Experimental study on seismic performance of shear walls with steel fiber recycled concrete

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Abstract. The paper studies the seismic performance of shear walls with steel fiber recycled concrete. Four shear wall specimens were designed and manufactured in this paper and tested under low cyclic loading. The effects of waste fiber and recycled aggregate on the seismic behavior of shear wall were studied. The results show that the incorporation of waste fiber can delay the generation of cracks in concrete. The incorporation of waste fiber can improve the bearing capacity and ductility of shear wall to some extent, while the recycled aggregate has little influence on the bearing capacity and ductility of shear wall.

1. Introduction
With the rapid development of urbanization, a large number of buildings have been demolished and rebuilt, at the same time, a large amount of construction waste such as waste concrete was generated. In order to treat the waste concrete reasonably and achieve the purpose of effective utilization of resources and sustainable development of society, many scholars at home and abroad\cite{1-4} used waste concrete and other wastes to replace natural aggregate of concrete to prepare recycled concrete. However, due to a large number of micro-cracks and more internal defects such as cement slurry on the surface of the recycled aggregate in the crushing process, the strength, toughness and cracking resistance of the recycled aggregate concrete are reduced to different degrees, so its application in practical projects is limited to some extent. According to the research data at home and abroad\cite{4}, the waste fiber processed from textile waste could improve the mechanical properties of recycled concrete in a certain range.

At present, most scholars\cite{5-6} at home and abroad focus on the research of recycled aggregate concrete and fiber concrete\cite{7-8}, respectively. Most of the research on fiber recycled concrete is about the study of its material properties. There are not many reports on the research of fiber recycled concrete components. This paper has carried out experimental research on the seismic performance of the shear wall with steel fiber recycled concrete, which provides a reference for the research on waste fiber recycled concrete components and lays a theoretical foundation for the application of waste fiber recycled concrete in practical projects in the future.

2. The experiment
2.1 Design of mix proportion
The recycled coarse aggregate used in this test is made by artificial breaking of the abandoned concrete used in the laboratory test of the monitoring station. The strength of the original concrete is C40. The waste fiber is made of recycled waste polypropylene carpet, which is cut manually and the
length is 19 mm. The natural coarse aggregate is gravel, and the particle size of crushed stone is the same as that of recycled coarse aggregate, which is 5 ~ 20 mm. The cement is 42.5R grade Portland cement. Specific concrete mix ratio is shown in Table 1.

| Number | Material usage/kg/m³ | Replacement rate of regenerated coarse aggregate/% | Waste fiber Volume ratio/% | Waste fiber The length of fiber/mm |
|--------|----------------------|-----------------------------------------------|---------------------------|----------------------------------|
| 1      | 434 706 884 295 206 25 | 0                                             | 19                        |
| 2      | 434 706 884 295 206 25 | 1                                             | 19                        |
| 3      | 434 706 884 589 206 50 | 0                                             | 19                        |
| 5      | 434 706 884 589 206 50 | 1                                             | 19                        |

2.2 Design of mix proportion

In order to study the effect of waste fiber incorporation on the seismic performance of shear walls with steel fiber recycled concrete, four shear wall specimens were made. The bottom of the specimen is the foundation beam of C30 ordinary concrete, the middle part is the shear wall with steel fiber recycled concrete, and the upper part is the loading beam made of C30 ordinary concrete. The specimens were numbered SWRC1, SWRC2, SWRC3 and SWRC4. All specimens were of the same size. The size of the specimens was shown in Figure 1. The design scheme of the specimen is shown in Table 2.

![Figure 1. Size of specimen](image)

2.3 Test loading device and loading system.

In this test, the hydraulic loading system in the structural laboratory was adopted for the test, and the load-displacement mixed control loading method was adopted. The force is measured by a force transducer during loading. During the test, the hydraulic loader can move horizontally with the
deformation of the specimen, so as to ensure that the vertical force test is always in the straight direction, and to minimize the horizontal friction at the support on the top of the hydraulic loader caused by the deformation of the specimen, so as to ensure the correct force boundary conditions of the specimen. The vertical load was calculated as 800kN. Before the repeated horizontal load V loading test, the vertical load was applied to the predetermined value of 800kN and remained unchanged. After the vertical load is stabilized, horizontal load is applied. The horizontal load is controlled by the mixed load and displacement. Each load is 50kN and the cycle is repeated once, increasing step by step until the specimen yields. Displacement loading began after the yielding of the specimen, and record the horizontal displacement as $\Delta y$ when the specimen was in yield. The step distance of displacement control is 1/8 of $\Delta y$. When the horizontal load reached 85% of the peak load of the specimen, the loading stopped and the test ended. The test loading device is shown in Figure 2.

![Figure 2. Schematic diagram of loading device](image)

### 3. Experimental phenomena and results

SWRC2 and SWRC4 have shear failure, which is a relatively normal failure mode of low shear wall. The horizontal cracks are relatively rare and appear at the root of the wall first. When the horizontal load reaches the ultimate load, the original horizontal cracks begin to tilt downward at an angle of 45 degrees. There are inclined cracks in the wall above the wall height. Under the action of repeated load, the "X" shaped shear crack is formed in the core of the wall.

SWRC1 and SWRC3 were damaged by bending shear. The cracks are very thin and appear later, mainly at the root of the wall. There are many horizontal cracks in the wall, which develop rapidly along the root and finally run through. In the case of failure, the corner concrete is crushed, and then the longitudinal reinforcement of the concealed column yields. There are two main reasons for the analysis: first, it is caused by the difference of pouring time. When pouring, the base shall be poured first. Although a rough surface is reserved at the top of the bottom beam, the final part of the wall body and the bottom beam is still insufficient. Second, there is an additional moment effect. During the loading process, the absolute level of the actuator can not be guaranteed, so there will be an additional bending moment. However, this kind of damage can be avoided in the test as long as the construction technology is ensured and the reinforcement of concealed column is increased properly.

From the experimental phenomenon in the loading process, it can be seen that the development form of inclined cracks of recycled concrete shear wall with waste fiber are similar to that of ordinary
concrete shear wall. However, due to the constraint of waste fiber on the wall cracks, the wall cracks appear later and develop slowly.

From the final failure mode of the test, it can be seen that the concrete damage in the compression zone of the shear wall of recycled concrete is relatively serious, and the trend becomes more obvious with the increase of the replacement rate of recycled aggregate. This may be due to the damage accumulation in the early stage of recycled concrete, and the strength and stiffness degradation in the later stage is faster. The failure modes of compression zone of some specimens are shown in Figure 3.

Figure 3. The distribution of cracks

4. Analysis of seismic performance

4.1 Analysis of bearing capacity

The measured values of cracking load, yield load and ultimate load of each specimen are listed in Table 3. In Table 3, \( F_{cr} \) is the cracking load of the specimen; \( F_y \) is the yield load of the specimen; \( F_u \) is the ultimate load of the specimen, and \( \mu_{yu} = F_y/F_u \) is the ratio of yield load to ultimate load, that is, the flexion strength ratio.

| Number | \( F_{cr} \)(kN) | \( F_y \)(kN) | \( F_u \)(kN) | \( \mu_{yu} \) |
|--------|----------------|----------------|----------------|-------------|
| SWRC1  | 316.07         | 409.42         | 461.44         | 0.68        |
| SWRC2  | 283.56         | 389.50         | 438.17         | 0.64        |
| SWRC3  | 300.35         | 380.59         | 403.77         | 0.73        |
| SWRC4  | 330.86         | 418.42         | 472.68         | 0.66        |

As shown in Table 3:

1) The replacement rate of recycled aggregate of SWRC1 is the same as that of SWRC2, the former is added with waste fiber. The yield load and ultimate load of SWRC1 are 5.1% and 5.3% higher than those of SWRC2 respectively. It shows that the waste fiber has a certain influence on the bearing capacity of recycled concrete shear wall.

2) Compared with SWRC2, the ultimate load of specimen SWRC3 decreased by 4.1%, and its yield load decreased by 2.3%. It can be seen that the content of recycled concrete has little influence on the bearing capacity of recycled concrete shear wall.

4.2 Result analysis of ductility performance

The measured displacement and ductility coefficients of each specimen are shown in Table 4. In Table 4, \( U_{cr} \) is the horizontal displacement of specimen cracking; \( U_y \) is the yield horizontal displacement; \( U_u \) is the ultimate displacement; \( \mu = U_u/U_y \) is the displacement ductility coefficient.

| Number | \( U_{cr} \)(mm) | \( U_y \)(mm) | \( U_u \)(mm) | \( \mu \) |
|--------|----------------|----------------|----------------|---------|
| SWRC1  | 1.10           | 3.18           | 21.56          | 6.78    |
| SWRC2  | 0.94           | 3.12           | 20.17          | 6.46    |
| SWRC3  | 0.81           | 3.46           | 18.97          | 5.48    |
| SWRC4  | 1.24           | 3.72           | 22.60          | 6.07    |
As can be seen from Table 4:

1. The replacement rate of recycled aggregate of SWRC4 is the same as that of SWRC3, and its ductility coefficient is increased by 10.9%. It shows that the waste fiber can enhance the ductility performance of recycled concrete shear wall. This is because the waste fiber slows down the development of wall cracks and improves the deformation capacity of wall.

2. The ductility coefficient of SWRC3 is 18% lower than that of SWRC2. It can be seen that the content of recycled coarse aggregate has a certain influence on the bearing capacity of recycled concrete shear wall.

5. Analysis of seismic performance

This paper mainly introduces the test phenomenon and result analysis of 4 recycled fiber reinforced concrete shear walls, and the bearing capacity and ductility of each specimen are compared and analyzed.

The experimental analysis shows that:

1. The performance of the recycled concrete shear wall mixed with recycled coarse aggregate is basically similar to that of the ordinary concrete shear wall in bearing capacity and other aspects, and it has good seismic performance. So it is feasible to use recycled coarse aggregate to replace natural aggregate in shear wall structure.

2. When the replacement rate of recycled coarse aggregate is less than 50%, the failure characteristics and degradation process of recycled concrete shear walls with different replacement rates are basically the same. The replacement rate of recycled coarse aggregate has little impact on the performance of recycled concrete shear walls.

3. After adding waste fibers, the ductility of recycled concrete shear walls is improved. With the increase of load during the loading process and the development of cracks, the later deformation capacity of walls is improved.

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References

[1] XIAO J, LAN Y.(2006)Experimental study on flexural properties of recycled coarse aggregate concrete beams[J].Special Structures. 23(1): 9-12.

[2] LIU Y S, WANG X J, JIN T et al.(2007)Study on the mechanical properties and constitutive relation of steel fiber reinforced concrete[J]. Journal of university of science and technology of China.37( 7) : 717-723.

[3] XU C K, FEI C C.(2016)On anti-crack performance of regenerated concrete beam with various organic fibers[J].Shanxi Architecture.42( 2) : 109-111.

[4] ZHOU J H, ZHANG D, YANG Y S.(2013)Test study on flexural properties of waste fiber recycled concrete beams[J]Journal of Shenyang Jianzhu University. 29(2): 290-296.

[5] LIU S, LENG F.(2007)Technology of recycled aggregate concrete[M].China Building Materials Press.Beijing.

[6] Tanaka R, Miura S, Ohaga Y.(2002)Experimental study on the possibility of using permanently recycled concrete for reinforced structures[J].Journal of the Society of Materials Science.51 ( 8 ) : 948-954.

[7] LI G W, YANG Y H.(2001)Experimental study on characteristics of polyacrylic fiber concrete[J].Advances in Science and Technology of Water Re- source.( 5);15-18.

[8] Andrzej M B.(2008)Fiber reinforced cement-based( FRC) composites after over 40 years of development in building and civil engineering[J].Composite Structure.86;3-9.