We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900
Open access books available

185,000
International authors and editors

200M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Chapter

Construction Technology of Precast Pier Foundation Filled with Demolished Concrete Lumps

Wengui Li, Bin Lei, Zhiyu Luo and Fuzhi Yang

Abstract

Applying of demolished concrete lumps (DCLs) in the pier foundation is an effective way to improve the efficiency of construction waste resource utilization. Fifty-two cylindrical specimens with the size of ∅ 250 mm × 500 mm were fabricated by mixing of DCLs with the fresh concrete (FC) and used to investigate the influence of two key factors, the gradation of the DCLs and the height setting of layered "steel mesh," on the uniaxial compression and flexural strength properties of the compound concrete specimens. Results indicate that the layered "steel mesh" in the specimens can restrain the settlement and segregation of the DCLs and improve the compressive and flexural strength of the specimens significantly. Normally, there are two types of failure damage mode of the test pieces, the failure of the interface between DCLs and the FC and the fracture failure of the DCLs. When the stress level is below 0.5, the test piece is in the elastic stage. Crack development occurs when stress level further increase to 0.7–0.9. The pieces with the layered pouring height of H2 and the DCLs of R3 present the optimum compressive strength and flexural strength and also best construction effect.

Keywords: demolished concrete lump, precast pier foundation, construction technology, uniaxial compression test, flexural test

1. Introduction

Currently, China is in an important stage of urbanization development. A large number of construction wastes are generated in a series of projects such as the large-scale reconstruction of old cities and demolition of temporary or illegal buildings. It has become a trend to accelerate the resource utilization of construction waste. Literature [1] proposed a new method of recycling of waste concrete components, which use the large size of waste concrete block directly in the member. Instead of the normal way of using the waste concrete aggregate (fine aggregate size of 0.075–4.75 mm and coarse aggregate size of 4.75–40 mm) [2, 3], this method reuses the construction waste at the large block scale or even segmental level (scale 40 mm or higher), which thereby avoids the cumbersome process of production of recycled aggregate and results in a significant reduction of cost. The material obtained by mixing the waste concrete block with the new concrete is called as the regenerated block concrete. A large number of relevant studies have been conducted, which mainly include strength prediction of the compound concrete made of demolished concrete lumps (DCLs) and fresh concrete

(FC) [4–8], failure characteristics [9, 10], size effect [10, 11], basic creep [12–14], freeze–thaw mechanical properties [15, 16], pouring process [7, 17–19], hydration temperature rise [20, 21], impermeability [21], etc. Abundant theoretical achievements have been made based on these experimental studies. For field application, the exploration on the application of this compound concrete mainly focuses on the steel-concrete composite structure. There are good theoretical basis and broad prospect for the engineering application of the compound concrete [18].

Pier foundation is a foundation form between the rigid independent foundation and the manually dug pile foundation [22, 23]. Combining with the favorable geological conditions of Nanchang city, it is of great value to carry out the research on pier foundation, which will have a good application prospect in the foundation and foundation reinforcement treatment of multi-storey houses (such as villas and houses). Due to the large volume of the pier foundation, the large-diameter DCLs can be directly poured into the pier foundation with the FC in an appropriate ratio, thereby improving the efficiency of building resource utilization. At the same time, under the background of green, energy-saving, environmental protection and sustainable development as well as from the motivation of simplifying the material consumption and energy consumption for recycling of DCLs, the concept of precast pier foundation with DCLs mixed with FC is put forward. By the method of prefabrication, the quality of pier foundation filled with DCLs and FC can be well guaranteed. At the same time, it can achieve benefits such as more convenient construction, no noise [24], and construction cost-efficiency. This method is especially helpful when there is no favorable condition for site construction, the pump truck cannot arrive at the scene, there is a need to speed up the construction progress, etc. Research on precast pier foundation filled with DCLs and FC of the research has very important value.

In order to apply the compound concrete better in the pier foundation, the experimental research on the construction technology of the precast pier foundation filled with DCLs and FC was carried out. For related literatures mentioned above, it was found that current experimental studies for the compound concrete mainly concentrate on several factors including size of DCLs, mass replacement rate, strength difference of waste concrete strength, different proportions of FC and the shape of test piece shape, etc. However, there is no research for the gradation of DCLs, and the engineering problem of concrete segregation is likely to occur during the pouring and vibration process. In this paper, the corresponding test plan is proposed for these problems, and the suggestions for guiding the construction of precast pier foundation of compound concrete are obtained through test analysis. It provides theoretical basis for the engineering application of precast pier foundation filled with compound concrete.

2. Experimental procedures

2.1 Raw materials

The component materials of the compound concrete are the following: (1) Cement: Nanchang conch brand with 42.5 grade ordinary Portland cement (P.O 42.5) is adopted. The initial setting time of the cement is 203 min, and the final setting time is 250 min. (2) Fine aggregate: Ganjiang sand with apparent density of 2468.4 kg/m^3 and particle size less than 4.75 mm is adopted. It is a medium sand and is graded in zone II. (3) Coarse aggregate: crushed stone was used as coarse aggregate in the test, with particle size range 4.75–20 mm. (4) Water: the test water used is the potable tap water. (5) DCLs: in the test, the DCLs were taken from the concrete removed from the back street of Nanchang University and then processed into DCLs with particle size of 40–80 mm by crushing tools. According to the needs of this research, the



Figure 1.
Demolition and transformation of DCLs.



Figure 2.
Test DCLs after treatments.

original DCLs were sorted into two piles of DCLs with particle size of 40–60 mm and 60–80 mm, respectively, as shown in **Figures 1** and **2**. Before pouring, the DCLs must be wet, and the saturated surface-dry aggregates were used for pouring. (6) Fly ash: Hougang grade I fly ash was used in the test. The main components of fly ash are SiO_2 and Al_2O_3, accounting for more than 60% of the total content. (7) High-efficiency water-reducing agent: SM-F ultra-dry powder active high-efficiency water-reducing agent was used in the test, and the commonly used dosage was 0.5–1.5% of the cementitious materials.

2.2 Specimen design and production

A total of 52 cylinder specimens with size of ∅250 mm × 500 mm are used for this research, which consist of 13 groups of specimens with 4 specimens for each group. Research involves the following two factors: (1) The grade of DCLs. Four kinds of gradation with 40–60 mm to 60–80 mm DCL ratios of 2:8, 4:6, 6:4, and 8:2 are designed [25]. (2) The setting of the layered barrier "steel mesh." The design

w/c	Water (kg/m^3)	Cement (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	Fly ash (kg/m^3)	Water reducer (kg/m^3)
0.49	190	282	1087	688	98	6.46

Table 1.
Mix proportions of fresh concrete.

Notation	Number of specimens	Height of the layered pouring	Particle size grading of DCLs (40–60 mm: 60–80 mm)	$f_{cu,new}$ (MPa)	$f_{cu,old}$ (MPa)	η (%)
H1-R0	4	0 mm layer	—	36.37	22.12	30
H1-R1	4		2:8			
H1-R2	4		4:6			
H1-R3	4		6:4			
H1-R4	4		8:2			
H2-R1	4	100 mm layer	2:8			
H2-R2	4		4:6			
H2-R3	4		6:4			
H2-R4	4		8:2			
H3-R1	4	200 mm layer	2:8			
H3-R2	4		4:6			
H3-R3	4		6:4			
H3-R4	4		8:2			

Note: $f_{cu,new}$ and $f_{cu,old}$ represent the compressive strength of DCLs and FC, respectively. H represents the height of layered pouring, and R represents the gradation of waste concrete blocks.

Table 2.
Specimen parameters.

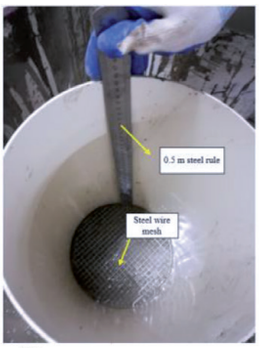
considered three kinds of layered method, which are 0, 100, and 200 mm layer. The quality of the construction technology are reflected and estimated by the mechanical properties of the specimens.

Specimens were made by mixing of DCLs with FC, and the same mixture ratio with water to cement ratio (w/c) of 0.49 is adopted for FC as given in **Table 1**. The compressive strength value of the FC test cube is 36.37 MPa. According to the results from rebound hammer, the compressive strength value of the DCLs is determined as 22.12 MPa. The replacement ratio η of the DCLs is set as the constant value of 30% [10], which is defined as the mass proportion of the DCLs to the overall specimen. The samples designed with different parameters are summarized in **Table 2**. The manufacturing process of compound concrete specimen is shown in **Figure 3**.

2.3 Test loading scheme

2.3.1 Uniaxial compression test of the specimen

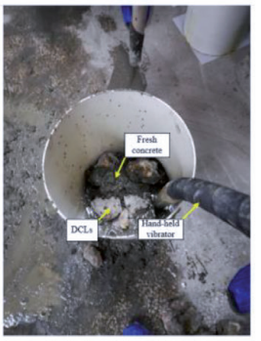
Microcomputer-controlled servo universal testing machine (model: SH-T4306) in Nanchang University mechanics laboratory is used for uniaxial compression test. Four YWC-30 type displacement meters with the range of 30 mm and accuracy of 0.005 mm are set around the specimen with a space of 90° to measure the displacement changes in the process of compression. The displacement meters



Step 1: pour 30 mm FC and then place the wire mesh



Step 2: put in the prepared DCLs



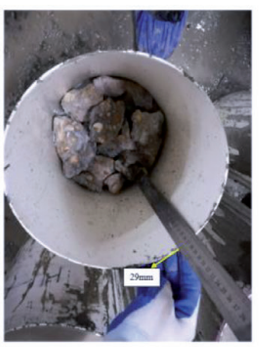
Step 3: add FC with vibration



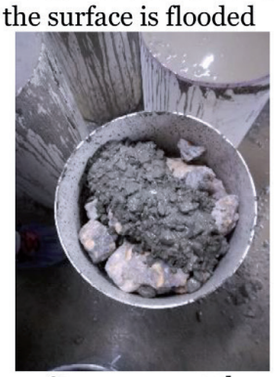
Step 4: when reaching 37 mm, vibrate until there is no obvious bubble and the surface is flooded



Step 5: place in the wire mesh for the second time



Step 6: put in the prepared DCLs for the second time



Step 7: repeat the above steps until the mould is filled



Step 8: vibrate the concrete to compact and smooth the surface



Step 9: formed specimen

Figure 3.
Construction process of specimens.

are placed in the middle of the specimen and the measuring distance is 0.4 times the height of the specimens. During the test of cylindrical specimens, the pressure direction was consistent with the pouring direction. The flatness of the upper surface of casted cylindrical specimens could not easily meet the compression test requirements. Therefore, 1 cm standard fine sand was laid on the upper surface of uneven specimens during the test. In order to prevent the sand laid on the upper surface of the specimen falling into the oil cylinder and damaging the press equipment, the specimen is firstly put into a stainless steel basin and then placed on the press machine. According to ASTM C39 (Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens) [26], the loading rate was set as 0.3 mm/min, and the test data were collected using UT7116Y static strain gauge with a collection frequency of 1 HZ. Before loading the press machine, the preloading value is set at about 30% of the peak load. The test device is shown in **Figure 4**.



Figure 4.
Uniaxial compression test device.



Figure 5.
Flexural strength test equipment.

2.3.2 Flexural strength test of specimens

Microcomputer-controlled universal electronic testing machine (model: LD26.305) in the structure laboratory of Nanchang university is adopted for the flexural strength test. The range of this machine is up to 300KN and the accuracy grade is 0.5. For the size of ∅250 mm × 500 mm of the casted specimens in this research, it does not meet the requirements for the flexural strength test. However, according to the bending test study for rectangular pavement brick with different spans between two supports [27], when the cross/thickness ratio is 2:1 or 3:1, there is no significant influence of the support span on the flexural strength of the rectangular road brick. As a result, it is feasible to use this kind of sample for bending test. According to the provisions of 4.6.3 in the code [28], the specimen is preloaded. The preloading load value is equal to 20% of the peak load, and the load is continuously and uniformly applied at the rate of 250 N/S. The test device is shown in **Figure 5**.

3. Uniaxial compression

3.1 Experimental phenomena

In this study, uniaxial compression tests were carried out on 13 groups of 26 specimens, and the results showed that no cracks were observed on the surface of the

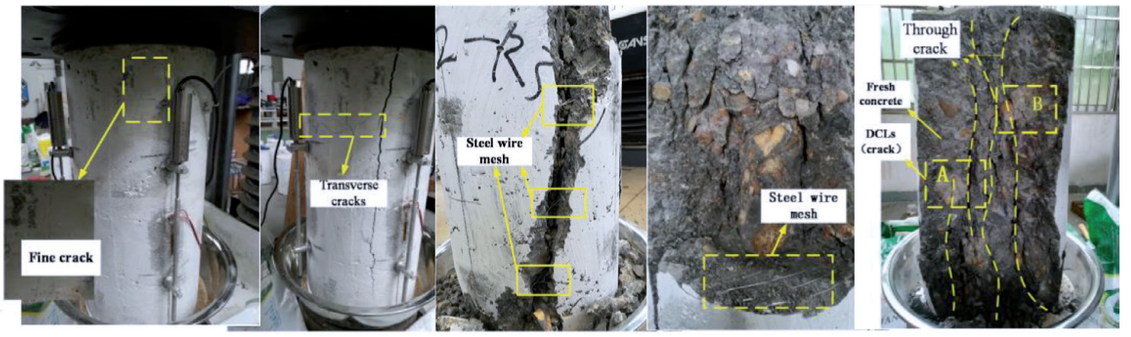


Figure 6.
Failure modes of typical samples. (a) Failure of H2 and H3 in various loading stages, (b) Failure of H1.

specimens at the initial stage of loading. Besides, when the load increases continuously to about 70–90% of the peak loading, tiny cracks start to appear at both ends of the specimen, as shown in **Figure 6**(**a1**). Further increasing the load to the peak load leads to the gradual expansion of the micro-cracks on the surface of samples, and the place where the "steel wire mesh" is placed generates cracks around the specimen. With the increase of the load, the crack propagation on the surface of specimen is relatively slow, and only few penetrative cracks are formed, but the crack ratio will gradually increase. After achieving the peak load, the specimen damage slows down with the loading. When the load decreased to 50–65% of P_u (P_u represents peak load), the load remains almost unchanged with the increases of displacement. At this period of time, the "wire meshes" restrain the rapid crack of specimens, improve the ductility of the specimens, and also improve the compressive strength of recycled concrete block, as shown in **Figure 6**(**a2**) and (**a3**).

As revealed in **Figure 6**(**a3**) and (**a4**), when constrained by "wire mesh" for crack, specimen maintains its integrity. At the same time, the "wire meshes" in the specimen also help to decrease the settlement of DCLs in the process of casting the samples, making it distribute uniformly in the specimen. In **Figure 6 (b)**, it can be seen that the interface between the DCLs and the FC is well poured without any cracks. By observing areas A and B in the figure, it can be found that the DCL is cracked, while the interface between the DCLs and the FC is not cracked, indicating that the DCLs and FC interface are not the obvious weak parts of the specimen.

3.2 Analysis of test results

The top surface treatment method and test values of each specimen are given in **Table 3**. Compared with the test results in literature [5, 10], the test results in this study are relatively low. The main reason is attributed to the absence of transverse constraint effect, namely, the "hoop effect" on the test piece due to the addition of sand on the uneven test surface. Besides, the size effect of the test piece also exacerbates this phenomenon.

3.3 Influence of gradation of DCLs on compressive strength

Based on the compressive strength values of each specimen in **Table 3**, the change of compressive strength with the gradations of DCLs for H1, H2, and H3 specimens classified by layered pouring height is given in **Figure 7**. According to the trend in **Figure 7**, the following conclusions can be drawn: (1) the compressive strength of compound concrete increases with the increase of the proportion of DCLs with

Notation	Surface	Compressive strength (MPa)		Notation	Surface	Compressive strength (MPa)	
		Test results	Average value			Test results	Average value
H1-R0–1	Place sand	15.77	15.95	H2-R3–1	Place sand	12.71	12.02
H1-R0–2	Place sand	16.12		H2-R3–2	Place sand	11.33	
H1-R1–1	Place sand	9.93	9.93	H2-R4–1	Place sand	11.49	11.38
H1-R1–2	No sand	14.13		H2-R4–2	Place sand	11.27	
H1-R2–1	Place sand	11.27	11.02	H3-R1–1	Place sand	10.72	11.38
H1-R2–2	Place sand	10.77		H3-R1–2	Place sand	12.04	
H1-R3–1	Place sand	12.52	12.37	H3-R2–1	Place sand	12.21	11.67
H1-R3–2	Place sand	12.21		H3-R2–2	Place sand	11.12	
H1-R4–1	Place sand	11.07	11.26	H3-R3–1	Place sand	12.34	13.54
H1-R4–2	Place sand	12.04		H3-R3–2	Place sand	14.75	
H2-R1–1	Place sand	11.73	11.73	H3-R4–1	No sand	14.28	11.51
H2-R1–2	No sand	15.32		H3-R4–2	Place sand	11.51	
H2-R2–1	Place sand	10.11	11.86				
H2-R2–2	Place sand	13.61					

Note: For average compressive strength of H1-R1, H2-R1, and H-R4, the compressive strength is taken directly from the sample with sand.

Table 3.
Results of compressive strength test.

particle size of 40–60 mm until it reaches 60%. When exceeding 60%, further increase in the content of DCLs with particle size of 40–60 mm would lead to strength reduction. (2) With the change of DCL grade, the specimens H1, H2, and H3 all show the maximum compressive strength when the grade is R3, which corresponds to the case that the ratio of 40–60 mm DCLs to 60–80 mm DCLs is 6:4. It is caused by a reason that under this gradation, the bulk density of DCLs is the highest, namely, a better natural gradation [29]. (3) The gradation of DCLs has a certain impact on the strength of compound concrete. For H1-type specimens, the compressive strength of H1-R3 is 24.57% higher than that of H1-R1. Similarly, the compressive strength of H2-R3 is 5.62% higher than that of H2-R4, and the compressive strength of H3-R3 is 18.98% higher than that of H3-R1. (4) With the same proportion, the strength of compound concrete specimens mixed by both FC and DCLs is lower than the specimens just made of FC. The greatest reduction occurs for H1-R1 sample. Compared with H1-R0, the compressive strength of it decreases by 37.7%.

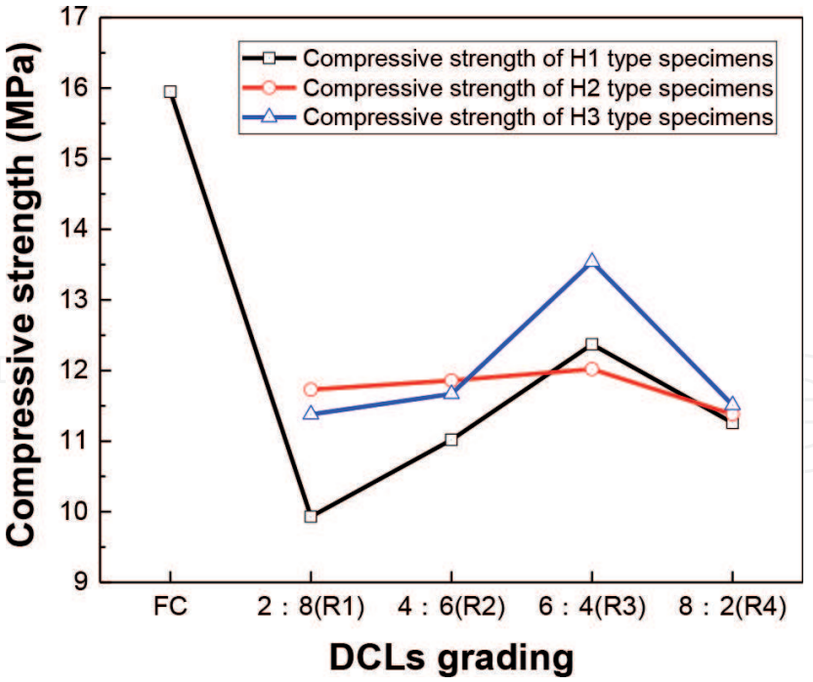


Figure 7.
The compressive strength of compound concrete with different DCL gradations.

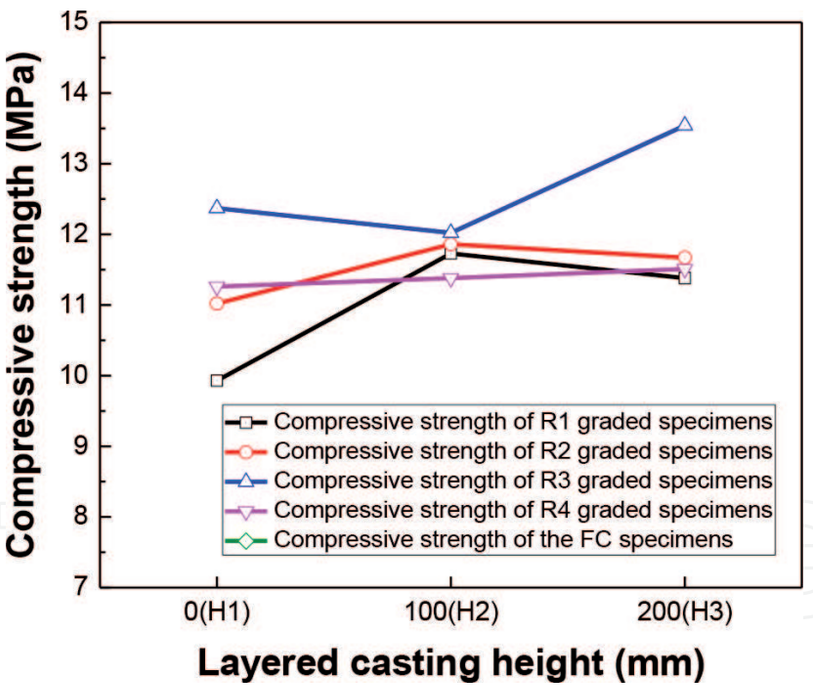


Figure 8.
The compressive strength of compound concrete with different layered casting heights.

3.4 Influence of layered pouring height on compressive strength

According to the compressive strength values of each specimen in **Table 3**, the influence of different layered pouring heights on the compressive strength of classified samples R1, R2, R3, and R4 with different DCL gradations is shown in **Figure 8**. The following conclusions can be drawn according to the results in **Figure 8**: (1) the compressive strength of compound concrete increases by 1.05–12.27% after steel wire mesh is put into each layer when layered pouring is adopted for R1, R2, and R4 gradations. (2) With the increase of the height of the layered pouring, the overall

performance change is not the same for all samples. The compressive strength of samples with R1 and R2 gradation DCLs increases first and then decreases with the increase of layered pouring height, which may be because the "steel wire mesh" is more in layered height of H2 specimen than in H3 specimen. The "steel wire mesh" inhibits the transverse deformation of the specimen, consumes part of the energy, and improves the compressive strength of the specimen. The compressive strength of sample with R4 gradation DCLs remains stable, indicating that this gradation is reasonable and plays a major role in the strength of compound concrete. The compressive strength of sample with R3 gradation DCLs is decreased first and then increased with the increase of the layered pouring height. The compressive strength value of this sample is higher than that of other gradation specimens when has the same layered pouring height. (3) When the height of layered pouring is set as H2, the measured compressive strength is more stable and less discrete.

3.5 Analysis of stress: strain relationship curve

Studying the changing trend of stress–strain curve is an important way to understand the deformation properties of specimens. In this paper, 13 groups of tests were carried out. Based on the analysis and consideration of both the two factors, it can be seen that the casting quality of the specimens is better when the gradations are R3 and R4, and it is easier to ensure the casting quality when the height of the layered casting is H2. Therefore, the stress–strain curves of R3 and H2 specimens were selected for comparative analysis in this paper to provide the theoretical basis for the application of compound concrete in prefabricated pier foundation.

As shown in **Figures 9** and **10**, the following conclusions can be drawn from the analysis: (1) the slope of the origin tangent line of the stress–strain curve of the FC specimen is greater than that of the specimen with DCLs, and the development trend of the stress–strain curve of the specimen with DCLs is consistent with that of the FC specimen. (2) The greater the compressive strength of the specimen in the steeper rising section of the curve, the greater the stiffness of the specimen. (3) Increasing the proportion of DCLs with particle size ranging from 40 to 60 mm

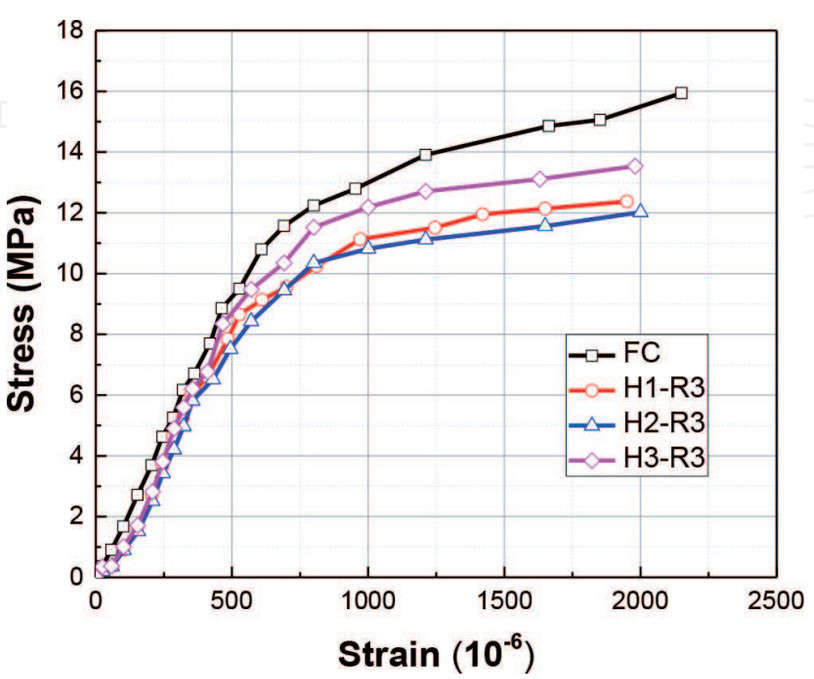


Figure 9.
Comparison of stress–strain curves of R3 specimens.

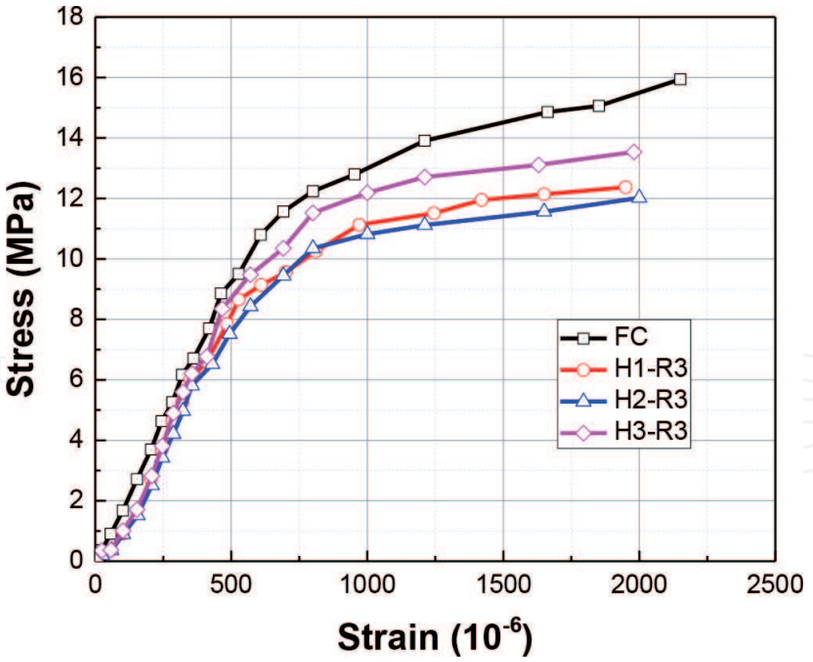


Figure 10.
Comparison of stress–strain curves of H2 specimens.

leads to the steeper rising section of the stress–strain curve and the smaller peak strain. When the particle size exceeds 60%, with the increase of the content of corresponding DCLs, the rising section of the stress–strain curve becomes gentle, and the peak strain increases. (4) The peak strain of the compound concrete specimen is in the range of 1800 × 10^{-6} to 2200 × 10^{-6}. The specimens are in elastic stage when the stress is around 0.5 f_c^0 fc0 (f_c^0 fc0 refers to the peak stress) and in crack development stage when the stress reaches 0.7–0.9 fc0 f_c^0.

4. Results and analysis of flexural strength

4.1 Experimental phenomena

In this study, 13 groups and 26 pieces of specimens were tested. The results show that:

1. In the loading process, micro-cracks are found in the tensile area of the pure bending section, which is, at the bottom of the pure bending section. With the increase of the load, the crack of the specimen gradually develops toward the compression region, and the final typical failure form of the specimen is shown in **Figure 11**. The failure crack of the specimen in the pure bending section is not through the whole section, which is affected by the steel wire mesh added into the specimen. The ultimate failure of the crack is parallel to the direction of stress, that is, the included angle is about 90^0.

2. As shown in **Figure 12**, two types of damages are identified for the fracture surface:

   a. In terms of the interfaces between the DCLs and FC as shown in **Figure 12**, the DCLs in the areas A and B correspond to the groove in areas A and B, indicating that the damage fracture of the specimen in bending test is due to the weak bond between the DLCs and FC interface.

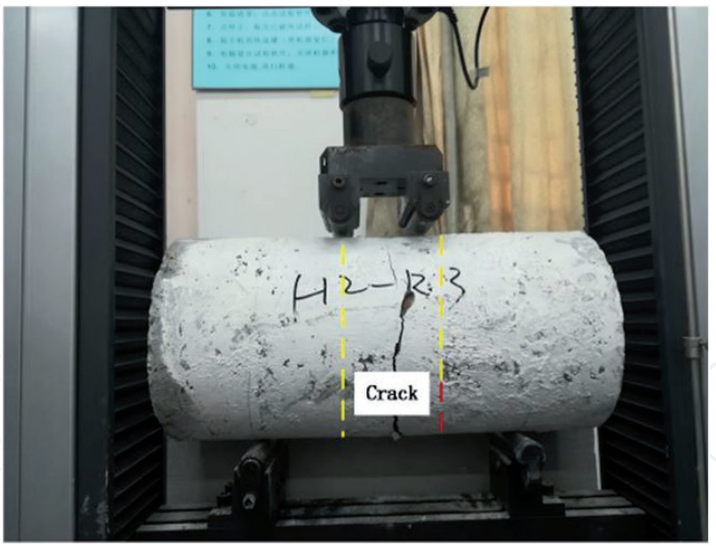


Figure 11.
Typical flexural failure modes.

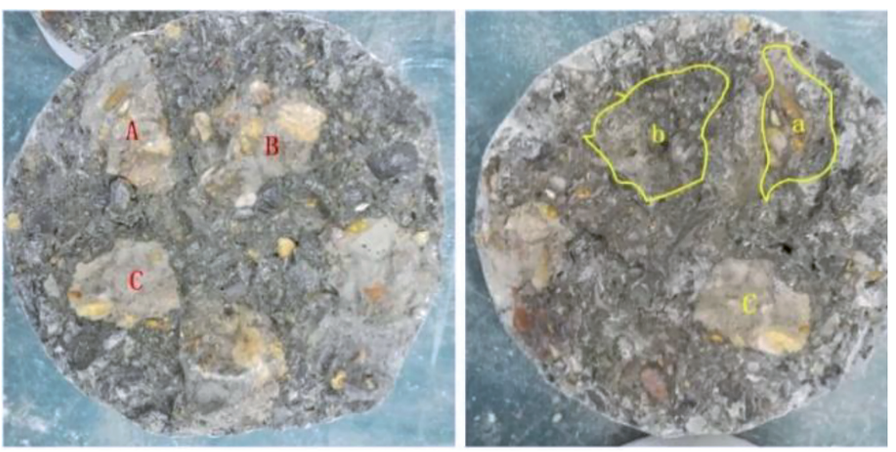


Figure 12.
Typical fracture surface.

b. The fracture failure of DCLs. Micro-cracks are generated on the DCLs during the crushing process. Besides, the strength of the DCLs is lower than that of the FC. Those factors lead to the fracture of the DCLs during flexural test.

4.2 Influence of gradation of waste concrete blocks on flexural strength

Based on the flexural strength results of each specimen in **Table 4**, the variation of flexural strength of specimens H1, H2, and H3 classified according to the height of layered pouring with the gradation of DCLs is present in **Figure 13**. The following conclusions can be drawn from **Figure 13**: (1) flexural strength of the fresh concrete specimen is higher than that of the recycled concrete specimen. Flexural strength of compound concrete arises with the increase of content of DCLs of the particle size from 40 to 60 mm. However, the limitation content for 40–60 mm DCLs is 60%, and the flexural strength of compound concrete would decrease if there is a further increase in its content. (2) As the gradation of DCL changes, the specimens H1, H2, and H3 classified according to the height of layered pouring all show the best flexural strength when the gradation is R3, namely, the ratio of 40–60 mm to 60–80 mm DCLs is 6:4. The flexural strength of H3-R3 specimen was

Notation	Flexural strength (MPa)		Notation	Flexural strength (MPa)	
	Test results	Average value		Test results	Average value
H1-R0–3	3.43	3.62	H2-R3–3	3.13	3.18
H1-R0–4	3.82		H2-R3–4	3.23	
H1-R1–3	2.84	2.81	H2-R4–3	2.92	2.96
H1-R1–4	2.78		H2-R4–4	3.00	
H1-R2–3	2.76	2.81	H3-R1–3	2.78	2.80
H1-R2–4	2.86		H3-R1–4	2.81	
H1-R3–3	2.99	3.04	H3-R2–3	2.91	2.91
H1-R3–4	3.09		H3-R2–4	2.92	
H1-R4–3	3.30	3.01	H3-R3–3	3.18	3.20
H1-R4–4	3.38		H3-R3–4	3.23	
H2-R1–3	2.88	2.92	H3-R4–3	2.83	2.86
H2-R1–4	2.95		H3-R4–4	2.88	
H2-R2–3	2.99	3.02	—	—	—
H2-R2–4	3.06		—	—	—

Table 4.
Results of flexural strength test.

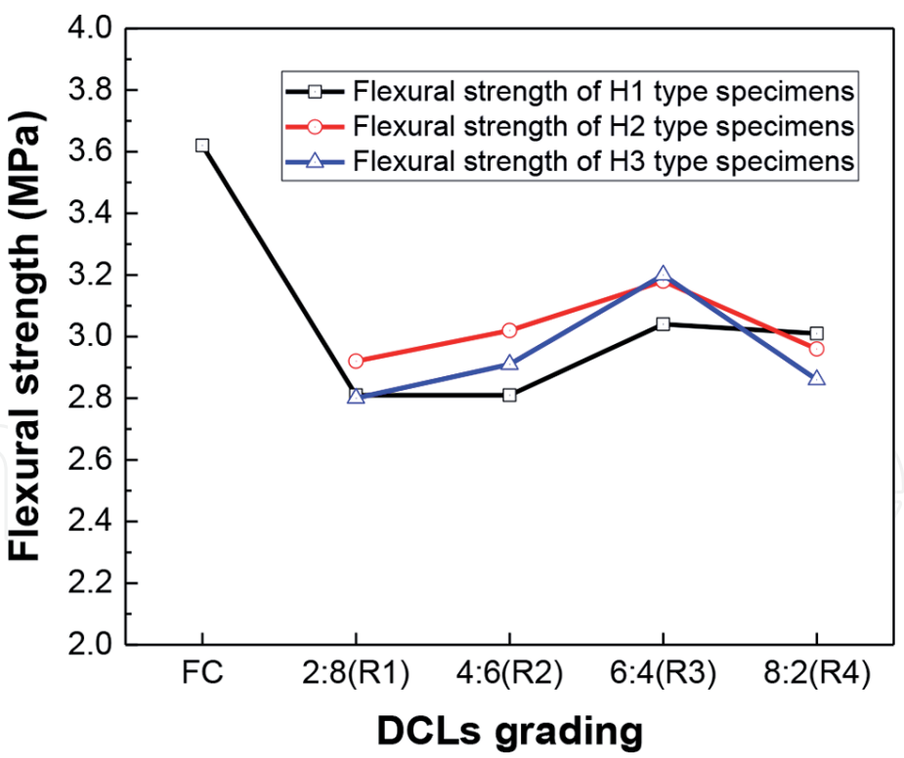


Figure 13.
Flexural strength of compound concrete with different gradations of DCLs.

14.28% higher than that of H3-R1. (3) Flexural strength of H2 type specimens is generally more regular than that of H1 and H3 type specimens. Except for differences for few situations, for instance, flexural strength of H2-R3 is 0.63% lower than that of H3-R3 and flexural strength of H2-R4 is 1.66% lower than that of H1-R4, the H2 type specimens generally show the best flexural strength.

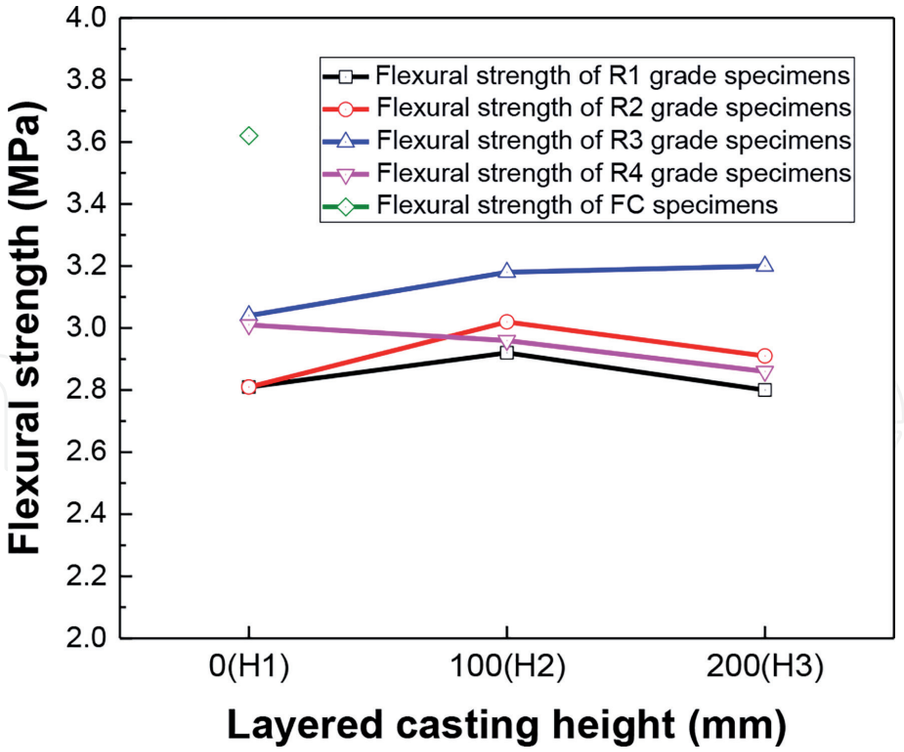


Figure 14.
Flexural strength of compound concrete with different layered casting heights.

4.3 Influence of layered pouring height on flexural strength

The influence of layered pouring height on flexural strength of compound concrete with R1, R2, R3, and R4 grade DCLs is displayed in **Figure 14**. The following conclusions can be drawn from **Figure 14**: (1) the flexural strength of compound concrete with R3 gradation DCLs is higher than that of compound concrete with R1, R2, and R4 gradation DCLs. The R1 and R2 graded compound concrete achieve their maximum flexural strength value when the lamination height of them is 100 mm, which is not the same for R3 and R4 graded compound concrete. It is hard to reveal the change law of the flexural strength as it is affected by many factors. (2) The flexural strength of the compound concrete with R1, R2, and R3 gradations of DCLs are improved with the addition of the layered steel wire mesh. However, with the addition of steel wire mesh, the flexural strength of the compound concrete with R4 gradation of DCLs decreases, which may be due to the poor casting quality of the samples under this grade, resulting in the reduction of the flexural strength.

5. Suggestions on construction technology of precast pier foundation

Based on the phenomenon and results of uniaxial compression test and flexural test, suggestions are provided for the construction of precast pier foundation filled with DCLs and FC in practical engineering. In the uniaxial compressive test, the specimens are layered pouring according to the height of "steel wire mesh," which can increase the compressive strength of the compound concrete specimens by 12.27% at most. Adjusting the gradation of DCLs can realize a maximum improvement of 24.57% for the compressive strength of the compound concrete specimens. In the flexural test, the flexural strength of compound concrete is also improved with the adjustment of the above two factors. Therefore, both the gradation of DCLs and the setting of layered "steel wire mesh" at suitable height

can effectively improve the casting quality and construction technology for the construction of precast pier foundation filled with DCLs and FC. Combining the results of uniaxial compression strength test with those of flexural strength test, the specimen can achieve the optimum strength performance when the gradation of DCLs in it is R3.

According to the results of uniaxial compression test and flexural test, the specimens with layered pouring height of H2 can reach the optimum strength value. Namely, "steel wire mesh" is set according to the height of 100 mm for layered pouring. In the test, when the ratio of the diameter to the height of the specimen is set as 1:2 and the pouring layer ratio of the specimen is set as 1:5, better casting quality is achieved. In order to serve as a reference for the construction technology of the precast pier foundation filled with DCLs and FC, the concept of "pouring layer ratio" is proposed which refers to the ratio of the height of the pouring layer to the height of the specimen. According to the size of precast pier foundation filled with DCLs and FC, the height of layered pouring is set according to the "pouring layer ratio."

There are important points that should be noted during the pouring process of compound block: (1) the DCLs should be wetted before pouring to prevent the DCLs from absorbing too much water during pouring. Otherwise, it would affect the workability of FC and reduce the construction quality. (2) The sample should be vibrated by handheld vibrator during pouring. According to the code [30], there are three points to be noted as follows:

1. The insertion depth in the vibratory process should be controlled within the range of 50–100 mm. Besides, it cannot be too close to the mold, and suitable distance is around 50–100 mm. The other side should not collide with the steel cage to avoid damaging the strain gauge and affecting the measurement of test data.

2. The vibration time of each vibration point is determined by satisfying aspects that the FC would no longer sink (the surface appear floating slurry, the DCLs being surrounded by FC, and no over vibration and leakage vibration).

3. After completing a vibration process and needing to exchange the vibrate position, the vibrator has to be raised vertically slowly instead of being dragged horizontally in concrete.

The coarse aggregate particle size of the FC used in the casting of compound concrete should be no more than 20 mm, and the slump of FC should be at large value of about 160 mm. In the pouring process, the FC and the DCLs are put into the concrete repeatedly and alternately, which should be accompanied by sufficient vibration.

6. Conclusion

1. The failure phenomenon of the specimen in the uniaxial compression test shows that adding "steel wire mesh" to the specimen for layered pouring can restrain the settlement and segregation of the DCLs. In addition, during the unloading stage, the added "steel wire mesh" inhibits the rapid cracking and improves the ductility of the specimen and thus enhances the compressive strength. In the flexural test, two failure forms are present on the failure surface of the specimen, namely, the failure of interface between the DCLs and the FC and the fracture failure of the DCLs.

2. The compressive and flexural strength of the compound concrete would increase gradually with the increase of the proportion of 40–60 mm DCLs until it reaches 60%. The maximum strength achieved at the gradation of R3 (40–60 mm DCLs: 60–80 mm DCLs = 6:4) and further increase in the proportion of 40–60 mm DCLs would results in decrease of strength. The compressive strength of H1-R3 specimen was increased by 24.57% compared with H1-R1. The flexural strength of H3-R3 specimen was 14.28% higher than that of H3-R1.

3. Stress–strain curve of the compound concrete filled with DCLs and FC was analyzed. It is concluded that the slope of the origin tangent line of the stress–strain curve of the FC specimen is greater than that of the specimen with DCLs and the development trend of the stress–strain curve of the specimen with DCLs is consistent with that of the FC specimen. The peak strain of the compound concrete specimen is in the range of 1800×10^{-6} to 2200×10^{-6}. The specimens are in elastic stage when the stress is around $0.5 f_c^0$ (f_c^0 refers to the peak stress) and in crack development stage when the stress reaches $0.7–0.9 f_c^0$.

4. It is concluded from the analysis that the compressive strength and flexural strength of the specimens are best when the height of layered pouring is H2 and the grade of DCLs is R3, and it also reflects that the construction process has the best effect under this condition. The suggestions for the construction technology of precast pier foundation filled with DCLs and FC are proposed.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (51668045 and 51808133) and Jiangxi Science and Technology Committee (20161BBG70056). The authors also acknowledge the research supports from the Australian Research Council (ARC), Australia.

Author details

Wengui Li[1*], Bin Lei[1,2], Zhiyu Luo[1] and Fuzhi Yang[2]

1 Center for Green Technology, School of Civil and Environmental Engineering, University of Technology Sydney, NSW, Australia

2 School of Civil Engineering and Architecture, Nanchang University, Nanchang, Jiangxi, P.R. China

*Address all correspondence to: wengui.li@uts.edu.au

IntechOpen

© 2019 The Author(s). Licensee IntechOpen. Distributed under the terms of the Creative Commons Attribution - NonCommercial 4.0 License (https://creativecommons.org/licenses/by-nc/4.0/), which permits use, distribution and reproduction for non-commercial purposes, provided the original is properly cited. BY–NC

References

[1] Wu B, Liu Q, Liu W. Primary study on recycled-concrete-segment filled steel tubular members. Earthquake Resistant Engineering and Retrofitting. 2008;**4**:120-124. (in Chinese)

[2] GB/T 25176. Recycled Fine Aggregate for Concrete and Mortar. Beijing: China Building Industry Press; 2010. (in Chinese)

[3] GB/T 25177. Recycled Coarse Aggregate for Concrete. Beijing: China Building Industry Press; 2010. (in Chinese)

[4] Wu B, Zhang S, Yang Y. Compressive behaviors of cubes and cylinders made of normal-strength demolished concrete blocks and high-strength fresh concrete. Construction and Building Materials. 2015;**78**:342-353

[5] Zhang J. Experimental Study on Axial and Seismic Behaviors of Square Thin-Walled Steel Tubular Columns Filled with Demolished Concrete Lumps. Guangzhou: South China University of Technology; 2011. (in Chinese)

[6] Zhang S. Compressive Behaviors of Cubic and Cylindrical Specimens Made of Normal-Strength Demolished Concrete Blocks and High-Strength Fresh Concrete. Guangzhou: South China University of Technology; 2014. (in Chinese)

[7] Liu L. Test Study on Casting Technology and Uniaxial Compressive Behaviors of Compound Concrete Made of Demolished Concrete Lumps and Fresh Concrete. Guangzhou: South China University of Technology; 2017. (in Chinese)

[8] Wu B, Liu L, Zhao X. Test study on uniaxial compressive behaviors of compound concrete made of normal-strength demolished concrete lumps and high-strength self-compacting concrete. Journal of Building Structures. 2016;**37**(S2):73-78. (in Chinese)

[9] Wu B, Liu C, Wu Y. Compressive behaviors of cylindrical concrete specimens made of demolished concrete blocks and fresh concrete. Construction and Building Materials. 2014;**53**:118-130

[10] Liu C. Size Effect on Compressive Behaviors of Cubes and Cylinders Made of DCBs & FC and Seismic Behaviors of Double Thin Skin Hybrid Walls Filled with DCBs & FC. Guangzhou: South China University of Technology; 2013. (in Chinese)

[11] Wu B, Liu C, Yang Y. Size effect on compressive behaviours of normal-strength concrete cubes made from demolished concrete blocks and fresh concrete. Magazine of Concrete Research. 2013;**65**(19):1155-1167

[12] Yan H. Creep Behaviour of Cylinders Made of DCBs & FC and Thin-Walled Circular Steel Stub Columns Filled with DCBs & FC. Guangzhou: South China University of Technology; 2014. (in Chinese)

[13] Ai W. Creep Behaviour of Cylinders Made of Normal-Strength DCLs and High-Strength FC and Stub Steel Columns Filled with Normal-Strength DCLs and High-Strength FC. Guangzhou: South China University of Technology; 2017. (in Chinese)

[14] Wu B, Ai W, Zhao X. Test on basic creep behaviors of compound concrete made of normal-strength demolished concrete lumps and high-strength fresh concrete. Journal of Building Structures. 2016;**37**(S2):109-114

[15] Li Z. Mechanical Properties of Compound Concrete Containing Demolished Concrete Lumps at Room

Temperature and after Freeze-Thaw Cycles. Guangzhou: South China University of Technology; 2018. (in Chinese)

[16] Wu B, Li Z. Mechanical properties of compound concrete containing demolished concrete lumps after freeze-thaw cycles. Construction and Building Materials. 2017;**155**:187-199

[17] Wu B, Ji M, Zhao X. State-of-the-art of recycled mixed concrete (RMC) and composite structural members made of RMC. Engineering Mechanical. 2016;**33**(1):1-10. (in Chinese)

[18] Wang L, Jin H. Research and discussion on recycled concrete engineering application. Building Construction. 2016;**12**:1754-1756. (in Chinese)

[19] Xu J. Preliminary Application on the Engineering Adaptability of Concrete Structural Members Filled with Demolished Concrete Lumps. Guangzhou: South China University of Technology; 2012. (in Chinese)

[20] Wu B, Wu D. Test study on hydration temperature of compound concrete made of demolished concrete lumps and fresh concrete. Procedia engineering. 2017;**210**:120-125

[21] Wu D. Study on Temperature Rise of Hydration and Impermeability of Concrete Made of Demolished Concrete Lumps and Fresh Concrete. Guangzhou: South China University of Technology; 2018. (in Chinese)

[22] Liu Z. Experimental Investigation of Non-reinforced Concrete Pier Foundation. Shenyang, China: Northeastern University; 2009. (in Chinese)

[23] Liu Z, Zhu F, Shu Z. Research on horizontal capacity of widen-bottom non-reinforced concrete pier foundation on cohesive soil. Journal of Liaoning Technical University (Natural Science). 2008;**6**:850-852. (in Chinese)

[24] Jiang J, Gao G. Study on modifying coefficient of end-bearing resistance of large diameter belled piles. Rock and Soil Mechanics. 2006;**12**:2282-2288. (in Chinese)

[25] Dai Z. Gradation of coarse aggregate of dam concrete. Yangze River. 1994;**09**:14-20. (in Chinese)

[26] ASTM C39. Standard test method of compressive strength of cylindrical concrete specimens: American Society for Testing and Materials. 2001

[27] Benítez A, Bertone J, Civitillo P. Verification test research on flexural strength test method of concrete pavement brick. Building Block and Block Building. 2010;**05**:24-28. (in Chinese)

[28] SL352. Code of Test for Hydraulic Concrete. Beijing: China Building Industry Press; 2006

[29] Li J, Xiao J, Sun Z. Properties of recycled coarse aggregate and its influence on recycled concrete. Journal of Building Materials. 2004;**04**:390-395. (in Chinese)

[30] GB/T 50081. Standard test method for mechanical properties of ordinary concrete. Beijing: China Building Industry Press; 2002