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Evaluation of strength and road performance of drainage stabilized macadam base prepared from polyurethane glue and cement stabilized macadam milling

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ABSTRACT: *In order to provide practical reference for the practical application of Permeable polyurethane stabilized recycled gravel aggregate (PPSRA), which is made of polyurethane glue and cement stabilized gravel milled material, its strength and road use. The effects of performance were studied. Firstly, the unconfined compressive test and the flexural test were used to analyze the effect of porosity, glue dosage and glue component ratio on its strength. Then, the water stability and water permeability of PPSRA were tested by water immersion Marshall test and permeability test. The road is evaluated by performance. The results show that the strength increases with the increase of the amount of glue; when the distribution ratio of A and B is 1:2.5, the strength of PPSRA peaks, and the strength of PPSRA increases with the increase of porosity. The compressive modulus of PPSRA is 800-1300 MPa, the residual stability is 85%-90%, and the permeability coefficient is 0.8-1.0* $cm \cdot s^{-1}$.

KEY WORDS: *drainage polyurethane stabilized recycled gravel material; cement stabilized macadam milling material; glue dosage; strength; road performance*

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I. INTRODUCTION

In recent years, China has paid more and more attention to the research and development and use of environmentally friendly materials. Many domestic and foreign experts and scholars have also turned their research directions into new environmentally friendly road materials and water permeable materials, and have achieved fruitful results(2015). In the aspect of grassroots drainage, Chinese scholar Li Lihui(2008) studied the drainage asphalt stabilized macadam base, and used the dichotomy method to determine the maximum asphalt content of the ATPB mixture corresponding to the leak test. The drainage asphalt mixture was determined by Marshall test. The optimum amount of asphalt used; Sadaf Khosravifar(2012) combined the recycled asphalt pavement and or recycled concrete with the binder to obtain Foamed asphalt stabilized base (FASB), which obtained the strength of the additive to the foamed asphalt stabilized base. The influence law; Ahmed Ibrahim(2014) studied the strength, fluidity, durability and other properties of self-consolidating concrete containing recycled asphalt pavements (SCCRAP), and proposed the idea that it is not recommended to replace coarse aggregate in self-curing concrete with more than 25% RAP; T. Takada et al.(1995) proposed a method to utilize the large amount of ash discharged from a coal-fired fluidized bed combustion boiler as a roadbed material, and studied the use of fluidized coal from coal combustion. Conditions and paving tests required for a large amount of ash discharged from a bed-fired boiler as a roadbed material Results; Zhi Yufeng(2007) put forward drop weight refractometer (FWD) data calculating modulus deviation of the base material, evaluate the uniformity of the roadbed, to reflect construction quality. It is concluded that the material modulus calculated by FWD has a high correlation with the roadbed uniformity; Xu Zhoucong(2015) introduced the quality control method during the construction process on the basis of summarizing the construction process of the polyurethane gravel mixture permeable pavement test road. Accumulated experience in the application of polyurethane pavement permeable pavement; Bao Sheng（2015） et al. measured the mechanical properties of porous polyurethane gravel mixture, and measured the whole process compressive and flexural stress-strain curves. The results show that the gravel morphology has no PPM strength. Influence, but has a significant impact on the elastic modulus and initial pressure deformation; Xue Fei（2015） and other experimental research, to find out the factors affecting the strength of polyurethane gravel mixture is mainly the interface adhesive strength of polyurethane adhesive, mixture The total area of the point-to-point contact, the nature of the aggregate, including the shape of the aggregate and the basic mechanical properties; Zhao Boxun2013 and other experimental research, to find out the actual construction ratio of the polyurethane gravel permeable pavement and the strength and porosity of the different limb adhesives The rate and water permeability have been tested. The results show that the polyurethane gravel permeable pavement has the advantages of good water permeability and high flexural strength, but the compressive strength is low. The compressive strength gradually increases with the increase of the amount of mucous membranes of the limbs and is inversely proportional to the porosity. Xu Kaiquan（2017） and other researches achieved the regeneration of the base material by adding foamed asphalt to the cement stabilized gravel milling material. The compressive strength and splitting test determined the optimum dosage of foamed asphalt; Yueqin Hou（2014） and other researches on the asphalt mixture with different content of recycled concrete aggregates, it is concluded that the RCA content has no effect on its dynamic stability. However, it will reduce its water stability and low temperature bending strain. Through experiments, it can be concluded that when the RCA content is 60%, all the detection indexes can meet the specification requirements; Wang Huoming（2014） and others pass the "non-standard Kentaba scattering test" and "leak test" on the polyurethane gravel. The experimental study on the amount of glue used in permeable pavement was carried out. According to its strength characteristics, permanent deformation and water stability, the application of polyurethane glue in pavement construction was analyzed. The test proved that the porous polyurethane gravel mixture can reach a better road. With performance.

In order to strengthen the recycling of waste pavement base materials and the research of new road materials, this paper uses cement stabilized macadam milling and polyurethane glue as test materials to test the PPSRA strength and road performance. As a new type of road construction material, polyurethane glue has little research on the application of cement stabilized macadam milling materials at home and abroad. In view of this, this paper uses the similar material research results to study the strength characteristics of different particle size PPSRA and the road performance of water permeability and water stability（2017）, which provides reference for the practical application of PPSRA.

II. PPSRA TEST RAW MATERIALS

The polyurethane glue is made up of the component A and the component B. The component A is a transparent color glue, the component B is a reddish brown curing agent and a mixture of fillers. The component A absorbs moisture in the air and is damp, which causes the glue to harden. Foaming, component B is prone to oxidation in air. Therefore, when the distribution ratio of the A and B groups is carried out, the time should be controlled within half an hour. Through the test analysis of the polyurethane glue in the proportion of different A and B components, it is determined that the ratio of the composition of the glue to the component B is 1:2-1:3. Three kinds of composition ratios of A and B were selected during the test, which were 1:2, 1:2.5, 1:3.
The cement stabilized gravel milling material adopts a secondary road cement stabilized gravel milling planing material, and its basic performance is shown in Table 1.

Table 1 Basic properties of cement stabilized macadam milling

Aggregate maximum nominal particle size /mm	Apparent density /g·cm^{-3}	Water absorption rate /%	Crushed value /%	Needle-like content /%
40	2.671	3.035		8
30	2.695	2.897	25.9	10
25	2.687	3.133		9

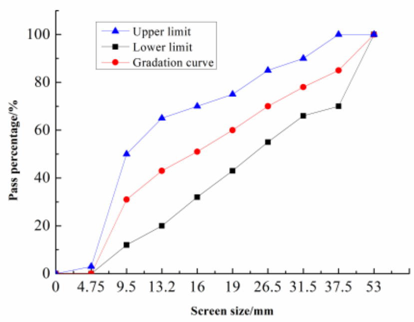


Figure 1 PPSRA-22 grading curve

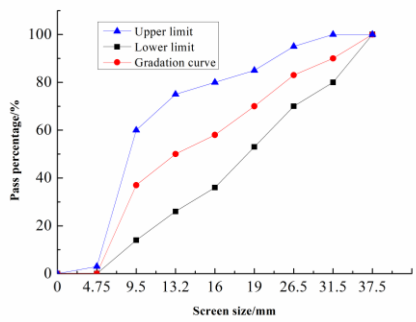


Figure 2 PPSRA-20 grading curve

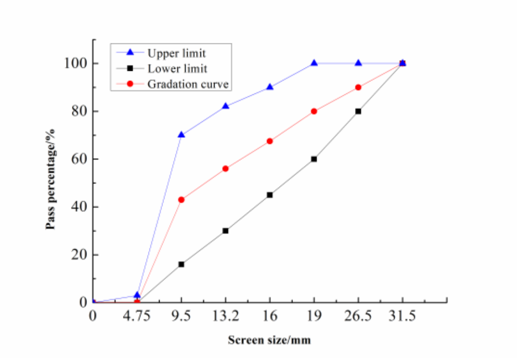


Figure 3 PPSRA-18 grading curve

Since the voids of the polyurethane mixture mixed with the fine aggregate are filled with the fine aggregate of the glue, the water permeability is greatly reduced, and the addition of the fine aggregate also causes a large amount of glue to be wrapped on the surface of the fine aggregate, which increases the glue Dosage. Therefore, in the case of meeting the specifications, the fine aggregate having a particle size range of 0-4.75 mm is removed when the aggregate is selected, and the cement stabilized gravel milling material having a particle size range of 4.75 mm to 31.5 mm is used. The three types of porosity cement stabilized macadam milling materials used in the test correspond to the water-permeable polyurethane stabilized macadam base layer is PPSRA-22, PPSRA-20, PPSRA-18, and the gradation curve is shown in Figure 1-Figure 3.

III. TEST METHOD AND TEST PIECE PREPARATION

3.1 Unconfined compression test and flexural test

The compressive and flexural strength characteristics of PPSRA were modified on the basis of the compression and flexural test of ordinary asphalt mixture. The different porosity, the amount of glue and the unconfined compressive strength of the test specimen were measured. And flexural strength.

3.2 drainage test

In order to determine the drainage performance variation with PPSRA porosity, hydrostatic molding method cylindrical specimens, specimen size of 100×100 mm. The permeability coefficient of the test piece was tested by a water permeable tester. Three parallel test pieces were formed in each set of tests, and the average value was taken as the test result.

3.3 Immersion Marshall test

Currently, the water stability test method for PPSRA or blank, so this reference to Highway Engineering asphalt and asphalt testing procedures (JTG E20-2011), with large compaction test the porosity of the three kinds of large molded optimum mix Marshall test specimens, the water stability of PPSRA mixture was tested by immersion Marshall test residual stability.

3.4 Preparation of test pieces

At present, there is no relevant test procedure for the drainage of polyurethane stabilized recycled gravel materials at home and abroad. Therefore, this paper refers to the open-grade asphalt stabilized macadam mixture in the Technical Specifications for Highway Asphalt Pavement Construction (JTG F40-2004). The grading curve requires the determination of the grading range. The test pieces were formed in accordance with the Testing Procedures for Asphalt and Asphalt Mixtures for Highway Engineering (JTG E20-2011). Due to the large fluidity of the polyurethane glue, a thin layer of glue is easily formed on the surface of the aggregate, and the surface of the aggregate cannot be covered when the amount of glue is small, resulting in poor adhesion between the aggregates. Excessive amount of glue may lead to the test. A glue seal is formed on the bottom of the piece. Therefore, the optimum polyurethane glue dosage range is 3%-5% through the Schellenberg Leakage Test and the Kentberg Fly Test. During the test, the gradation of each aggregate particle size was taken as 3 glues at intervals of 1%. According to the laboratory test, the ratio of the glue components was 1:2.5.

IV. ANALYSIS OF STRENGTH CHARACTERISTICS RESULTS

4.1 Effect of porosity on strength

The porosity was controlled by changing the aggregate gradation and the amount of glue, and the strength of different porosity was analyzed. In view of the fact that there is no test specification for PPSRA at this stage, this test is tested with reference to the method for producing asphalt Marshall test specimens in the

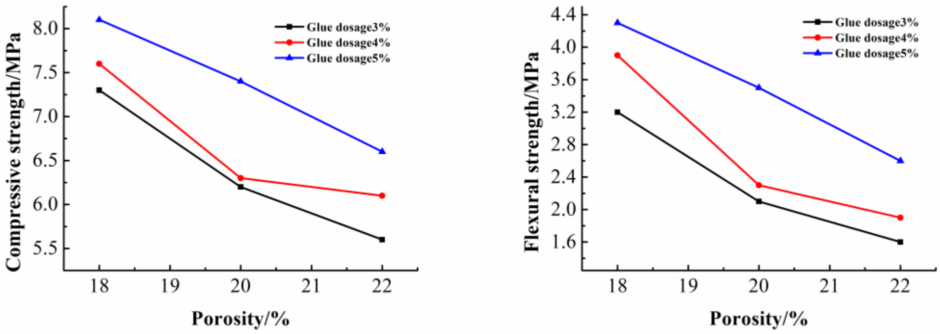
Test Procedure for Highway Engineering Asphalt and Asphalt Mixture (JTG E20-2011). The test equipment mainly includes: Los Angeles wear meter, LSM-7 Marshall stability meter, and microcomputer controlled electro-hydraulic servo universal testing machine.

The standard compaction density of the Marshall test piece was determined according to the Marshall standard compaction test to determine the amount of mix material for a large Marshall test piece. Large-scale compaction method was used to compact the 152.4×95.3mm large Marshall test piece. During the test, the test piece was compacted 75 times on each side, 3 in each group. For the counter-pressure and anti-fold test pieces, a cylindrical test piece of 100×100 mm was formed by static pressure method, and the test piece after molding was shown in Fig. 4.

(a) Two sets of test pieces **(b) Single test piece**

Figure 4 test specimen

The void ratio, compressive strength and flexural strength of the three kinds of glue test pieces were measured for 24 hours. The effect of porosity on the compressive and flexural strength of PPSRA is shown in Figure 5.



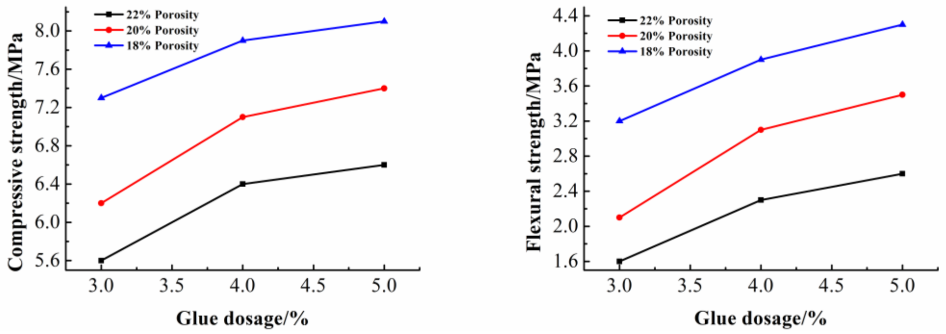
(a) Compressive strength **(b) Flexural strength**

Figure 5 intensity versus porosity curve

It can be seen from Fig. 5 that the compressive and flexural strength of PPSRA decreases with the increase of porosity. According to the linear regression analysis, the correlation coefficient r between the two is 0.93, indicating that there is strong linearity between the two. Correlation. The increase in porosity leads to a decrease in the compactness of the test piece, which affects the overall stability and bearing area of the test piece, resulting in a decrease in the compressive and flexural strength of the test piece.

4.2 Effect of glue dosage on strength

In order to determine the effect of the amount of glue on the strength of PPSRA, the strength test of PPSRA



(a) Compressive strength **(b) Flexural strength**

Figure 6 Strength versus glue usage curve

with 3%, 4% and 5% of the glue was carried out. The test results are shown in Figure 6.

It can be seen from Fig. 6 that the strength of PPSRA and the amount of glue have a certain regularity. First of all, in the range of the amount of glue, the compressive strength and flexural strength increase rapidly with the increase of the amount of glue, and then the growth rate tends to be stable. This shows that before the optimum amount of glue is reached, the adhesion between the glue and the aggregate exerts a structural strength on the PPSRA, which can strengthen the strength of the PPSRA, but as the amount of glue increases, the thickness of the glue film changes. In addition, in addition to the structural glue that binds, some of the free glue is added to the mixture, which causes a large amount of voids in the mixture to be filled with glue, and the increase in free glue does not significantly enhance the strength of the mixture. Therefore, 4% of the amount of glue is tested in the road performance analysis.

4.3 Effect of porosity on compression modulus

The compressive strength characteristics of PPSRA were modified according to the compression test of ordinary asphalt mixture. The test piece was compacted according to the “Testing Procedure for Highway Engineering Asphalt and Asphalt Mixture” (JTG E20-2011). After the unconfined compressive strength of the three best nominal particle size PPSRA ratios was determined, the cylindrical specimens were loaded step by step according to the test method, and the specimens were rebounded at 0.5 times the maximum compressive load. The deformation is calculated from the deformation modulus, and the test results are shown in Table 2.

Table 2 Results of compressive rebound modulus test

Types of PPSRA	Compressive modulus /MPa			average value /MPa
PPSRA-22	873	795	812	826.7
PPSRA-20	921	859	967	915.7
PPSRA-18	1260	1050	1575	1295.0

It can be seen from the test results that the compressive elastic modulus of the three largest nominal particle sizes PPSRA is 800-1300 MPa, the smaller the maximum nominal particle size of the aggregate is, the larger the compressive rebound modulus is, and the compressive rebound modulus is higher than that of ordinary asphalt. The concrete is low. When designing the road base layer, the rebound modulus of the base layer has a wide range of values. Therefore, when applying PPSRA to actual engineering, it is necessary to select according to the requirements in the roadbed design specification.

V. PPSRA ROAD PERFORMANCE TEST

5.1 Water stability

In order to detect the water stability of PPSRA, the water stability of PPSRA mixture was tested by water immersion Marshall test to determine its water stability. The test results are shown in Table 3.

Table 3 Water stability test results

Types of PPSRA	Residual stability /%			average value /%
PPSRA-22	85.7	82.9	89.3	86.0
PPSRA-20	88.5	90.2	87.9	88.9
PPSRA-18	93.3	90.5	89.3	91.1

It can be seen from Table 3 that the PPSRA residual stability of the three different porosity is different. PPSRA-18 has the best water stability, the residual stability is 91.1%, PPSRA-22 has the worst water stability, and the residual stability is 86.0%. The three porosity PPSRAs meet the technical requirements of >75% in the Technical Specifications for Highway Asphalt Pavement Construction (JTG F40-2004), meeting the water stability requirements of the pavement base. It can be seen that the water stability of PPSRA decreases with increasing porosity and is negatively correlated with porosity.

5.2 Drainage

The drainage of PPSRA is based on the seepage test of the asphalt mixture. The test instrument is tested by a water osmosis meter. The test results are shown in Table 4.

Table 4 permeability coefficient test results

Types of PPSRA	Permeability coefficient/$cm \cdot s^{-1}$			average value/$cm \cdot s^{-1}$
PPSRA-22	0.897	0.825	0.807	0.843
PPSRA-20	0.831	1.036	0.756	0.874
PPSRA-18	0.916	0.883	1.081	0.941

It can be seen from Table 4 that the permeability coefficient of the three kinds of porosity PPSRA is 0.8-1.0 $cm \cdot s^{-1}$, which is in accordance with the Technical Specifications for Highway Asphalt Pavement Construction (JTG F40-2004). The permeability coefficient for the drainage subgrade is not less than 0.35. $cm \cdot s^{-1}$. The water permeability of PPSRA mainly depends on the porosity. According to the Marshall test results, the porosity of the three kinds of porosity PPSRA is not much different. Therefore, the permeability coefficient of the three kinds of porosity PPSRA is similar in the drainage test, and both can meet the roadbed. Water permeability requirements.

VI. CONCLUSION

In this paper, with reference to the asphalt mixture test procedure, the indoor test is used to determine the optimum ratio of PPSRA to B: 1:2.5. Through the unconfined compression test and the flexural test, the effect of porosity and glue dosage on strength is determined. Regularity, water stability and drainage of PPSRA were tested by water immersion Marshall test and penetration test, and the following conclusions were drawn.

(1) From the results of unconfined compression test and flexural test, the compressive strength and flexural strength of PPSRA in the range of glue dosage increase rapidly with the increase of glue dosage, and then the growth rate tends to be flat. The strength of the piece will tend to be stable when the amount of glue reaches a certain ratio; in the test, the compressive modulus of the PPSRA is 800-1300 MPa, and the compressive modulus of the PPSRA is slightly smaller than that of the ordinary asphalt mixture. The aggregate used is cement stabilized gravel milled concrete, which will have a great impact on its compressive strength. Further research is needed on the application of natural aggregate and polyurethane glue to the pavement base; from the relationship between porosity and strength The compressive and flexural strength of PPSRA decreases with increasing porosity, and there is a strong linear correlation between the two. This indicates that the compactness of the specimen has a decisive influence on the strength.

(2) According to the road performance test results, the residual stability of the three kinds of porosity PPSRA is greater than 85%, meeting the technical requirements of >75%, meeting the water stability requirements of the pavement base; from the drainage test, PPSRA The permeability coefficient is 0.8-1.0 $cm \cdot s^{-1}$, which is much larger than the 0.35 $cm \cdot s^{-1}$ specified in the specification, so PPSRA has good drainage.

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