Mixture Strength of Recycled Concrete Based on Structural Forms

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Abstract: In order to test the application of recycled concrete with different particle grading in the road base, strength tests of different structural forms of the mixture are designed; the results show that the seven day strength of the mixture can meet the requirements of the road base, and the compressive strength of the skeleton dense structure is the highest. It is suggested that appropriate equipment should be used to process concrete waste and produce recycled materials with dense skeleton structure.

1. Introduction
Waste concrete is one of the main components of urban construction waste. There is a widespread phenomenon that the construction waste is discarded at will and random in urban construction. The garbage besieged city has become a common problem in the rapid development of cities in China. The recycling and resource-based treatment of waste concrete is imminent.

The research of domestic scholars on recycled aggregate of concrete mainly focuses on the following aspects [1-12]:
(1) the classification of concrete as recycled aggregate, the separation and crushing process of recycled aggregate and the production process;
(2) the basic performance of recycled aggregate of concrete, the impact of original concrete on the performance of recycled aggregate, adding other materials to enhance the performance of recycled aggregate;
(3) the mix proportion method of recycled aggregate, damage principle and damage characteristics;
(4) study and formulate relevant laws and regulations, supporting economic policies and systems to encourage the application of recycled aggregate.

Compared with natural aggregate, recycled aggregate of concrete has many different characteristics [13-15], such as more surface pores, less density, high water absorption, low strength and large crushing value. Due to the influence of site, equipment, technology and concrete strength grade, it is difficult to effectively control the particle size of concrete recycled materials, the content of needle and flake particles is high, and the practical application of the project is more difficult.

2. Structure of municipal road base 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 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).

3. Experiment of recycled concrete

It is not clear to define the structural form of subgrade mixture based on the aggregate particle grading of mixture at present [16-22]. This paper uses the grading range of skeleton dense cement stabilized macadam (Table 1) in the code for design of highway asphalt pavement (jtgd40-2006) for reference to approximately estimate the particle grading of three structural forms of mixture, namely, suspension dense, skeleton void and skeleton dense. Based on the basic characteristics and market conditions of concrete recycled materials, combined with the requirements of relevant specifications [23], the recycled material grading is designed (Table 2).

Table 1 grading range of skeleton dense aggregate

| layer | mass percentage (%) |
|-------|---------------------|
|       | 31.5 | 19.0 | 9.5 | 4.75 | 2.36 | 0.6 | 0.075 |
| base  | 100  | 68-86| 38-58| 22-32| 16-28| 8-15| 0-3   |

Table 2 percentage of particles passing through sieve

| mesh size | percentage of particle size (%) |
|-----------|---------------------------------|
|           | skeleton void | skeleton dense | suspension dense |
| 31.5      | 100            | 100            | 100              |
| 19        | 67             | 77             | 87               |
| 9.5       | 37             | 48             | 59               |
| 4.75      | 21             | 27             | 33               |
| 2.36      | 15             | 22             | 29               |
| 0.6       | 7              | 12             | 16               |
| 0.075     | 0              | 2              | 4                |

The recycled concrete is directly sampled from a quarry in the western suburb of Zhengzhou (Fig. 2). The particle grading of the recycled concrete unconfined compression test block is made according to three types of structure: skeleton gap, skeleton dense and suspension dense (Table 2).
Three groups of test pieces (9 pieces in each group) were prepared according to 6% weight of 42.5 ordinary Portland cement. According to T0843-2009 in the specification [23], the static pressure method is used to form 1:1 cylindrical test piece, the standard dimension of the test mold is: diameter*height = Ø100mm*100mm, and the test piece is wet cured for 6 days under the standard curing condition according to T0845-2009 curing method, and the test is carried out after 24h curing in water (Fig. 3).

4. Analysis of experimental results

Fig. 4, Fig. 5 and Fig. 6 are the seven-day unconfined compressive strength histogram of recycled concrete mixture of different structural forms (S1-S9 in the figure is the test block No.1-9). Fig. 4 shows the range of numerical change from 4.3 to 7.0MPa, with high strength and small dispersion; Fig. 5 shows the range of numerical change from 6.0 to 7.3MPa, with high strength and small dispersion; Fig. 6 shows the range of numerical change from 4.1 to 7.2MPa, with low strength and small dispersion except for S1.

Three types of recycled concrete structure can meet the requirements of road base strength: the compressive strength of skeleton dense structure is the largest, the strength of suspended dense structure is the lowest, and the skeleton void structure is between them. Furthermore, it can be concluded that the inlay and occlusion effect of recycled concrete skeleton structure is relatively obvious, and the influence of aggregate crushing value is relatively small.
Three types of recycled concrete structure all can meet the requirements of road base strength: the compressive strength of skeleton dense structure is the largest, the strength of suspended dense structure is the lowest, and the skeleton void structure is between them. Furthermore, it can be concluded that the inlay and occlusion effect of recycled concrete skeleton structure is relatively obvious, and the influence of aggregate crushing value is relatively small.

5. Conclusion
Based on the basic characteristics of concrete recycled materials and relevant specifications, the particle gradation of recycled materials with three structural forms of suspension density, skeleton gap and skeleton density is designed, and the strength test is carried out with 6% weight of 42.5 grade cement. The seven-day strength of the three types of structure mixture can meet the requirements of the road base, among which the compressive strength of the skeleton dense structure is the highest, the strength of the suspended dense structure is the lowest, and the skeleton void structure is between them. It is suggested to select appropriate equipment to process concrete waste to generate recycled materials with dense skeleton structure.

The recycling of concrete can reduce the site, cost and adverse impact on the environment for stacking concrete waste, and indirectly reduce the mining and processing of stone materials, reflecting the effect of resource saving, environment-friendly and sustainable development.

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