Mechanical performance of waste-rubber modified recycled-aggregate-concrete subjected to elevated temperature

Y.C. Tang[1, 2], W.X. Feng[2], L.J. Li[2], J.M. Chen[2], L.Y. Ma[2], D.J. Bao[2]

[1] School of Urban and Rural Construction, Zhongkai University of Agriculture and Engineering, Guangzhou, 510006, China
[2] School of Civil and Transportation Engineering, Guangdong University of Technology, Guangzhou, 510000, China

Presenting author email: ryan.twain@gmail.com

Abstract
This paper determines the effects of elevated temperatures and rubber contents on the compressive behaviour of rubber crumb modified recycled aggregate concrete. The rubber particles used in the experiments are made of the recycled tire, and the recycled aggregate concrete are made of waste concrete. The stress-strain curve, compressive strength, stiffness and explosive spalling resistance of 141 standardized rubber crumb modified recycled aggregate concrete specimens with 0%, 4% and 9% rubber contents were experimentally investigated subjected to 25°C, 200°C, 400°C and 600°C. Further, a fitting equation for the stress-strain curve of rubber crumb modified recycled aggregate concrete was proposed and compared with other formulas. The results suggested that waste rubber crumb can significantly mitigate the weight loss, as well as improve the residual compressive strength, energy absorption capacity and explosive spalling resistance of rubber crumb modified recycled aggregate concrete. The recommendation of rubber crumb content of 4% is recommended as the specimens display better residual strength and stiffness.

Keywords: Rubber recycled aggregate concrete, Explosive spalling resistance, Elevated temperature

1. Introduction

The development of the rubber industry has created increasing amounts of waste rubber, posing a great burden to the environment and threats to human life and property. The problem of black pollution caused by rubber tires has caused widespread concern in countries around the world.Waste tire rubber is extremely difficult to degrade in landfill treatment. As a result,the reasonable disposal of the waste rubber has become a severe social and environmental problem in the world.Producing recycled rubber and incorporating it into concrete can reduce environmental pollution and conserve resources.Due to the low elastic modulus, excellent deformation and energy dissipation capacity of rubber, rubber concrete has been applied in road paving and shock-absorbing structures.At present, most of the research is focused on the mechanical properties of rubber concrete.It is shown that the incorporation of rubber improved the ductility, toughness and crack resistance ability of the normal concrete although the compressive strength of concrete may be slightly reduced. Meanwhile,rubber also improves the frost resistance and fatigue resistance of concrete.As a result,rubber concrete has the advantages of light weight,shock absorption, noise reduction, sound insulation, etc.It can be widely used in seismic structures, road soundproof walls and anti-impact structures.A few scholars have discussed the high temperature performance of rubber concrete. It is found that rubber concrete is more susceptible to high temperature,but its thermal reaction is basically similar to normal concrete and can be applied to structural engineering.Liu et al. (2011) indicated that low content rubber powder (1%) burnt after exposure to evaluated temperatures, can release space for the escaping of water vapour in concrete and thus effectively prevent the concrete from bursting.

Against this background, in order to promote environmentally friendly recycled materials, we conducted a preliminary exploration on the performance of waste-rubber modified recycled-aggregate-concrete (RRAC). Liu et al. (2015) found that incorporating rubber significantly increased the fatigue life of the recycled concrete. Li et al. (2016) argued that the incorporation of rubber powder increased the ductility and toughness of recycled concrete and suggested that less than 10% of the rubber and more than 0.864 mm of rubber should be used in paving works. However, the Mechanical performance of waste-rubber modified recycled-aggregate-concrete subjected to elevated temperature has never been studied to date. In order to improve the bursting resistance of recycled concrete under high temperature and investigate the high temperature reaction and residual mechanical properties after high temperature, 141 test pieces were prepared with temperature (20℃, 200℃, 400℃, 600℃) and rubber content (0%, 4%, 9%) as the main parameters.The residual compressive strength, deformation performance and bursting resistance mechanism were also discussed.

2. Experimental program

2.1 Selection of materials and mix proportion

Typical normal Portland cement with a nominal compressive strength of 32.5 MPa was used. The maximum particle size of the ordinary river sand was 4.75 mm with continuous grading. In addition, 5–35mm natural and recycled crushed stone aggregate were used. The fineness modulus of the rubber powder is 40. The 144 test pieces are divided into 10 groups of 12 cylindrical test pieces and 12 cubic test pieces. R4 represents rubber recycled concrete with a strength grade of C50 and a rubber content of 4%.

The design temperature is four groups of 20℃, 200℃, 400℃, and 600℃. Each group has 12 recycled concrete test pieces and 12 rubber modified recycled-aggregate-concrete test pieces. The SX-28-13 chamber electric furnace is used in the high temperature experiment. The size of the furnace is 700mm×550mm×200mm and the Maximum temperature is 1000℃.The temperature is controlled by the intelligent temperature control system. The temperature rise curve refers to the ISO-834 standard fire action temperature rise curve, and the temperature in the furnace (30℃) is directly raised to the design temperature. After the constant temperature for 1 hour, stop rising the temperature and open the furnace door when it is cooled to 70℃. Then cool the furnace to room temperature naturally. Conducting the compressive strength test 1 day later.

3. Test results and discussion

3.1 Experimental phenomena

3.2 Mass loss

Weighing and comparing the specimens of recycled aggregate concrete with and without rubber crumb, the average mass loss rate of the specimens exposing to different temperatures shown in Fig. 3.

It can be seen from the figure that the mass loss rate of recycled concrete is much higher than that of rubber crumb modified recycled aggregate concrete at the same temperature. Moreover, the mass of recycled aggregate concrete remains constant after the temperature reaches 400℃.Compared with recycled aggregate concrete, the mass loss rate of rubber crumb modified recycled aggregate concrete is lower at all temperatures, and the mass loss rate is still increasing slowly after the temperature reaches 400℃.

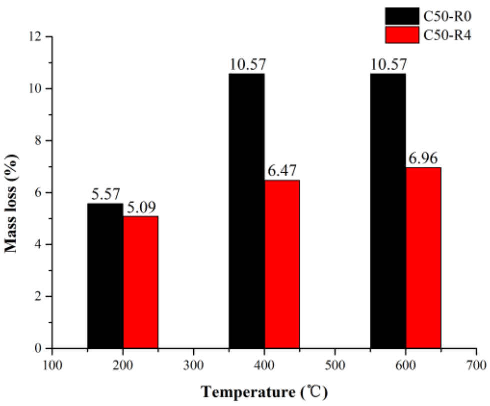

Fig.3 The average mass loss rate of rubber crumb modified recycled aggregate concrete specimens

3.3 Relative residual compressive strength

3.4 The relationship curve of stress - strain

3.5 Stress - strain curve fitting and comparison

4. Conclusion

In this paper, the effects of elevated temperatures and rubber contents on the compressive behaviour of rubber crumb modified recycled aggregate concrete are discussed. The following conclusions can be drawn from the test results, analyses and discussions:

Exposing to high temperature, as temperature increased, contrast to recycled aggregate concrete with the same gradation, rubber crumb modified recycled aggregate concrete has lower weight loss rate, higher relative residual compressive strength and better basic mechanical characteristics.

· As temperature increased， the change of stress and strain of rubber crumb modified recycled aggregate concrete become larger. The higher the temperature, the larger the peak strain, the smaller the peak stress, the larger the strain corresponding to the peak stress. In general, under high temperature, the mechanical properties of rubber modified recycled aggregate concrete deteriorate.

· Exposing to 200-400℃, the peak stress of rubber crumb modified recycled aggregate concrete is higher than recycled aggregate concrete with the same gradation while the peak strain is lower. The result indicates that mixed with rubber crumb, recycled aggregate concrete will get higher ultimate stress in this temperature range, and the deformation is lower when destroyed, which shows better compressive properties than that of recycled concrete with the same gradation.

· Compared with the existing fitting formulas, the fitting equation proposed in this paper has the highest coincidence.

Acknowledgements

Reference