Experiment on Recycled Construction Waste Mixture Used in Subbase

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Abstract: In order to improve the recycling efficiency of construction waste and make rational use of the concrete and brick demolished in the process of urban construction, the application of construction waste recycling mixture in road engineering was studied in this paper. Test results showed that the reasonable combination of recycled concrete and brick slag could achieve the purpose of reasonable utilization of construction waste and meet the strength of municipal road base mixture.

1. Introduction

The main components of construction waste are concrete, brick and other materials. There are also differences in the composition of construction waste demolished for different structural forms such as brick structure, frame structure and frame shear structure (Table 1).

Table 1 proportion of construction waste in Zhengzhou area[1]

| Composition       | Construction waste proportion (%) |
|-------------------|-----------------------------------|
|                   | Brick structure | Frame structure | Frame shear structure |
| Concrete          | 9.01             | 53.42            | 54.61                |
| Brick             | 48.72            | 8.43             | 8.02                 |
| Stone, gravel     | 21.18            | 12.97            | 12.05                |
| Sand and soil     | 9.43             | 11.33            | 10.89                |
| Glass             | 0.35             | 0.20             | 0.59                 |
| Metal             | 3.17             | 3.41             | 5.31                 |
| Plastic           | 0.46             | 0.61             | 0.59                 |
| Wood              | 5.53             | 7.26             | 6.03                 |
| Ceramic tile      | 1.05             | 1.16             | 1.07                 |
| Others            | 1.10             | 1.21             | 0.84                 |
| Total             | 100              | 100              | 100                  |

The recycled mixture of construction waste refers to the recycled mixture of concrete, brick slag and other materials in a certain proportion after crushed. For now, the reuse of construction waste
mainly refers to the use of construction waste recycling materials. Construction waste has been studied and applied in the field of domestic road engineering[2-6], but most of them focused on the physical and mechanical properties of recycled concrete[7-12].

Many studies have shown that there is a large proportion of impurities in recycled aggregate of construction waste, and the low strength of recycled aggregate led to the low utilization rate and narrow range of recycled aggregate of construction waste. A certain proportion of waste brick and waste concrete mixture recycled materials have been suggested to use in practice in some experimental research[13], but the application research in road engineering has not been found. In order to improve the overall utilization rate of construction waste and make rational use of the concrete and bricks removed in the process of urban construction, it is necessary to expand the application research of construction waste recycling materials in road engineering.

2. Structure analysis of subgrade mixture
When the pore volume of the coarse aggregate after compaction of the base material is smaller than that of the fine aggregate and binder, the coarse aggregate is dispersed or suspended in the continuous and compacted fine aggregate and binder to form a suspension dense structure; when the pore volume of the coarse aggregate after compaction of the base material is far larger than that of the fine aggregate and binder, the part of the void between the coarse aggregate skeleton is not completely filled by fine aggregate, and forming a skeleton void structure; when the volume of the gap after the coarse aggregate compaction of the base material is equal to that of the fine aggregate and binder, the skeleton dense structure will be formed.

In terms of physical concept, the formation of the three structures, namely suspension compaction, skeleton void and skeleton compaction, depends on the relative relationship between the void volume of coarse aggregate and the compaction volume of fine aggregate (Fig. 1). Compared with the other two structure forms, skeleton dense structure used in road base can give full play to the characteristics of recycled materials, reduce the cement consumption, improve the crack resistance and erosion resistance, and also can fully take into account the requirements of bearing capacity, stiffness and fatigue resistance.

3. Study on mixture ratio of recycled materials
Construction waste recycling material comes from an open-air construction recycling material processing plant in the western suburb of Zhengzhou. In addition to the relatively large number of needle and flake particles, recycled coarse aggregate of skeleton dense graded concrete can form a good skeleton inlay structure, inhibit the volume shrinkage caused by capillary action, adsorption action and intermolecular action due to the reduction of water content, and has good strength and anti dry shrinkage performance (Fig. 2). The brick recycled material is a type of large discreteness, high water absorption, high crushing value and limited strength, so it can only be used as filling material (Fig. 3).
The addition of brick slag recycled material complements the compactness of road base mixture, which can not only make rational use of brick slag material, but also reduce the cost of mixture to a certain extent. During the formulation of Beijing local standard "code for construction and quality acceptance of recycled pavement base of urban road construction waste" (DB11/T999-2013), a large number of experiments showed that fine aggregate has little effect on the strength of recycled mixture.

According to the production situation of construction waste in Zhengzhou area, the particle size of recycled material is reasonably adjusted and picked off, and recycled concrete and recycled brick are mixed together, the purpose of reasonably utilizing construction waste and meeting the strength of municipal road base mixture can be achieved.

4. Strength test of mixed recycled material
Based on the principle of embedding and extruding different particle sizes, the content of recycled brick as fine aggregate can vary from 0 to 30% in the actual engineering, and grading design of mixture for engineering inspection is followed (Table 2).

Table 2 proportion of recycled mixture (%)

| concrete Recycled material | Brick recycled material |
|---------------------------|------------------------|
| 100                       | 0                      |
| 90                        | 10                     |
| 80                        | 20                     |
| 70                        | 30                     |
According to the analysis of preliminary test data, the concrete recycled material was used as the coarse aggregate to form the embedded skeleton dense structure, and the brick recycled material was used to supplement the skeleton void. The 42.5-grade ordinary Portland cement, with the dosage of 5.5%, was selected as binder to consolidate the mixture.

In order to ensure the experimental effect and keep close contact with the actual project, Henan Construction Engineering Quality Inspection and Test Center Station Co., Ltd. was entrusted to carry out the engineering test, and specific engineering test process is arranged as followed:

(1) Raw material inspection of recycled concrete;
(2) Inspection of mixed recycled materials of brick and concrete;
(3) Strength test of recycled mixture of brick slag and concrete.

Particles that greater than 40mm were removed from the recycled concrete, and Table 3 showed the raw material inspection results of recycled concrete. From table 3, it can be seen that the content of fine aggregate (particle size no more than 4.75mm) in recycled concrete is low, and it is improved after adding recycled brick. The crushing value can meet the requirements of the specification, but the crushing value of 70% concrete + 30% brick mixture is abnormal.

| Inspection items | 70%C+ 30%B | 80%C+ 20%B | 90%C+ 10%B | 100%C |
|------------------|------------|------------|------------|-------|
| Particle gradation (%) | 37.5mm | 100.00 | 100.00 | 100.00 | 100.00 |
| | 31.5mm | 94.00 | 79.40 | 73.60 | 70.60 |
| | 26.5mm | 69.60 | 56.60 | 52.50 | 50.50 |
| | 19mm | 47.40 | 33.00 | 25.80 | 21.80 |
| | 9.5mm | 32.60 | 21.00 | 16.10 | 10.10 |
| | 4.75mm | 18.00 | 11.00 | 8.20 | 5.20 |
| | 2.36mm | 5.20 | 3.60 | 4.20 | 4.20 |
| | 0.6mm | 3.80 | 3.30 | 3.10 | 3.10 |
| | 0.075mm | 1.40 | 1.40 | 1.90 | 1.90 |
| Bulk density under vibration state (g/cm³) | 1.39 | 1.40 | 1.45 | 1.46 |
| Bulk density in natural state (t/m³) | 1.26 | 1.28 | 1.31 | 1.34 |
| Crushing value (%) | 28.40 | 29.90 | 26.80 | 25.50 |

Take 80% concrete+20% brick mixed recycled material to form 1:1 cylinder specimen by static pressure method according to T0843-2009 in the specification[14], standard dimension of test mold is diameter*height=Ø100mm*100mm. The specimens were cured under standard curing condition for 6D according to the standard curing method, and the tests were conducted after curing in water for 24h.
Fig. 4 showed the test results of 80% concrete + 20% brick mixture recycled material. The average unconfined compressive strength for seven days is 2.3MPa (the coefficient of variation is 6.09), which can meet the requirements of municipal road subbase.

The engineering test showed that the mixture recycled material can be used as the road subbase in the actual project.

5. Conclusion
The low strength of recycled construction waste, especially recycled brick waste, leads to the low utilization rate and narrow application range. A certain proportion of recycled mixture of waste brick and waste concrete has not been found in the application research of road engineering for present. In order to improve the overall utilization rate of construction waste and make rational use of the concrete and bricks removed in the process of urban construction, this paper studies the application of construction waste recycling mixture in road engineering.

Based on the skeleton dense structure of the road subbase, the particle size of the recycled material was reasonably adjusted, and concrete recycled material and brick recycled material were properly mixed, the purpose of reasonably utilizing the construction waste and meeting the strength of the municipal road base mixture could be achieved.

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