Journal of Architectural Research and Development

Research Article

Effect of High-Stress Equal Amplitude Cyclic Loading on Mechanical and Deformation Characteristics of Rubber Concrete

Xin Huang*, Yu Chen

School of Civil Engineering and Architecture, Anhui University of Science and Technology, Huainan, Anhui 232001, China

Abstract: In order to study the mechanical and deformation characteristics of rubber concrete under repeated loading, 50 cycles of high-stress equal amplitude cyclic loading and uniaxial compression tests were carried out on 30 concrete specimens of 5 groups. The change of uniaxial mechanical properties and the deformation during cyclic loading of normal concrete (NC) and rubber concrete (RC) with 5%, 10%, 15%, and 20% content were analysed. The results show that the peak stress and modulus of elasticity decrease and the peak strain increases with the increase of rubber content. After cyclic loading, the degradation degree of NC peak stress and elastic modulus reached 11.0% and 36.8% respectively. This study can provide a basis for the application of rubber concrete.

Keywords: Rubber concrete, Cyclic loading, Mechanical properties, Total strain

Publication date: September, 2019

Publication online: 30 September 2019

****Corresponding author:*** Xin Huang, 2944970296@qq.com

1 Introduction

The change of mechanical properties and strain trend of concrete under cyclic loading plays an important role in studying the dynamic damage characteristics of concrete materials and improving its toughness and elastic properties[1-3]. Rubber, as an additive with elasticity, toughness, and ductility, is often mixed into concrete to make it light and durable, elastic shock absorption, water permeability and other advantages[4-7].

There are many achievements in rubber concrete research over the years. With the addition of rubber, the strength of concrete will inevitably decrease. Khatib[8] et al. summarized the change rule between rubber content and concrete strength, and established the mathematical model between rubber content and concrete strength. About Anti-cracking shrinkage, Kang[9] et al. studies show that the addition of rubber in concrete can significantly delay the cracking time of specimens, and the delay time is prolonged with the increase of the content of rubber.

2 Test materials and methods

2.1 Raw materials

Cement: P. C 42.5 composite Portland cement produced by Huainan Bagongshan Cement Plant. Mixing water: ordinary tap water. Sand: river sand. Coarse aggregate: gravel, continuous gradation 5-20 mm. Rubber particles: particle size 20 mesh (0.85 mm). Rubber particles were processed from scrap rubber tires. Rubber photographs and scanning electron microscopy are shown in Figure. 1. Microscopic appearance is porous, layered and loose. Fly ash: Class I fly ash was produced in Huainan Pingwei Power Plant. Water reducer: HPWR high-performance water reducer was produced in Qinfen Building Material Factory, Shaanxi Province.

Ordinary concrete was prepared according to JGJ55-2011 *Specification for Mix Ratio Design of Ordinary Concrete*. Rubber concrete specimens were made by equal volume substitution method, that is, rubber content was 5%, 10%, 15% and 20% of cementitious material quality, and equal volume was used to replace part of sand.

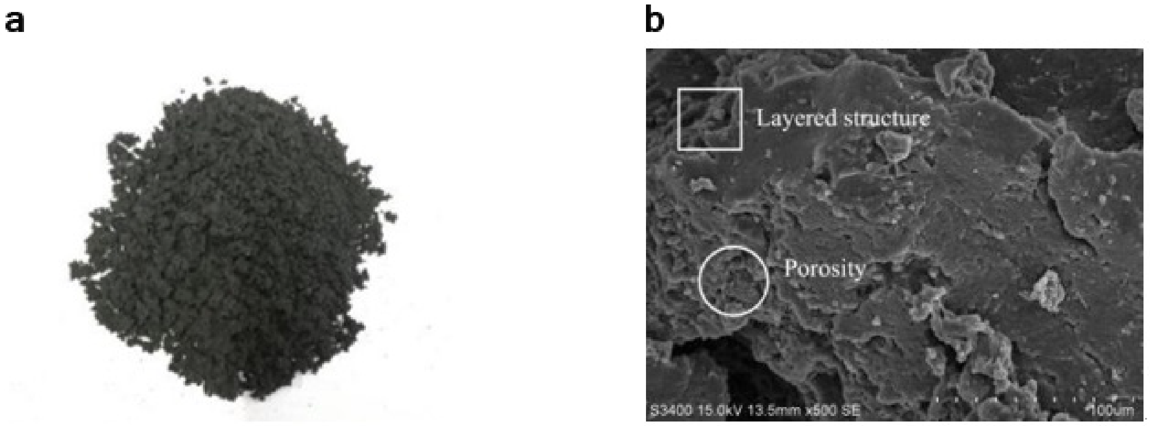

Figure 1. Macro and micro characteristics of rubber: (a) macroscopic appearance and (b) macroscopic appearance

2.2 Concrete mix proportion design

In the experiment, rubber particles processed from waste rubber tires were used as additives. The particle size was 0.85 mm. Five groups of tests were designed. They were ordinary concrete specimens, which were recorded as NC. Rubber concrete specimens with rubber content of 5%, 10%, 15%, and 20% were recorded as RC-1, RC-2, RC-3 and RC-4 respectively. There were 6 specimens in each group, totaling 30 specimens. The specimen size is a cylinder of 50 mm×100 mm. The matching of each group of specimens is shown in Table 1.

Table 1. Specimen mix ratio parameter

Serial number	Test piece number	Mix ratio/kg·m^{-3}							Moisture content/%
		cement	Fly ash	River sand	Stone	Water	Water reducing agent	Rubber	
1	NC	310	50	791	1115	150	3.4	0	2.32
2	RC-1	310	50	692	1115	150	3.4	18	3.32
3	RC-2	310	50	593	1115	150	3.4	36	4.09
4	RC-3	310	50	494	1115	150	3.4	54	4.38
5	RC-4	310	50	395	1115	150	3.4	72	4.76

Notes: NC represents normal concrete, RC-1, RC-2, RC-3 and RC-4 respectively represent rubberized concrete having a blending amount of 5%, 10%, 15%, and 20%.

2.3 Test method

RDL-200 electronic creep relaxation tester was used to test the axial deformation of the specimens. During the test, an extensometer was set up in the direction of the height of the specimens to measure the axial deformation of the specimens. The loading device is shown in Figure 2.

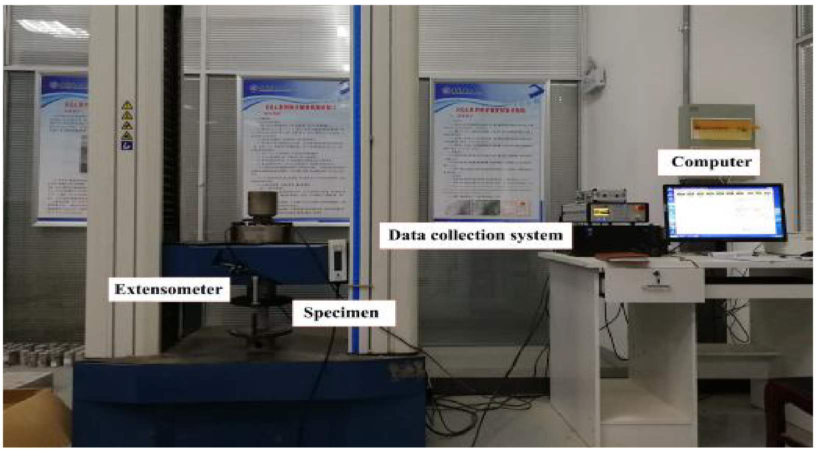

Figure 2. Test loading device

In order to reduce the influence of specimen surface smoothness on the test and ensure the stability of the test instrument, all specimens were preloaded at the beginning of the test, and the preload was 500 N. The loading rate is 60 kN/min, the unloading rate is 30 kN/min, the loading and unloading time is one cycle and 50 cycles. The loading limit is 90% of the uniaxial compressive strength of the specimens, and the unloading limit is 0 kN.

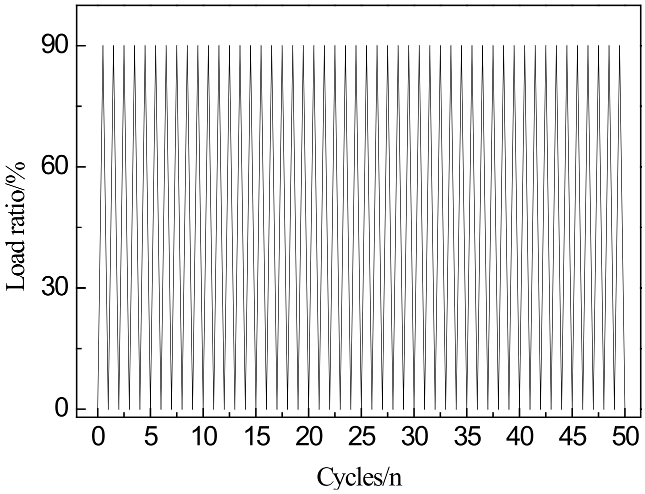

Figure 3. Cycle loading system

3 Test results and analysis

3.1 Analysis of uniaxial test results

The loading mode is controlled by displacement and the loading rate is controlled at 3 mm/min.

Table 2. Uniaxial mechanical parameters of rubberized concrete

Test piece number	Compressive strength/MPa	Elastic Modulus/GPa	Peak strain/10^{-2}
NC	20.35	3.15	1.664
RC-1	18.34	2.07	1.957
RC-2	16.72	1.87	2.139
RC-3	13.84	1.67	2.499
RC-4	12.88	1.60	3.264

It can be seen that the compressive strength and modulus of elasticity of concrete decrease in varying degrees and the peak strain increases with the addition of rubber; with the increase of rubber content, the compressive strength decreases by 9.88%, 17.84%, 31.99% and 36.71% in turn; the modulus of elasticity decreases by the same trend, the maximum decreases by 49.2% and the minimum by 34.2%. The peak strain of RC-4 group is the largest, which is 96.2% higher than that of NC group, indicating that rubber concrete has good ductility.

3.2 Cyclic loading result analysis

According to the uniaxial compression test results, the upper limit loads NC, RC-1, RC-2, RC-3 and RC-4 of each group under uniaxial cyclic loading are 36, 32, 29, 24 and 23 kN, respectively.

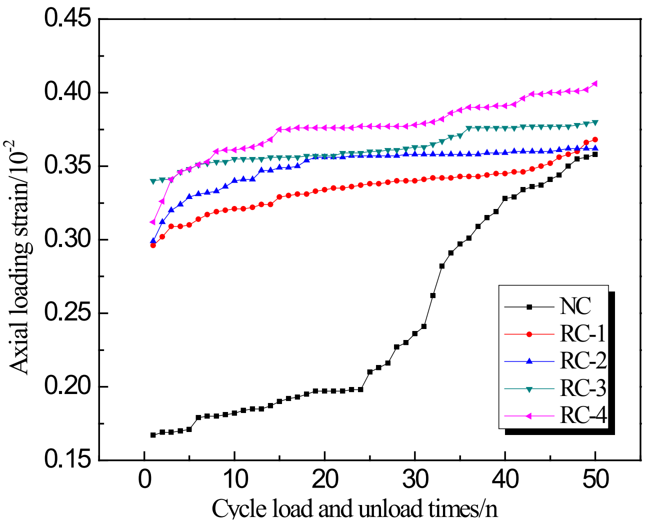

Figure 4. Axial load strain curve

It can be seen that the strain curves of concrete with different rubber content have the same trend. When the number of cycles is less than 20, the strain increases rapidly, with an average growth rate of 2.2×10^{-5}/time. Then the strain growth decreases and tends to stabilize gradually, with an average growth rate of 7.7×10^{-6}/time, which is 35% of the average growth rate of the previous stage. The change rule of ordinary concrete increases rapidly when the cyclic loading is about 25 times, and the increment reaches 0.087×10^{-2} from 10 cycles to 35 cycles. After that, the increment rate of axial strain decreases gradually and tends to be stable.

4 Conclusion

(1)With the increase of rubber content, the compressive strength and modulus of elasticity of the specimens decrease and the peak strain increases. After 50 cycles of loading, the compressive strength and modulus of elasticity of the specimens deteriorated to varying degrees, but the deterioration degree decreased with the increase of rubber content.

(2)During cyclic loading, the total strain of rubber concrete is higher than that of ordinary concrete, and the total strain increases with the increase of rubber content. At the same time, the relative strain difference of rubber concrete is much smaller than that of ordinary concrete, which shows better stability.

References

[1] Liang H, Peng G, Zou SB, et al. Research on the Stress-strain Curve of the Concrete Under Cyclic Loading and Unloading[J]. Journal of Civil Engineering and Management, 2014, 31(04):55–9.

[2] Hu HJ, Peng G, Xie JY, et al. Study on Dynamic Behaviour of Concerete by Cycle Loading and Unloading Condutuons[J]. Engineering Mechanics, 2015, 32(06):141–5.

[3] Xu LH, Li B, Chi Y, et al. Experimental Investigation on Stress-strain Relation of Steel-polypropylene Hybrid Fiber Reinforced Concrete Subjected to Uniaxial Cyclic Compression[J]. Journal of Building Structures, 2018, 39(04):140–52.

[4] Li Y, Wang L. The Research Progress of Portland Cement Concrete Containing Crumb Rubber[J]. Concrete, 2006(04):91–3+95.

[5] Chen B, Zhang YM, Chen SX, et al. Fundamental Research of Properties of Rubberized Concretes[J]. Concrete, 2004(12):37–9.

[6] Yuan Y, Zheng L. Experimental Study on Dynamic Properties of Rubberized Concrete[J]. Journal of Tongji University(Natural Science), 2008(09):1186–90.

[7] Siddque R, Naik TR. Properties of concrete containing scrap-tire rubber-an overview[J]. Waste Mamagement, 2004, 24(06):563–9.

[8] Khatib Z.K, Bayomy F.M. Rubberized portland cement concrete[J]. Journal of Materials in Civil Engineering, 1999, 11(3):206–13.

[9] Kang JF, Ren HB, Zhang PZ. Cracking-resistance and Flexural Property of Rubberized Concrete[J]. Acta Materiae Compositae Sinica, 2006(06):158–62.