars and explores the axial compression performance, failure modes, and local buckling effects of different types of concrete filled in steel tubes on the structural performance of steel tube concrete. Therefore, it is particularly important to study the axial compression performance of steel-concrete columns and explore reasonable design methods to delay the local buckling of steel pipes, and accurately evaluate the seismic performance of steel-concrete columns under large earthquake responses.

Keywords: Recycled concrete; CFST; axial compression performance; recycled CFST.

**Corresponding author: Email: 327769402@qq.com;*

1. INTRODUCTION

With the increase of urban population and functional demand, more and more cities are starting to build various types of high-rise and super high-rise buildings. Due to the continuous expansion of town building scale, as shown in Fig. 1, the problem of excessive consumption of resources and construction waste has become increasingly serious. In order to achieve sustainable development of the construction industry, the application of recycled coarse aggregate concrete based on the secondary utilization of waste concrete has emerged. At present, a large amount of research on the compressive performance of recycled coarse aggregate concrete has been carried out both domestically and internationally. The general results indicate that the mechanical properties of recycled coarse aggregate concrete have decreased [1], which to some extent limits the application of recycled concrete in practical engineering. If recycled concrete is added to steel pipes to form recycled steel pipe concrete, it can improve the mechanical properties of concrete.

2. CURRENT RESEARCH STATUS OF RECYCLED CONCRETE

2.1 Development of Recycled Concrete

In the 1950s, countries such as the Soviet Union, Germany, and Japan conducted a series of studies on how to use waste concrete. In order to promote research on the technology of using waste concrete, relevant international conferences were held, and guidelines and regulations were formulated. Due to Japan's unique geographical location and national conditions, research on the feasibility of using recycled concrete was conducted earlier. In the 1980s, Japan released standards for coarse aggregates in recycled concrete [2], gradually improving the treatment measures for waste concrete and increasing its secondary utilization rate. Germany and the United States have conducted extensive experimental research on recycled concrete and have developed relevant specifications to promote its application in practical engineering. The technology of using recycled concrete in highway construction in these two countries is very mature [3,4]. In the 1980s, the Netherlands had already formulated relevant specifications for the preparation of various types of concrete using recycled aggregates, and clearly specified the technical requirements for preparing concrete containing recycled aggregates in the specifications. It was also pointed out that when the content of recycled aggregates was less than 20%, the design method was the same as that of ordinary concrete [5]. In the early 20th century, sustainable development research institutions proposed environmental standards related to recycled aggregates [6], further promoting research on the utilization of waste concrete in various countries, especially developed countries. The style of recycled concrete is shown in Fig. 2.

2.2 The performance of Recycled Concrete

Mandal et al. [7] studied the compressive strength relationship between recycled concrete and ordinary concrete through experiments, and the results showed that the strength of recycled concrete would decrease by about 15%. Yun [8] designed 17 reinforced concrete column components with different replacement rates using the replacement rates of recycled coarse aggregate and recycled fine aggregate as parameters for axial compression testing. The research results showed that all 17 specimens produced had good performance and their ultimate bearing capacity met the allowable values set by the Concrete Association. Yan Chunling et al. [9] studied the influencing factors on the compressive strength of recycled concrete. The results indicate that the first influencing factor on compressive strength is age, the amount of recycled coarse aggregate is the second influencing factor, and finally the water cement ratio. Gao Xu et al. [10] obtained the results of compressive tests on cubic specimens with different replacement rates and different ages. The compressive strength of cubic specimens with the same replacement rate of recycled coarse aggregate increased with age, but the higher the replacement rate, the lower the compressive strength. The experimental results of Tabsh et al. [11] indicate that the loss rate of recycled aggregate is slightly higher than that of natural aggregate, but it does not exceed an acceptable range. The replacement rate of recycled aggregate determines the splitting tensile strength of concrete. In general, the strength of recycled concrete is about 20% lower. Wang Pixiang et al. [12] found through relevant experimental results that adding an appropriate amount of high-efficiency water reducing agent can change the distribution of voids inside the recycled aggregate, and the compressive strength of the prepared recycled concrete will also be correspondingly improved. Juan et al. [13] found through research that recycled aggregates with a mortar content lower than 44% can be used to prepare concrete. Xing Zhenxian and Zhou Yuenong et al conducted experimental research on the basic properties of recycled concrete and found that compared with corresponding ordinary concrete, recycled concrete has lower brittleness, increased toughness, better comprehensive crack resistance, good cohesion and water retention of the mixture, and poor flowability. The workability can be adjusted by using water reducing agents to meet engineering requirements.

3. CURRENT RESEARCH STATUS OF CFST

Steel tube concrete is the process of pouring concrete into steel pipes and compacting them to increase their strength and stiffness, as shown in Fig. 3. Elremaily et al. [14] studied the performance of steel-concrete structures using six circular steel tube specimens. The results indicate that the specimen has good ductility, and due to the constraint of the steel pipe, the concrete strength has been significantly improved. Han Linhai and Zhong Shantong [15] analyzed the relationship between load and deformation of steel-concrete structures under various complex stress conditions through a combination of finite element analysis and experiments. Based on this, they proposed a calculation method for the bearing capacity and stiffness of steel-concrete structures. Li Bin [16] conducted a study on the bearing capacity performance of axially compressed short columns by combining experimental and theoretical analysis. The experimental results are consistent with theoretical calculations. Han [17] conducted extensive research and analysis on the seismic performance of steel-concrete structures in order to investigate their feasibility in practical engineering applications. The structure made of square or circular steel pipes has good seismic performance, and their ductility and stiffness also meet engineering applications. Wang Tiecheng et al. [18] studied the seismic performance of steel tube concrete columns using a finite element model by changing the three parameters of steel content, slenderness ratio, and axial compression ratio. The results indicate that among these three parameter influencing factors, the aspect ratio has the greatest impact on the deformation capacity of steel tube concrete columns; Within a certain range, steel tube concrete columns with high steel content, low aspect ratio, and high axial compression ratio have better energy dissipation capacity. Researcher P K. Gupta et al. [19] conducted experimental and computational studies on the stress performance of 81 circular steel tube concrete columns until failure. The experimental results showed that: (1) in CFT columns that were essentially damaged by local buckling, the confinement effect of the concrete core decreased with the increase of concrete strength; (2) For smaller D/t ratios, a steel pipe provides a good restraining effect on concrete; (3) From the results of the bare tube, it can be observed that as the D/t ratio increases, the bearing capacity of the unit volume of steel pipes gradually decreases. In order to study the elastic-plastic behavior of hinged steel tube concrete metal columns under axial load or eccentricity of approximately one axis, O'Shea and Bridge et al. [20] conducted a series of experiments to investigate the performance of circular thin-walled steel tube concrete with a D/t of 55-200. Experiments were conducted on bare steel pipes, unbonded concrete pipes loaded only with steel sections, filled concrete pipes loaded with both steel and concrete simultaneously, and filled concrete pipes loaded with concrete separately. Compare the obtained bearing strength with the strength calculated according to design standards and specifications. The results indicate that the filling of thin-walled circular steel tube with concrete has little effect on the local buckling strength of the steel tube. In order to obtain the strength of CFST under different loading conditions, O'Shea and Bridge [21] investigated loading conditions including axial loading only on steel, axial loading only on concrete, and simultaneous axial and small eccentric loading on both concrete and steel. All test specimens are relatively short, with an L/D of 3.5 and a D/t between 60 and 220. The compressive strength of the concrete used is 50, 80, and 120 MPa, respectively. Through these experiments, O'Shea and Bridge [22] concluded that the degree of constraint of thin-walled circular steel pipes on the internal concrete depends on the loading conditions. When only axial loading is applied to concrete and thin-walled steel is used as pure circumferential constraint, the constraint effect is the best. They also concluded that European standards can be used for the design of thin-walled steel pipes filled with ultra-high strength concrete when designing bearing capacity calculation formulas. Kilpatrick A [23] also reviewed the applicability of European standards for the design of steel tube concrete columns using high-strength concrete, and compared 146 columns from six different surveys with European standards. The concrete strength of the column is 23~103MPa. The average ratio of measured/predicted column strength is 1.10, with a standard deviation of 0.13.

4. RESEARCH STATUS OF RECYCLED CFST

Mohanraj et al. [24] conducted "experimental studies on the mechanical properties of recycled concrete columns under axial compression using recycled coarse aggregate replacement rate, steel pipe size, shape, and diameter to thickness ratio as the main parameters. Compare the experimental results with the theoretical values of Eurocode 4, Australian Standards, and American Code specifications". The results indicate that the theoretical values in the Eurocode 4 specification are in good agreement with the experimental values, while the theoretical values in the Australian Standards and American Codes specifications are slightly lower than the experimental values. Konno and Sato et al. [25,26] found that "the deformation behavior of recycled steel tube concrete is similar to that of ordinary steel tube concrete by studying the strength and deformation ability of recycled concrete. The results indicate that the Young's modulus of recycled concrete is lower than that of ordinary concrete, which can roughly predict the stiffness of steel pipe recycled concrete and the expansion rate within the elastic-plastic range related to Poisson's ratio". Liu et al. [27] used "a new damage mechanics approach to study steel tube recycled concrete. Research has shown

Fig. 1. Waste concrete

Fig. 2. Recycled concrete

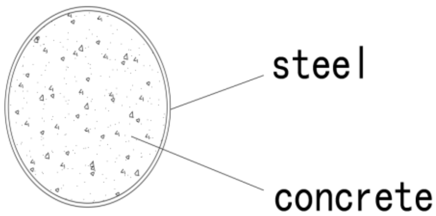

Fig. 3. Cross section diagram of CFST

that the bearing capacity and elastic modulus of recycled steel tube concrete are slightly reduced compared to ordinary steel tube concrete". Yang et al. [28] found "through experimental research that by changing the substitution rate of recycled concrete, the stress-strain curve trend of steel tube recycled concrete did not show a significant change, but the elastic modulus and bearing capacity both decreased slightly". Qiu Changlong [29] conducted "axial compression tests on steel tube recycled concrete specimens. The results show that as the replacement rate of recycled coarse aggregate increases, the slump of the specimens decreases, the water infiltration rate increases, and the compressive strength and tensile strength decrease; Adding expansion agents to recycled concrete can improve its compressive strength". Ibañez C et al. [30] studied "the behavior of axially loaded tubular columns filled with M20 grade concrete and partially substituted concrete. The variable parameters in the study were the aspect ratio (13.27, 16.58, and 19.9), as well as normal M20 grade concrete and partially substituted concrete (quarry dust and concrete fragments)". From the results, it can be seen that an increase in L/D ratio will reduce the bearing capacity of the composite column. Compared with hollow steel columns, CFST columns filled with partially substituted quarry dust and concrete debris achieved composite effect. The bearing capacity of CFST columns increased by 32% compared to hollow pipe columns. Liu YC [31]. Lyu F and others established a three-dimensional finite element (FE) model, which utilizes the RAC model composed of triaxial plastic failure and considers the influence of recycled aggregate replacement rate on the bearing capacity of the model. The finite element analysis results show that the ultimate bearing capacity of RACFST is reduced compared to traditional concrete filled columns, mainly due to the weakening of constraint effect and constraint efficiency. Piquer A specimens were subjected to failure tests at different replacement rates of recycled fine aggregate (FRA) and recycled coarse aggregate (CRA). The experimental results indicate that there is a significant composite effect between FRA and CRA, but the impact of FRA on the blocking effect is not significant. Qihan ShenThe use of FRA greatly reduces the constraint effect of RACFST. Qihan Shen et al. [32] conducted a series of push-pull tests on 56 specimens of recycled steel tube concrete columns (RAC-FST). The sample underwent a series of push tests, including section type, section size, strength of recycled aggregate concrete, substitution rate of recycled coarse aggregate, and interface treatment (i.e. oil coating, polishing). The analysis results indicate that the type and size of cross-section are the two main parameters that affect the bonding strength between steel pipes and recycled aggregate concrete cores. Li Na et al. [33] conducted a comprehensive study on the axial behavior of 39 slender steel fiber recycled aggregate concrete filled steel tube columns (SRACFST). The experimental parameters are slenderness ratio and steel fiber volume. The quality replacement rate of recycled aggregates, the strength grade of concrete, and the diameter to thickness ratio of steel pipes. The results indicate that slender SRACFST columns exhibit similar compressive behavior to ordinary slender columns. The defects of recycled steel tube concrete can be compensated for by the restraining effect of the steel tube and the bridging effect of the steel fiber. As the slenderness ratio increases. The restraining effect of steel pipes and steel fibers will gradually disappear. Shiming Zhou et al. [34] tested 18 circular columns and 18 square columns to determine the effects of constraint coefficients and recycled aggregate substitution rates on the axial compression behavior of these columns. The axial compression load and longitudinal strain curves indicate that with the increase of constraint factors, there are three trends: post peak softening, plasticity, and strengthening. Correspondingly, sliding tests were conducted, and generally speaking, the bonding strength of recycled aggregate stainless steel tube concrete columns (RAC-FSST) is lower than that of steel tube concrete columns (CFST), because the surface of stainless steel tubes is relatively smooth, while the shrinkage deformation of core recycled aggregate concrete is larger. The structural components containing large (60-300mm) demolished concrete blocks (DCLs) proposed by Wu B, Lin L et al. are a new method for recycling demolished concrete. They studied the long-term creep behavior of CFST columns (4 specimens) and their cylindrical core tubes (6 specimens), taking into account the effects of DCL substitution rate and axial compression ratio on their creep behavior. The test results show that the basic creep of cylindrical composite concrete specimens is greater than that of cylindrical fresh concrete (FC) or dismantled concrete specimens, but it increases with the increase of DCL replacement rate; The creep behavior of composite CFST specimens is almost the same as that of cylindrical FC specimens.

5. CONCLUSION

In summary, steel-concrete columns have advantages such as high bearing capacity, good seismic performance, environmental friendliness, and good fire resistance. In steel-concrete columns, the restraining effect of steel pipes on the internal concrete puts the concrete in a triaxial compression state, which improves the compressive strength of the concrete; The concrete inside the steel pipe can effectively prevent local buckling of the steel pipe. Research has shown that the bearing capacity of steel tube concrete columns is higher than the sum of the corresponding bearing capacities of steel tube columns and concrete columns. The interaction between steel pipes and concrete transforms the failure of concrete inside the steel pipes from brittle failure to plastic failure. The ductility performance of the components is significantly improved, the energy consumption capacity is greatly enhanced, and it has superior seismic performance, which can be used in large building structures and bridge structures. The failure types of recycled steel tube concrete are similar to those of steel tube concrete. In terms of mechanical properties, it compensates for the shortcomings of low strength and internal damage of recycled aggregates. In terms of resources, it can to some extent solve the problem of difficult to treat construction waste, achieving the goal of purifying the environment and recycling resources. In terms of economy, replacing concrete with recycled aggregates can reduce the production cost of steel tube concrete. So if the combination of theory and practice can prove that such components can be used in construction, it has a certain positive significance for building engineering, resource utilization, and environmental protection. After extensive research and analysis, it is believed that the form of recycled steel tube concrete structure is feasible.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Peng Gaifei, Huang Yanzhu, Zhang Jiufeng. The influence of aggregate defects on the mechanical properties of recycled concrete [J]. Journal of Building Materials. 2012;15(01):80-84.
2. Kazuo Hatsui The development trend and unresolved issues of recycled aggregate concrete in Japan [A] Xinjiang Western Construction Co., Ltd., China Silicate.
3. Society of Concrete and Cement Products Branch. Proceedings of the International Academic Symposium on Ecological Environment and Concrete Technology [C]. Xinjiang Western Construction Co., Ltd.
4. Division of Concrete and Cement Products of China Portland Institute: China Portland Institute. 2005:9.
5. Mostafa Tavakoli, Parviz Soroushian Drying Shrinkage Behavior of Recycled Aggregate Concrete [J] Concrete International. 1996;18(11).
6. Liu Tingting, Zhang Tao. Research status and existing problems of recycled concrete [J]. Shandong Building Materials. 2005; (04):58-60.
7. Chen Yonggang, Cao Beibei. Development Trends of Recycled Concrete at Home and Abroad [J]. Foreign Building Materials Technology. 2004;(03):4-6.
8. Mandal S, Gupta A. Strength and Durability of Recycled Aggregate Concrete[J]. IABSE Symposium Report, 2002; 86(6):33-46.
9. Choi WC, Yun HD. Compressive behavior of reinforced concrete columns with recycled aggregate under uniaxial loading[J]. Engineering Structures. 2012; 41:285-293.
10. Yan Chunling, Shi Yongtao, Hu Chunsheng, Hu Haibo. Test and regression analysis of compressive strength of recycled concrete [J]. Construction Technology. 2018;47(08): 102-106.
11. Gao Xu, Wang Ning. Experimental study on compressive strength of recycled concrete [J]. Cement Engineering. 2020;(04):29-30+34.
12. Tabsh SW, Abdelfatah AS. Influence of recycled concrete aggregates on strength properties of concrete[J]. Construction Building Materials. 2009;23(2):1163-1167.
13. Juan MSD, Gutierrez PA. Study on the influence of attached mortar content on the properties of recycled concrete aggregate[J]. Construction & Building Materials. 2009;23(2):872-877.
14. Elremaily A, Azizinamini A. Behavior and strength of circular concrete-filled tube columns[J]. Journal of Constructional Steel Research. 2002;58(12):1567-1591.

15. Han Linhai, Zhong Shantong Mechanics of steel tube concrete Dalian University of Technology Press [M]; 1996.
16. Li Bin Research on Steel Tube Concrete Structures [D]. Xi'an University of Architecture and Technology; 2005.
17. LinHai Han，Wei Li，YouFu Yang Seismic behaviour of concrete－filled steel tubular frame to RC shear wall high － rise mixed struc-tures [J]. Journal of Constructional Steel Research. 2009;65 (5):1249－1260.
18. Wang Tiecheng, Zhang Lei, Zhao Hailong, Du Chuang. Analysis of the influence of seismic performance parameters on steel tube concrete columns [J]. Journal of Building Structures. 2013;34(S1):339-344.
19. Gupta PK, Sarda SM, Kumar MS. Experimental and computational study of concrete filled steel tubularcolumns under axial loads [J]. Journal of Constructional Steel Research. 2007;(63):182–193.
20. O'Shea M, Bridge R. Circular thin-walled tubes with high strength concreteinfill. Composite construction in steel and concrete II. Irsee (Germany): ASCE. 1996: 780–93.
21. O'Shea MD, Bridge RQ. Design of circular thin-walled concrete filled steeltubes. J Struct Engng ASCE. 2000;126(11):1295–303.
22. Kilpatrick A, Rangan BV. Behaviour of high-strength composite columns.In: Composite construction — conventional and innovative. Innsbruck,Austria; 1997; 789–94.
23. Kilpatrick A, Taylor T. Application of Eurocode 4 design provisions to highstrength composite columns. Composite construction — conventional andinnovative. Innsbruck, Austria. 1997; 561–6.
24. Mohanraj EK, Kandasamy S, Malathy R. Behaviour of steel tubular stub and slender columns filled with concrete using recycled aggregates[J]. Journal of the South African Institution of Civil Engineering. 2011;53 (2):31-38.
25. Konno K, Sato Y, Kakuta Y, et al. The Property of Recycled Concrete Column Encased by Steel Tube Subjected to Axial Compression[J]. Transactions of the Japan Concrete Institute. 1997; 19:231-238.
26. Konno K, Sato Y, Uedo T, et al. Mechanical property of recycled concrete under lateral confinement [J]. Transactions of the Japan Concrete Institute. 2012; (20):287292.
27. Liu Y, Zha X, Gong G. Study on Recycled-Concrete-Filled Steel Tube and recycled concrete based on damage mechanics[J]. Journal of Constructional Steel Research. 2012;71(1):143-148.
28. Yang YF, Ma GL. Experimental behaviour of recycled aggregate concrete filled stainless steel tube stub columns and beams[J]. Thin-Walled Structures. 2013; 66:62-75.
29. Qiu Changlong Research on recycled concrete and analysis of mechanical properties of steel tube recycled concrete short columns [D]. Southwest Jiaotong University; 2009.
30. Ibañez C, Hernández-Figueirido D, Piquer A. Effect of steel tube thickness on the behaviour of CFST columns: Experimental tests and design assessment[J]. Engineering Structures. 2021;230.
31. Liusheng He, Yangang Zhao, Siqi Lin. Experimental study on axially compressed circular CFST columns with improved confinement effect[J]. Journal of Constructional Steel Research. 2018;140.
32. Qihan Shen, Jingfeng Wang, Jiaxin Wang, et al. Axial compressive performance of circular CFST columns partially wrapped by carbon FRP[J]. Journal of Constructional Steel Research. 2019;155.
33. Li Na, Lu Yiyan,Li Shan et al. Slenderness effects on concrete-filled steel tube columns confined with CFRP[J]. Journal of Constructional Steel Research. 2018;143.
34. Shiming Zhou, Qing Sun,Xiaohong Wu. Impact of D/t ratio on circular concrete-filled high-strength steel tubular stub columns under axial compression[J]. Thin-walled Structures. 2018; 132.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/114458