Experimental Study on Road Performance Index Of Graded-Gravel Flexible Base Course

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Abstract: In order to study the road performance of the graded-gravel material, the dynamic and static rebound modulus test of continuous-graded gravel was carried out, and through the tested road for field rebound modulus test and reverse, while the indoor and field CBR was tested. The results show that with the change of the load on the graded-gravel material, the modulus shows a good non-linear characteristic, and the modulus gradually increases with the load increasing. The indoor and field rebound modulus of the graded-gravel mixes are in accordance with the current specification requirements, and the CBR test value also meets the specification requirements. The research has reference significance for understanding the road performance characteristics of the graded-gravel and the future design and construction.

1. Introduction
Graded-gravel material has the advantages of low cost and convenience, which plays an important role in road construction. The base course was paved with graded-gravel material has a large space structure, showing very good insulating, drainage effect, and prevent the formation of reflective crack. Different climate zone and different level of traffic road on the premise of guarantee good drainage, and all can use graded-gravel material to build the base course [1-4].

2. Composition of graded-gravel gaterial
When the flexible base course of graded-gravel was not bonded with the binder material, the strength of the gravel particles and the squeezing force between the particles are the key to the formation of the base course strength [5]. In order to achieve high road performance, the structure layer needs to choose high quality gravel material, design reasonable graduation, adopt meticulous construction craft, and ensure that the gravel aggregates are packed evenly.

The basis of this paper is the experimental road of graded-gravel flexible base course where is paved in FunShen city, liaoning province. The experimental road aggregate is made of limestone, and the grading type is continuous grading. The physical performance experiment of gravel material are tested in the laboratory to guarantee the construction quality of the flexible base course.

The optimal moisture content and the maximum dry density of the graded-gravel are obtained by the compaction test in this paper, and the test results are shown in table 1.

| Test Specimen | 1 | 2 | 3 | 4 | 5 | 6 |
|---------------|---|---|---|---|---|---|
| dry density (g/cm³) | 2.44 | 2.46 | 2.48 | 2.46 | 2.43 | 2.45 |
| average moisture content (°) | 3.97 | 4.37 | 4.53 | 4.46 | 4.89 | 3.97 |
| Optimal moisture content | 4.32% | maximum dry density | 2.48g/cm³ |
3. Performance test and result of the flexible base course road of graded-gravel

3.1. Test results and analysis of indoor rebound modulus

The graded-gravel is a kind of loose granular material which does not contain the binding material. It can not be used as semi-rigid base material to carry out unconfined compression test with the top surface method to measure the compressive rebound modulus. However, it can be recommended by zhong Mengwu of Hunan Transportation Research Institute, with the side limit top surface method, and the theory of space elastomer is used to correct the errors caused by the test results[6]. The test results are shown in table 2 and Figure 1.

| sequence number | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
|-----------------|----|----|----|----|----|----|----|
| Δl(0.01mm)      | 19.5| 19.0| 18.8| 22.3| 21.8| 22.8| 21.1|
| Δp(MPa)         | 0.67| 0.68| 0.67| 0.68| 0.69| 0.68| 0.71|
| E(MPa)          | 361.03| 366.85| 394.13| 314.53| 342.28| 317.36| 366.34|

Figure 1. Schematic diagram of rebound modulus

Figure 2 shows that with the continuous change of the load acting on the graded-gravel material, the modulus exhibits a better nonlinear characteristic, with the load gradually increasing, the modulus also gradually increases. 《Specifications for Design Of Highway Asphalt Pavement》（JTG D50-2006）recommends that the level of grading gravel which is paved in the base course shall be between 300 and 450 Mpa[7].

3.2. Test results and analysis of the field rebound modulus

The elastic modulus of the pavement structure of the graded gravel is determined by the field load-bearing plate method[8]. The measured modulus of field measurement is the comprehensive modulus of the road surface after paving. To obtain the modulus of the grading gravel layer, and the field data need to be calculated in reverse. The modulus results of the field load-bearing plate method are used, and reversed modulus is shown in table 3.

| test road pile number | right rebound modulus | Left rebound modulus |
|-----------------------|-----------------------|----------------------|
| K8+150                | 290.74                | 405.63               |
| K8+120                | 446.31                | 326.30               |
| K8+090                | 405.63                | 515.25               |
| K8+060                | 347.54                | 249.92               |
| K8+030                | 307.49                | 393.64               |
| K8+000                | 354.86                | 313.22               |
| K7+970                | 286.35                | 336.94               |
| K7+940                | 274.55                | 251.29               |
| K7+910                | 436.03                | 531.53               |

Mean of modulus of graded gravel  358.47 MPa
From the above data, the value of the graded gravel modulus is 358.47 Mpa. 《Specification Of Asplate Pavement Design》 (JTG D50-2006) stipulated that the modulus of gravel base course is between 200 and 500 Mpa. The graded gravel modulus of this paper is within the specified range, which meets the requirements.

3.3. Test and analysis of dynamic rebound modulus of graded gravel

The experimental equipment adopts the material testing machine of MTS810(Material Test System), the test load frequency is taken as 10 Hz. The force transmitted by the indenter under this dimension does not act on the cylinder wall and is only transmitted within the piece to prevent the confining pressure of the test tube from affecting the test results, simulate the stress transmission of the actual pavement structure to the maximum extent[9]. The experiment instruments and loading process are shown in Figure 2, and the dynamic rebound modulus test data of graded gravel are shown in table 4.

![Figure 2. Experimental instrument and loading process]

| sequence number | first group | second group | third group | four group | five group |
|-----------------|-------------|-------------|------------|------------|------------|
| Δl (mm)         | Δp (MPa)    | Δl (mm)     | Δp (MPa)   | Δl (mm)    | Δp (MPa)   |
| 1               | 0.221       | 0.695       | 0.181      | 0.481      | 0.239      | 0.981      | 0.229 | 0.802 | 0.221 | 0.704 |
| 2               | 0.219       | 0.685       | 0.179      | 0.480      | 0.241      | 0.976      | 0.222 | 0.798 | 0.230 | 0.712 |
| 3               | 0.220       | 0.681       | 0.181      | 0.480      | 0.242      | 0.989      | 0.222 | 0.818 | 0.217 | 0.702 |
| 4               | 0.221       | 0.674       | 0.177      | 0.471      | 0.242      | 0.996      | 0.222 | 0.815 | 0.227 | 0.702 |
| 5               | 0.221       | 0.696       | 0.175      | 0.462      | 0.230      | 0.992      | 0.220 | 0.812 | 0.216 | 0.695 |
| 6               | 0.222       | 0.700       | 0.181      | 0.479      | 0.237      | 0.972      | 0.219 | 0.814 | 0.219 | 0.691 |
| 7               | 0.222       | 0.695       | 0.174      | 0.480      | 0.234      | 0.981      | 0.220 | 0.808 | 0.218 | 0.703 |
| 8               | 0.219       | 0.683       | 0.180      | 0.482      | 0.233      | 1.007      | 0.214 | 0.802 | 0.218 | 0.714 |
| 9               | 0.217       | 0.687       | 0.179      | 0.482      | 0.240      | 0.992      | 0.215 | 0.810 | 0.220 | 0.708 |
| 10              | 0.223       | 0.677       | 0.183      | 0.464      | 0.239      | 0.995      | 0.217 | 0.807 | 0.221 | 0.702 |

E 106.8MPa 92.1MPa 141.2MPa 125.3MPa 108.6MPa

The experimental data calculated the mean value of the rebound modulus of the graded gravel is 114.8 Mpa. During the experiment, the random distribution of the gravel material in the test tube had great influence on the test result, and the size of the gravel in contact with pressure head resulted in the difference of the test results. There is no standard test method in the study of the dynamic rebound modulus of graded gravel in china. The experimental results of different molding methods and forming conditions are different. Therefore, deep research is carried out in the experimental method, and a unified and standardized test method can be found to obtain valuable data.

4. CBR test for graded gravel

CBR is an indicator of assess the bearing capacity of the base course material in california. 《Specification Of Asplate Pavement Design》 (JTG D50-2006) stipulates that the CBR value should not be less than 100% when the graded gravel material is constructed at the base course, and the design of heavy-duty compaction standard is used.
4.1. Laboratory test

The results of the indoor CBR test are shown in Table 5.

| penetration rate (mm) | unit pressure p(KPa) | penetration rate (mm) | unit pressure p(KPa) | penetration rate (mm) | unit pressure p(KPa) |
|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| 0.0                  | 0                    | 1.8                  | 3916                 | 3.4                  | 6831                 |
| 0.2                  | 524                  | 2.0                  | 4222                 | 3.6                  | 7462                 |
| 0.4                  | 1031                 | 2.2                  | 4360                 | 3.8                  | 8093                 |
| 0.6                  | 1507                 | 2.4                  | 4440                 | 4.0                  | 8702                 |
| 0.8                  | 2058                 | 2.5                  | 4911                 | 4.2                  | 9307                 |
| 1.0                  | 2484                 | 2.6                  | 5364                 | 4.4                  | 9524                 |
| 1.2                  | 2982                 | 2.8                  | 5818                 | 4.6                  | 9600                 |
| 1.4                  | 3320                 | 3.0                  | 6120                 | 4.8                  | 10218                |
| 1.6                  | 3742                 | 3.2                  | 6489                 | 5.0                  | 10589                |

The CBR value of the indoor test is calculated to be 100.85%, which is in accordance with《Specification Of Asplate Pavement Design》(JTG D50-2006) that the graded gravel material build up the base course.

4.2. Field test

The on-site test adopts the CBR value test method of T0941—2008 in the《Regulation Of Road Subgrade Pavement Test Procedure》(JTG E60-2008) and calculates the CBR value of the field. The results of the on-site CBR test are shown in Table 6.

| Test pile no | Right CBR value (%) | Right CBR value (%) |
|--------------|---------------------|---------------------|
| K8+150       | 192.30              | 197.64              |
| K8+120       | 207.15              | 203.24              |
| K8+090       | 188.43              | 189.59              |
| K8+060       | 183.08              | 199.05              |
| K8+030       | 207.18              | 184.26              |
| K8+000       | 212.37              | 196.23              |
| K7+970       | 186.74              | 190.13              |
| K7+940       | 192.50              | 184.26              |
| K7+910       | 190.13              | 204.08              |

The test results show that the CBR value obtained from field test are all greater than 180%, and the CBR values in accordance with the specification should not be less than 100%.

5. Conclusion

(1) With the load acting on the graded gravel material is continuously changing, the modulus exhibits a better nonlinear characteristic. As the load increases, the modulus also increases gradually, and the data obtained from the experiment are of good correlation.

(2) The indoor and field tests of CBR for the graded gravel material selected for the test road were performed. The CBR values obtained in the graded gravel indoor and field tests were all greater than 100%. And the CBR value obtained from the field test was significantly higher than the indoor test. The graded-gravel material is built at the base course, with heavy-duty compaction standard design, CBR value should not be less than 100% of the requirements.

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