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The Study on the Performance of Regeneration Aggregate Pavement Base Material Under Standard Grading Median

Hui Zhao[1], Xiaoping Cai[1,a], Wencui Yang [1],Penghuan Liu[1]

[1]Harbin Institute of Technology School of Transportation Science and Engineering, Harbin , China.

[a]0414a2@163.com

Abstract. In recent decades, with social and economic development, many new buildings and buildings have been built, while many old buildings have been demolished. Therefore, the world should consider how to reuse construction waste. Reuse of construction waste as aggregate to new buildings or road construction is an effective way. The effect of median aggregate regeneration aggregate on the performance of pavement base material was studied in this paper. Recycled concrete aggregate was used to replace 25 %, 50 % and 75 % of natural aggregate by volume, respectively. While the recycled clay brick was used to replace 5 %, 10 %, 15 % and 30 % of natural aggregate by volume. In addition, recycled aggregate composed of recycled concrete and recycled clay bricks in different proportions was used to replace aggregate of road base materials. The maximum dry density, optimum moisture content, unconfined compressive strength and drying shrinkage of road base materials were studied. The results show that the optimum moisture content increases with the increase of recycled aggregate replacement, and the biggest dry density decreases with the increase of recycled aggregate replacement. Recycled aggregate can improve the 7 d unconfined compressive strength of pavement base material and reduce the dry shrinkage rate in a certain range of replacement rate. When the aggregate was 100 % recycled aggregate, with the increase of recycled clay brick content, the 7d unconfined compressive strength of the material decreases and the drying shrinkage would increase.

Keywords: construction waste; regeneration aggregate; optimal moisture content; the biggest dry density; unconfined compressive strength; drying shrinkage

1. Introduciton

In recent years, with the continuous development of China's construction industry, the demand for aggregate was also growing. Meanwhile, old buildings are being demolished [1]. In such cases, natural aggregates available for construction and concrete are decreasing, owing to increased demand in the construction industry worldwide. In some studies, the recycled aggregate(RA), which is produced from construction waste, has been considered to be economically and environmentally beneficial. In some studies, recycled aggregate (RA) generated from construction waste can be used in some construction projects[2;3;4], and more and more people begin to focus on the subject and application of construction waste recycling[5;6;7].

In the past few years, many scholars had studied the application of RA in some buildings. However, in these studies[8;9;10;11], RA was mainly used for mortar or concrete. At present, there are few studies on RA as pavement base material. In fact, using RA as subgrade material is an effective method. Despite this, a few studies indicates that RA could be used in highway base[12]. It can be seen that recycled aggregate obtained from waste concrete could replace natural aggregate and be added to pavement base material

2. Experimental Methodology

2.1 Materials

All mixtures were made of ordinary Portland cement in accordance with GB 175 - 2007. Physical properties of cement for experiments are shown in table 1.

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Table 1. Physical properties of cement

Initial setting time(min)	Final setting time(min)	Flexural strength(MPa)		Compressive strength(MPa)	
		3d	28d	3d	28d
195	245	4.0	7.8	23.1	47.8

Two types of recycled aggregates: recycled concrete aggregate (RCA) and recycled clay brick(RCB) are considered in this study. The natural aggregate used in the experiment is from Harbin, and the regeneration aggregate is from Shenzhen. First, RA is naturally dry. Then, RCA and RCB were screened with different sizes according to JTG/T F20-2015. The screening results showed that RA particle size distribution was inhomogeneity. Therefore, the RA used for road substrate needs to be selected in each sieve. The amount of NA and RA is determined according to the set range shown in Table 2. (We believe that the median gradation performs better in the experiment)

Table 2. distribution range of natural and recycled aggregates

The size of screening （mm）	31.5	26.5	19.0	9.5	4.75	2.36	0.6	0.075
Grading limit （%）	100	95	80.5	57	39	26	15	3.5

2.2 Details of Road Base Materials Mixes

The research of road subgrade material mixture includes three parts. RA consists of RCA and RCB in different proportions, and replaces NA to produce road subgrade materials. Firstly, the biggest dry density and optimum moisture content under different ratios were studied. Secondly, the unconfined compressive strength of each ratio was tested. Finally, the drying shrinkage was tested. Pavement base material fit as shown in table 3.

Table 3. Mixture ratio of pavement base material

Mix designation	NA (vol.-%)	RCA (vol.-%)	RCB (vol.-%)
1	100	0	0
2	75	25	0
3	50	50	0
4	25	75	0
5	95	0	5
6	90	0	10
7	85	0	15
8	70	0	30
9	0	85	15
10	0	70	30

2.3 Test Methods

All the tests in this paper were conducted according to the requirements of JTG E51 - 2009. Moreover, the compaction test was carried out according to the method of T0804 - 1994 to obtain the biggest dry density and the optimum moisture content. The unconfined compressive strength of 150 φ × 150 mm cylinder specimens was tested according to the requirements of T0843-2009 and T0805-1994. The 7-day drying shrinkage of 100 mm × 100 mm × 400 mm prism specimens was tested according to the standard T0854-2009. Three cylindrical and three prismatic specimens were prepared for each ratio, and tested according to the standard requirements, and then the average value was taken.

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3. Result And Discussion

3.1 Compaction Test

First, the dry density and optimal moisture of the road base materials ware tested in different mix designation. Then the optimum moisture content and the biggest dry density of the material are obtained by fitting. The results of optimal moisture content and the biggest dry density in the subgrade materials with RCA are presented in Table 4. The experimental results show that the biggest dry density of the pavement base material composed of RCA decreases with the increment of the volume replacement rate of recycled aggregate, and the optimum moisture content increases with the increment of the volume replacement rate of recycled aggregate. The optimal moisture content of the subgrade material composed entirely of RCA is more than twice that of the subgrade material composed entirely of NA.

Table 4. The biggest dry density and optimum moisture content of base material (RCB+NA)

Mix designation	The biggest dry density	optimal moisture content
1	2.46 g/cm^3	5.0%
2	2.45 g/cm^3	7.3%
3	2.38 g/cm^3	8.8%
4	2.33 g/cm^3	9.8%
5	2.27 g/cm^3	11.1%

Then the RCB was used to replace natural aggregate to prepare road base materials. It can be seen from Table 5 that the maximum dry density and optimum moisture content of pavement base materials increase with the increase of the volume substitution rate of RCB. Moreover, under the similar replacement rate, the optimal moisture content of the pavement base material with RCB is much higher than that of the pavement base material with RCA. At the same time the maximum dry density of the pavement base material using the RCB is lower than the pavement base material using the RCA. It reveals that RCB has more pores than RCA.

Table 5. The biggest dry density and optimal moisture content of base material (RCA+NA)

Mix designation	The biggest dry density (g/cm^3)	optimal moisture content(%)
6	2.43	5.9
7	2.40	6.9
8	2.38	7.4
9	2.33	10.3

Some mixtures ware designed that the aggregate was all replaced with RCA and RCB. Then the result of them is shown in Table 6. The maximum dry density of road base material using only recycled aggregate is much lower than the road base material using only NA. The optimal moisture content increased at least 158% when the NA was replaced by RCA and RCB.

Table 6. Optimal moisture content and the biggest dry density of base material RCA+RCB)

Mix designation	The biggest dry density (g/cm^3)	optimal moisture content(%)
1	2.46	5.0
10	2.18	12.9
11	2.07	14.3

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The reason for the above phenomenon is that the recycled aggregate contains more porous components and cement stones, and they have higher water absorption.

3.2 Results of Unconfined Compressive Strength

Figure 1a shows the relationship between the replacement level of RCA and the unconfined compressive strength. It is observed that the 7-day unconfined compressive strength increased with the increasing of the replacement level of RCA as a whole. The reason for this situation is that there are many powders in the RCA, which can be used as filling material in the mixture and increase the 7-day compression resistance of the system.

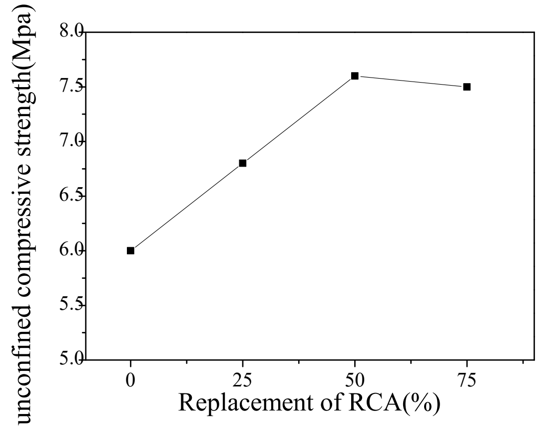

Figure 1a Effect of RCA replacement rate on 7 - day unconfined compression strength of samples

Figure 1b indicates that with the addition of RCB, the mixture 7-day unconfined compressive strength decreased with the increase of RCB content. With the content of RCB reaching 15%, the strength of the mixture decreases by 20%. The reason for the above phenomenon is that the RCB has low strength and produced many needle-like particles in the process of artificial crushing. RCB can greatly reduce the supporting role of aggregate in the whole system, which will lead to the reduction of the strength of the mixture.

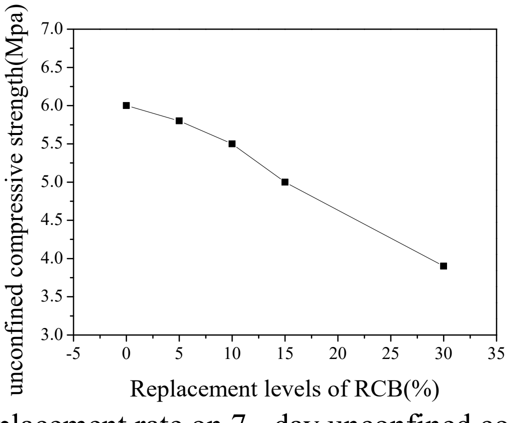

Figure 1b Effect of RCB replacement rate on 7 - day unconfined compression strength of samples

Table 7 shows the 7-day unconfined compressive strength of mixtures consisting entirely of aggregates of different proportions of RCA and RCB. A certain proportion of aggregate which composed of RCA and RCB can improve the strength of the sample. However, with the increase of the proportion of RCB in aggregate, the strength of the sample gradually decreases. When the RCB content is 15 %, the strength of recycled aggregate is higher than that of the sample with NA, while when the RCB content is 30 %, the strength of recycled aggregate is lower than that of the sample with NA.

Table 7 Effect of RCA and RCB replacement rate on 7 - day unconfined compression strength of samples

RCA (vol.-%)	RCB (vol.-%)	unconfined compression strength(Mpa)
85	15	6.6
70	30	6.0

3.3 Results of Drying Shrinkage

Road base materials were prepared by replacing NA with RCA and RCB according to different substitution rates. The effects of different substitution rates on the drying shrinkage of samples are shown in Fig. 2a and Fig. 2b. The results showed that the drying shrinkage rate of specimens increased with the increase of maintenance age. There was no significant difference in the drying shrinkage rate of the specimens with different replacement levels of RCA. The drying shrinkage of all specimens decreased with the incorporate of RCB. When the volume content of RCB is constant, the system using RA has a larger drying shrinkage rate than the other one.

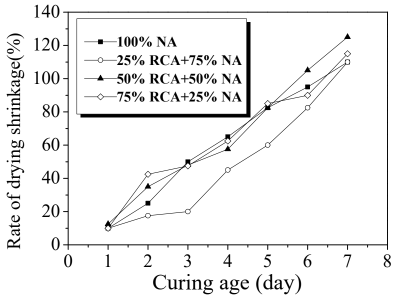

Figure 2a Effect of RCA replacement rate on drying shrinkage of samples

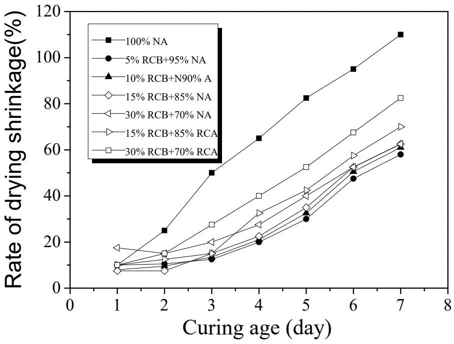

Figure 2b Effect of RCBreplacement rate on drying shrinkage of samples

4. Conclusions

Based on the experimental results observed through various laboratory tests on the RA and NA mixes, the following conclusions have been made:

(1) Recycled concrete has lower strength, higher water absorption and higher interfacial adhesion than natural aggregate.

(2) The performance of the sample is determined by the content of recycled aggregate. The biggest dry density and optimum moisture content increase with the increase of dosage. When RCA content does not exceed 40 % and RCB content does not exceed 15 %, both can be used as pavement base materials.

(3) Different types of RA have different effects on the strength. RCA can improve the 7-day unconfined compression strength of the system, while RCB can reduce the strength of the system.

(4) The effect of RCA on the drying shrinkage is not remarkable. While the RCB can decreased

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the drying shrinkage of the samples. When the proportion of aggregate is 70% RCA and 30% RCB, the drying shrinkage rate of 7 days reaches the maximum 80×10^{-6}.

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