

Research on Durability of Big Recycled Aggregate Self-Compacting Concrete Beam

Shuai Gao¹, Xuliang Liu¹, Jing Li^{1,*}, Juan Li², Chang Wang¹, and Jinkai Zheng¹

¹Shool of Pipeline and Civil Engineering, China University of Petroleum, Qingdao 266580, China

²Nanjing Jinling Petrochemical Engineering CO., Nanjing, Jiangsu 210042, China

*Corresponding author e-mail: lijingupc@163.com

Abstract. Deflection and crack width are the most important durability indexes, which play a pivotal role in the popularization and application of the Big Recycled Aggregate Self-Compacting Concrete technology. In this research, comparative study on the Big Recycled Aggregate Self-Compacting Concrete Beam and ordinary concrete beam were conducted by measuring the deflection and crack width index. The results show that both kind of concrete beams have almost equal mid-span deflection value and are slightly different in the maximum crack width. It indicates that the Big Recycled Aggregate Self-Compacting Concrete Beam will be a good substitute for ordinary concrete beam in some less critical structure projects.

1. Introduction

With the rapid development of city construction, the engineering quantities from reform demolition of old buildings and construction of new buildings have become larger and larger, which results in a great deal of construction waste and more than half of construction waste is waste concrete. Big Recycled Aggregate Self-Compacting Concrete technology^[1] uses waste concrete as recycled aggregate to solve the problem of increasing amount of construction waste, besides, the technology also can protect natural stone resources.

In China, the research on the recycling of waste concrete^[2] started fairly late, but it is developing rapidly with more and more attention be paid to the topic. On the other hand, The promulgation of technical regulations for recycled coarse aggregate such as *Recycled Coarse Aggregate for Concrete*, *Recycled Fine Aggregate for Concrete and Mortar* and other technical regulations have greatly promoted the development of recycled aggregate concrete technology. Therefore, the application of recycled aggregate concrete technology in practical engineering is particularly important.

In this paper, the four-point bending tests on Big Recycled Aggregate Self-Compacting Concrete beam and common concrete beam were carried out^[3], at the same time, the mid-span deflection and maximum crack width were used as durability indexes to evaluate the method to replace ordinary concrete beam with Big Recycled Aggregate Self-Compacting Concrete beam in practical engineering.

2. Experimental

2.1. Experimental materials

Big recycled aggregates used in the experiment were taken from waste concrete blocks from house removal of Xin'an village in Huang Dao city, and its' strength level is greater than C20, then crushed the concrete blocks into the size about 150mm by hand^[4]. In order to reduce the adverse effects



resulted from high water absorption of recycled aggregate on the workability of fresh concrete and ensure the use of recycled aggregate to be in saturated surface state, the soaking treatment was carried out before the test. The natural stones used in the test were taken from little yellow mountain in China University of Petroleum (East China).

In the experiment, C20 self-compacting concrete was used. Raw materials are as follows: Cement is P.O, grade 42.5 cement which is produced in Qingdao Shanshui India Cements; Fine aggregate is made of well graded medium coarse sand with the moisture content 5.8%, whose apparent density is 2770kg/m³ and fineness modulus is 2.98; The coarse aggregate should be of continuous grading macadam with nominal particle size not larger than 20mm, whose apparent density is 2680kg/m³; The admixture is poly-carboxylate superplasticizer; The water is made of civilian tap water; Fly ash is produced by Huangdao electric power plant, that all the indexes met the requirements.

2.2. Mix design of performance testing

The design of the self-compacting concrete was designed according to the volume method in the "Self-compacting concrete mix design specification", and the final C20 self-compacting concrete is shown in Table 1 by estimating, adapting, adjusting and determining^[5-6].

The slump and slump expansion degree were measured by the slump cylinder test method, and whether the concrete edge or the water was spilled at the edge of the concrete was measured by the slump cylinder test method. The final experimental results met the specification requirements.

Table 1. Ultimate mix proportion of self-compacting concrete. (kg/m³)

Material	cement	fly ash	Gravel	sand	reducing agent	water
Proportion	310	180	950	780	6.6	250

2.3. Experimental design and specimen making

Big Recycled Aggregate Self-Compacting Concrete Reinforced Beams were divided into three groups, respectively, PH1, PH2 and PH3. The size of the beam specimen is 300mm×450mm×2700mm. The detailed information is shown in Table 2. The mix proportion of specimen in each group was same, and the design strength is C20.

Table 2. Parameters of Big Recycled Aggregate Self-Compacting Concrete beams.

Specimen number	Large aggregate /kg		Size of beam specimen /mm			Longitudinal reinforcement	reinforcement area: A _s (mm ²)	Ratio of longitudinal reinforcement: ρ (%)	Thickness of protective layer: b (mm)
	Recycled aggregate	Rubble	width	height	Length				
PH1	197.1	0	300	450	2700	2C18	509	0.41	30
PH2	152.5	45.0	300	450	2700	2C18	509	0.41	30
PH3	145.2	67.1	300	450	2700	2C18	509	0.41	30

Specimens used layered pouring method, pouring the specimen after a day to carry out water conservation, 7 days after the demolition of mold, 28 days after the preparation of the experiment^[7].

2.4. Experimental loading

In this experiment, the four-point bending experiment was used to determine the durability index of Big Recycled Aggregate Self-Compacting Concrete Reinforced Beam^[8-9]. The main equipment is:

BX120-100AA type concrete strain gauge, BX120-3AA type steel strain gauge; 30T universal testing machine; DH3818 static strain test system; bridge crane; experimental device is shown in Figure 1.

Before the test was formally loaded, the test adjusted the hydraulic loading system for 10 KN preloading to ensure that the loading plate is in full contact with the beam specimen and then loaded at a loading rate of 0.25 KN/s.

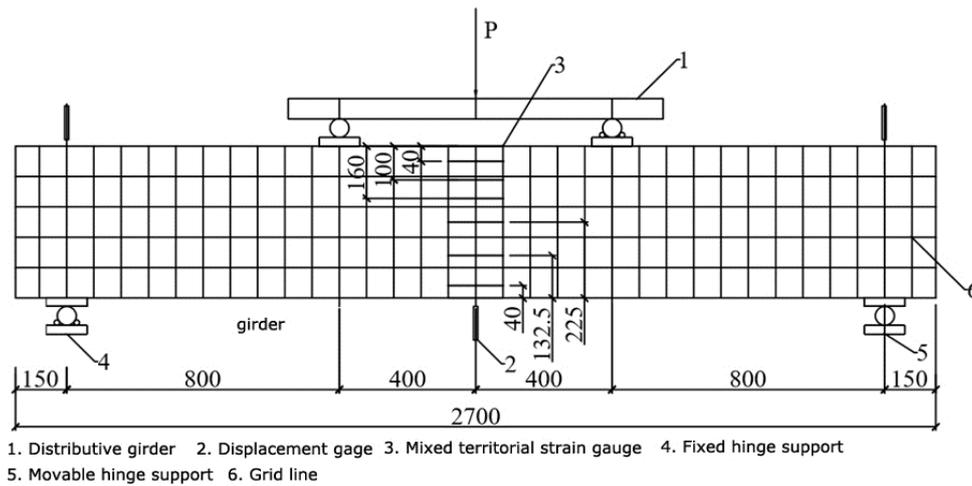


Figure 1. Experimental equipment.

3. Experimental results and analysis

3.1. Mid-span maximum deflection

The mid-span maximum deflection of specimens in each group are showed as the Table 3 with experimental data analysis.

Table 3. The mid-span maximum deflection of specimens in each group.

	Yield Load (KN)	Yield Moment (KN.m)	σ_{sq} (MPa)	ρ_{te}	ρ_{te}'	Ψ	B_s ($\times 10^{13}$)	B ($\times 10^{12}$)	f (mm)
PH1	126.56	50.624	278.3	0.0075	0.01	0.762	1.34639	6.732	4.609
PH2	131.58	52.632	289.9	0.0075	0.01	0.775	1.33086	6.654	4.848
PH3	140.06	56.024	308.6	0.0075	0.01	0.795	1.30783	6.539	5.251

Drawing the load-mid-span deflection curve of specimens in each group with above data, just as the Figure 2 shows. Then included the mid-span maximum deflection of common concrete beam in the Table 4 for comparison.

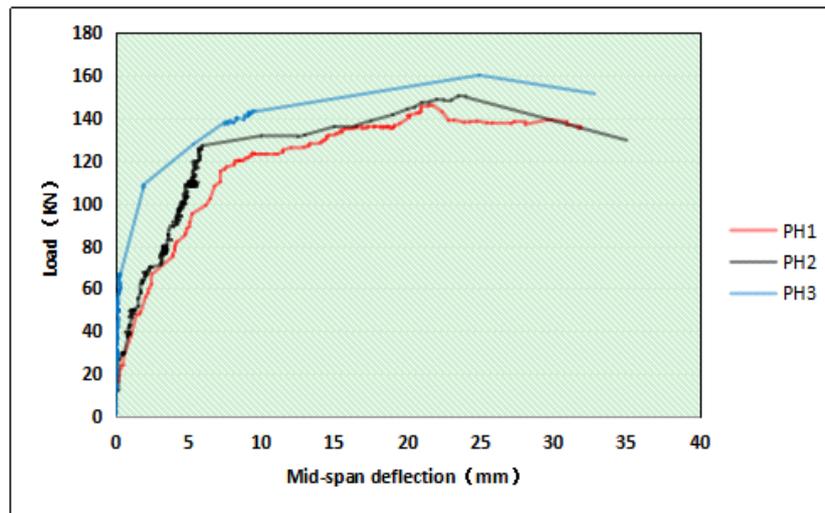


Figure 2. The load-mid-span deflection curve.

Table 4. Comparison of mid-span deflection.

	Actual deflection (mm)	Theoretical deflection (mm)	Ratio of actual value to the calculated value
PH1	7.5	4.609	1.63
PH2	5.97	4.848	1.23
PH3	5.38	5.251	1.02

It can be derived from experimental results and comparison results that:

(1) The flexural failure mechanism of Big Recycled Aggregate Self-Compacting Concrete Reinforced Beam and common reinforced concrete beam is similar, but the former possesses better ductility.

(2) The mid-span maximum deflection of Big Recycled Aggregate Self-Compacting Concrete Reinforced Beam is greater than that of the common reinforced concrete beam under the same conditions, but the difference value is in the acceptable region: $l_0/200=13.5\text{mm}$. This shows that the method to replace concrete beam with the Big Recycled Aggregate Self-Compacting Concrete Reinforced Beam is feasible, as far as the mid-span maximum deflection concerned.

(3) It can be found that the mid-span maximum deflection of Big Recycled Aggregate Self-Compacting Concrete Reinforced Beam and common reinforced concrete beam almost be equal when the mixing amount reaches an appropriate proportion, which provides more basis for Big Recycled Aggregate Self-Compacting Concrete in engineering.

3.2. Maximum crack width

The maximum crack width is listed in Table 5 with experimental data collected.

Table 5. Maximum crack width.

	σ_{sq} (MPa)	ρ_{te}	Ψ	d_{eq} (mm)	Theoretical ω_{max} (mm)	Actual ω_{max} (mm)	Ratio of actual value to the calculated value
PH1	278.8	0.01	0.762	18	0.398	0.42	1.06
PH2	289.9	0.01	0.775	18	0.421	0.47	1.12
PH3	308.6	0.01	0.795	18	0.459	0.51	1.11

It can be derived from experimental result in table 5:

(1) The maximum crack width of Big Recycled Aggregate Self-Compacting Concrete Reinforced Beam and common reinforced concrete beam almost be equal in flexural failure process. As far as the maximum crack width concerned, it's very feasible to replace common concrete beam with Big Recycled Aggregate Self-Compacting Concrete Beam.

(2) The goodness of fit is good between actual value and theoretical value for maximum crack width, therefore, the code formula to calculate the maximum crack width of common concrete beam is suitable for Big Recycled Aggregate Self-Compacting Concrete Beam.

4. Conclusion

Conclusions are as follows from this study:

(1) The flexural failure mechanism of Big Recycled Aggregate Self-Compacting Concrete Reinforced Beam and common reinforced concrete beam is similar, as far as the mid-span maximum deflection index concerned, the method to replace common reinforced concrete beam with the former meets the requirements for use.

(2) The code formula to calculate the crack width of common concrete beam is suitable for Big Recycled Aggregate Self-Compacting Concrete Beam. As far as the maximum crack width index concerned, more reliable basis is provided for the method to replace common concrete beam with Big Recycled Aggregate Self-Compacting Concrete Beam.

(3) As far as the durability index concerned, the method to replace common concrete beam with Big Recycled Aggregate Self-Compacting Concrete Beam is reliable in some flexural members of non-critical structures. However, there needs more experimental researches.

Acknowledgments

This work is financially supported by the S&T benefiting special project of Qingdao city of China (15-9-2-116-nsh).

References

- [1] Li Jing, Liu Zhen, Qu Xian Feng, et al. Finite element analysis of Compressive Strength of Recycled Coarse Aggregates-filled Concrete[J]. *Advanced Building Materials*, 2011, 250-253:331-334.
- [2] Du Ting, Li Hui Qiang, Guo Tai Ping, Zhou Zhi Qiang. The economic analysis of application on recycled aggregate of waste concrete[J]. *New Building Materials*, 2006, (06):30-33.
- [3] Faustino Mujika, Ainhoa Arrese, Itziar Adarraga, Usue Oses. New correction terms concerning three-point and four-point bending tests[J]. *Polymer Testing*, 2016.
- [4] Yuwadee Zaetang, Vanchai Sata, Ampol Wongsapornya, Prinya Chindapasirt. Properties of pervious concrete containing recycled concrete block aggregate and recycled concrete aggregate[J]. *Construction and Building Materials*, 2016, 111.
- [5] Hou Jing Peng, Zhang Lu. The mix design and experimental study on the performance of self-compacting concrete [J]. *Concrete*, 2013, (02): 95-96+101.
- [6] Hu Qiong, Yan Wei Hua, Zheng Wen Zhong. Experimental research on mechanical property of self-compacting concrete[J]. *Industrial Construction*, 2008, (10):90-93.
- [7] Li Jing, Wang Lin Fu, Liu Zhen, Jiang Lin. Research on the binding properties between big recycled aggregates and self-compacting concrete[J]. *Low Temperature Architecture Technology*, 2010, (09):10-12.
- [8] Liu Jia Yong, Wang Yao, Ge Xiao, Zhang Li Min, Zhang Dong Mei, Liu Xue Zhi. Research of four-point bending test[J]. *Physics Examination and Testing*, 2010, (02):44-47.
- [9] Xiao Jian Zhuang, Lan Yang. The experimental study on the flexural performance of recycled coarse aggregate beam[J]. *Special Structures*, 2006, (01):9-12.