

# Study on Effects of Different Replacement Rate on Bending Behavior of Big Recycled Aggregate Self Compacting Concrete

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**Abstract.** Big recycled aggregate self compacting concrete is a new type of recycled concrete, which has the advantages of low hydration heat and green environmental protection, but its bending behavior can be affected by different replacement rate. Therefore, in this paper, the research status of big Recycled aggregate self compacting concrete was systematically introduced, and the effect of different replacement rate of big recycled aggregate on failure mode, crack distribution and bending strength of the beam were studied through the bending behavior test of 4 big recycled aggregate self compacting concrete beams. The results show that: The crack distribution of the beam can be affected by the replacement rate; The failure modes of big recycled aggregate beams are the same as those of ordinary concrete; The plane section assumption is applicable to the big recycled aggregate self compacting concrete beam; The higher the replacement rate, the lower the bending strength of big recycled aggregate self compacting concrete beams.

## 1. Introduction

With the acceleration of urbanization, the problem of building aging and demolition is becoming more and more serious. The disposal and utilization of a large amount of construction waste need to be solved as soon as possible<sup>[1,2]</sup>. In order to reduce environmental pollution and waste of resources, and promote the sustainable development of society, big recycled aggregate self compacting concrete technology emerges as the times require.

In 2010, Professor Li Jing, China University of Petroleum (East China), proposed a new concrete construction method that take big size construction waste (such as waste concrete and waste bricks) as big recycled aggregates (the feature size is about 80~150mm), and then pouring the self compacting concrete (SCC), called big recycled aggregate self compacting concrete<sup>[6]</sup>. Compared with recycled concrete, its aggregate size is larger than that of traditional recycled aggregate (coarse aggregate 4.75 mm~40 mm, fine aggregate 0.075 mm~4.75 mm), the crushing efficiency is improved, energy consumption is reduced and the cement consumption is decreased. Compared with rockfill concrete, the big aggregates use waste concretes and waste bricks of large size in place of rubble and gravel in



rockfill concrete, which is more conducive to reduce environmental pollution and promote the sustainable development of society.

At present, some scholars have done some research on the big recycled aggregate self compacting concrete performance. Li Jing<sup>[3]</sup> carried out compressive strength test of big recycled aggregates self compacting concrete, found that the replacement rate of big recycled aggregate is higher, the compressive strength is lower; and elastic modulus of big recycled aggregate with single material is higher than the elastic modulus of blended materials made of recycled aggregates. The failure pattern of big recycled aggregates self compacting concrete is basically the same with ordinary concrete. The damage is mainly bond failure between big recycled aggregate and self compacting concrete, and the failure of some big recycled aggregate. Sun Limin<sup>[4]</sup> carried out test by using waste concrete as big recycled aggregate and found that the compressive strength of big recycled aggregate specimens is smaller than compressive strength of natural large aggregate specimens, but it has higher elastic modulus. Wu Bo<sup>[5]</sup> determined the strength prediction formula through the cube and cylinder shaft pressure test. Based on microscopic electron microscopy analysis, Li Fuhai<sup>[6]</sup> found that the bond behavior of the material depends on the properties of recycled aggregate and mortar, if the compatibility is good, the bond strength is high. Li Jing<sup>[7]</sup> found that big recycled aggregate and self compacting concrete has good bond performance through the test, and the greater the big recycled aggregate strength, the more rough the surface, the higher the bond strength is. Geng Ou<sup>[8]</sup> observed microstructure of big recycled aggregate concrete by means of SEM, and analyzed the crack propagation law.

## 2. Experiment Design of Big Recycled Aggregate Concrete Bending Behavior

### 2.1. Raw material

"Landscape brand" 42.5 cement produced by Qingdao Shanshui Cements Limited Company; Grade I fly ash produced by Qingdao Hengguang thermoelectric power plant; Zone II coarse sand, the modulus of fineness is 3.30 and the apparent density is 2760kg/m<sup>3</sup>; Polycarboxylate superplasticizer; Natural stone and waste concrete with particle size of 80~150mm.

### 2.2. Preparation of self compacting concrete

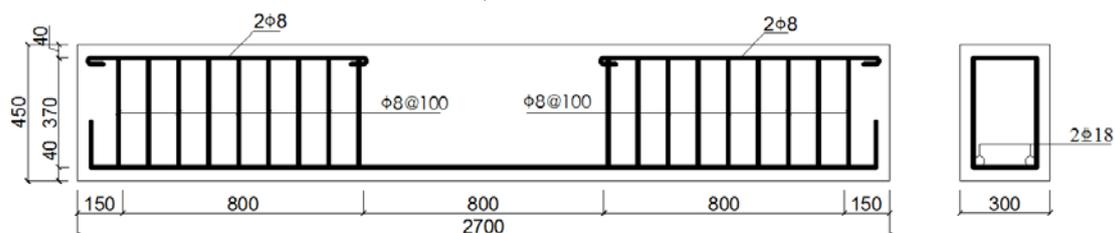
Lab configured C20 self compacting concrete is adopted in this experiment, and the mix proportion is shown in Table 1.

**Table 1.** Mix proportion of SCC used in the test ( kg/m<sup>3</sup> ) .

Cement	Gravel	Sand	Fly ash	Water	Polycarboxylate superplasticizer
290	1030	730	150	200	6.6
1	3.55	2.52	0.52	0.69	0.02

### 2.3. Specimen design and pouring

In order to study the bending behavior of big recycled aggregate self compacting concrete, 4 beams were made according to different replacement rates and experimental research on bending behavior has been carried out. One of the beams is big recycled aggregate plain self compacting concrete beam, and the other three are reinforced beams, the size and reinforcement of specimen as shown in Figure 1. The thickness of the concrete cover is 30mm, and the beam section is 300mm \* 450mm.



**Figure 1.** The size and reinforcement of specimen.

In the process of pouring, the big recycled aggregate is randomly placed in the template first, and then the self compacting concrete is filled to the whole template by multi-point pouring to complete the pouring of the whole specimen.

#### 2.4. Loading device and testing contents

The test was designed referring to relevant standard [9]. Loading through hydraulic servo loading system. Preloading is carried out before the loading, and the preload is to check whether the relevant equipment can work properly. After determining the equipment is normal, unload the load to zero, be ready for formal loading.

Multi-stage loading is used in the test, and 5 min is maintained after each stage loading so that data are recorded. In the process of loading, the cracking condition and crack development of beams are observed. After each loading stage, the newly developed cracks are marked with white chalk, and finally the cracking load and ultimate bearing capacity are measured. The variable parameter of the reinforced beams is the replacement rate of big recycled aggregate, and the designed parameters and test results are shown in table 2.

**Table 2.** Designed parameters and results of test of beam structures.

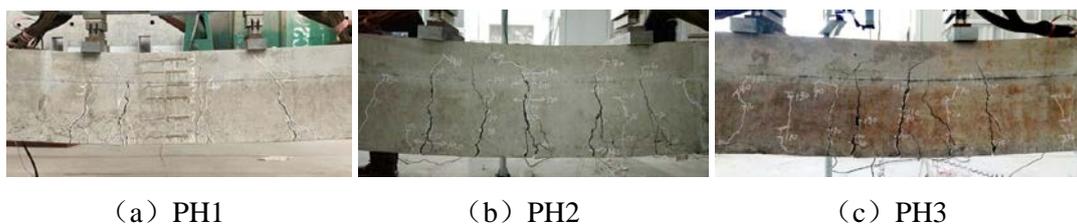
Number	Waste concrete	Stone	Longitudinal reinforcement	Cracking load /kN	Ultimate load /kN
SH1	100%	0	0	5.24	13.01
PH1	100%	0	2 $\Phi$ 18	30.18	154.11
PH2	85%	15%	2 $\Phi$ 18	30.36	161.53
PH3	70%	30%	2 $\Phi$ 18	30.97	164.14

### 3. Effects of Different Replacement Rates on Bending Behavior of Big Recycled Aggregate Self Compacting Concrete

#### 3.1. Crack development and failure pattern

During the test, it is found that the crack development process of the big recycled aggregate self compacting concrete beam is basically the same as that of the ordinary concrete beam. Cracks appear first at the bottom of the member, near the midspan or near the loading point, and the number of cracks increases with the increase of load, but the distribution of cracks is different with ordinary reinforced concrete beam.

From Figure 2, it can be seen that the big recycled aggregate replacement rate has a certain influence on the crack distribution of the beam. The crack distribution of PH2 beam is more uniform than that of PH1 beam and PH3 beam. The possible reason is that many micro cracks and minor defects exist in the big recycled aggregate of the PH1 beam, which results in more cracks in the areas with more micro cracks; The strength of stone in PH3 beam is high, and the random distribution of stone in the big recycled aggregate self compacting concrete beam allows the crack to bypass the higher strength area, which makes the distribution of cracks is sparse in the region of stone and is intensive in the region of big recycled aggregates. The replacement rate of PH2 beam is between the above two, the defects of big recycled aggregate are balanced by the distribution of stone and the distribution of cracks is more even.



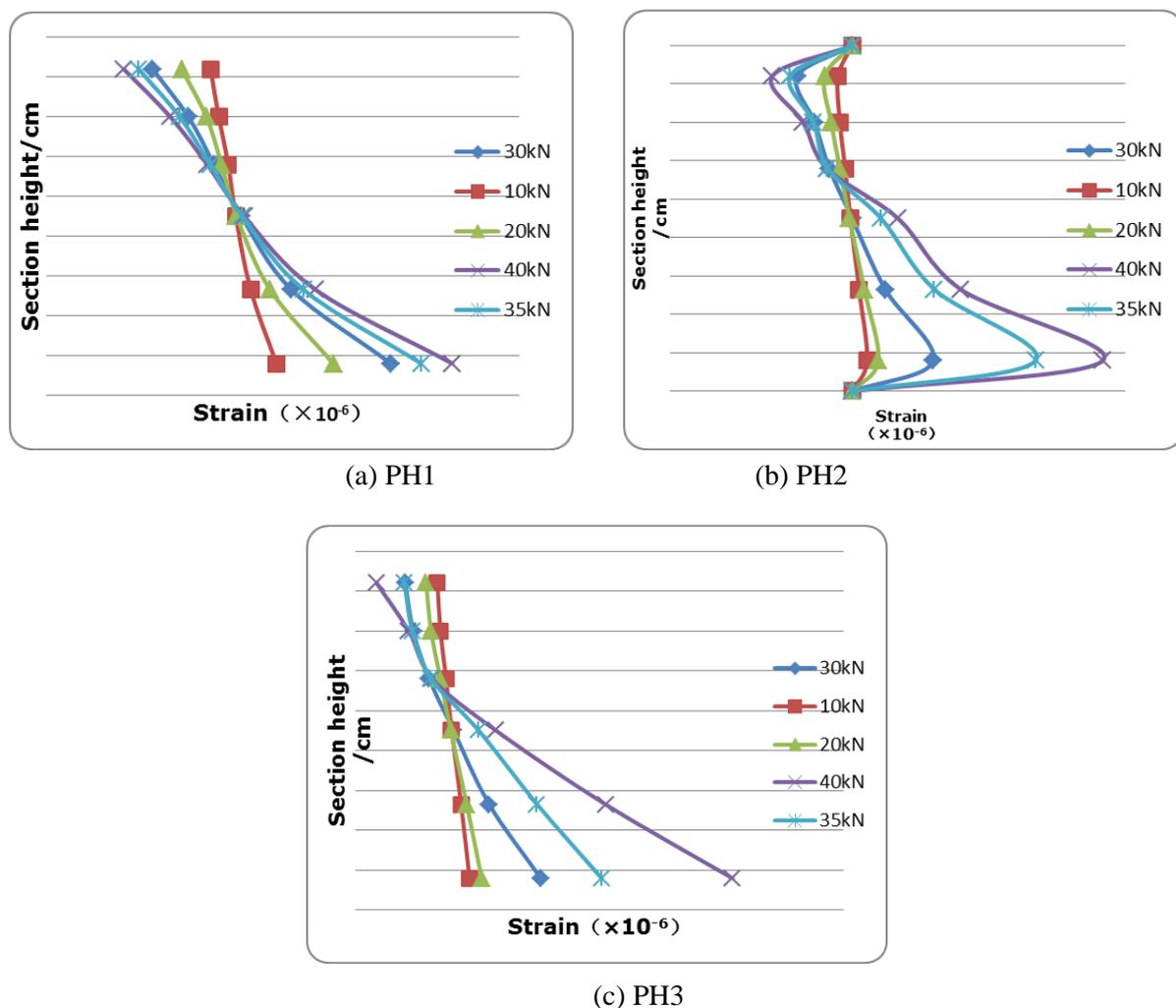
**Figure 2.** Cracks of specimen beams.

The loading process can be observed that the failure of the three big recycled aggregate self compacting concrete beams has undergone 4 stages of elasticity, cracking, yielding and failure, which

belongs to appropriate reinforcement failure. Finally, the tensile longitudinal reinforcement yield and the concrete in compression zone is crushed, which is consistent with the failure pattern of ordinary reinforced concrete beam and the failure pattern of recycled concrete beam and self compacting<sup>[10]</sup> concrete beam<sup>[11,12]</sup>.

### 3.2. Applicability of Plane Section Assumption

The plane section assumption is widely used in concrete, and it is one of the important assumptions of concrete beam, the premise of the calculation of concrete bending component in Code for design of concrete structures<sup>[13]</sup>. The analysis of the applicability of the plane section assumption is of great significance to the study of bending members of big recycled aggregate self compacting concrete beams. For the ordinary concrete beam, the longitudinal strain of the concrete at each point of the cross section varies linearly along the section height when the member is subjected to bending deformation. Figure 3 is curves of strain along beam cross section height of big recycled aggregate self compacting concrete with different replacement rates. It can be seen from the curves that during the test, the average strain curve of the concrete at each point of the midspan section is approximately straight regardless of the replacement rate of big recycled aggregates. The curve is basically consistent with that of the ordinary concrete beam and conform to the plane section assumption. Therefore, the plane section assumption can be used as the basis for the theoretical calculation of big recycled aggregate self compacting concrete beams.



**Figure 3.** Curves of big recycled aggregate self compacting concrete strain along beam cross section height.

### 3.3. Analysis of bending strength

It can be seen from Table 2 that the bending strength of big recycled aggregate self compacting reinforced concrete beam is much higher than that of plain big recycled aggregate concrete beams. The cracking load and the ultimate load of PH2 beam and PH3 beam were higher than that of PH1 beam, which means that the stone has a certain effect on the improvement of bending performance of big recycled aggregates self compacting concrete beams. The cracking load and ultimate load of PH3 beam is higher than that of PH2 beam, but not obviously. The replacement rate of big recycled aggregate affects the bending strength of beams. Reducing the replacement rate can improve the bending strength of the beam, but also increase the cost, and can not achieve the purpose of cost saving and effective use of construction waste. Therefore, the appropriate replacement rate should be chosen to save costs and to guarantee component strength to the greatest extent. In addition, the strength of big recycled aggregate maybe affected by its original defects. In order to ensure the integral performance of beams, big recycled aggregate with high strength and good integrity should be chosen as much as possible in actual engineering.

## 4. Conclusion and Prospect

Through the experimental research on the effect of different replacement rates on the bending behavior of big recycled aggregate self compacting concrete, the following conclusions are obtained:

- 1) The crack distribution of the big recycled aggregate self compacting concrete beam is affected by its replacement rate. The low or high replacement rate will cause uneven crack distribution of the beam, and the appropriate replacement rate can make the crack distribution of the beam more uniform.
- 2) The failure process and failure pattern of big recycled aggregate self compacting concrete beams are similar to those of ordinary concrete.
- 3) The plane section assumption is applicable to the big recycled aggregate self compacting concrete beams, and is unaffected by the replacement rate.
- 4) With the decrease of big recycled aggregate replacement rate, the bending strength of big recycled aggregate self compacting concrete beams is improved, but it is not obvious. In order to save costs and guarantee a certain strength, the appropriate replacement rate should be chosen to make the component. In practical engineering, the big recycled aggregate with high strength and good integrity should be used as far as possible to ensure the overall performance of the component.

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