Faulting Forecast of Concrete Pavement Considering Erosion and Void

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Abstract: According to the current forecast shortage of concrete pavement faulting, the field investigation of faulting in Guangxi was carried, and the relationship between the erosion height and faulting was good whether setting the dowel bar or not, and it is an effective method of setting dowel bars to reduce the faulting value. The concrete pavement structure was built in the test, it has shown that the erosion value of both lime-flyash stabilized macadam base and cement stabilized macadam base is increased exponentially with the enlargement of axle load, and the erosion value of lime-flyash stabilized macadam base is more 10%~12% than the cement stabilized macadam base. Finally faulting models of two base types considering erosion and void are established. The faulting model of lime-flyash stabilized macadam base with no dowel bar is verified by Liu-Nan expressway, the model has a good applicability.

1. Introduction

Faulting is one of the major diseases affecting the service capacity of cement pavement. If it is not timely treated, the cracking will happen with the repeated impact of vehicle load, and it will also reduce the driving comfort and safety. Many domestic and foreign road workers have conducted a lot of research work on the faulting[1-5]. Specifications for Design of Highway Cement Concrete Pavement had analyzed the joints. Fuqiang CHEN had stated the transverse joint faulting models and application of concrete pavement, which provides a useful reference to our models' establishment and a solid theory for popularizing and developing cement concrete pavement preventive maintenance[1]. Based on a case study of faulting evaluation criteria in Chongqing, a new method was proposed for rating the joint faulting with a consideration of the level of ride quality[2]. Water pumping beneath concrete pavement slabs is considered to be a major cause of concrete pavement failure, the conclusions of this work concern the effects of water pumping, the origin of loose, fine material and a description of the pumping mechanism based on limited field data[3,4]. Therefore, it is necessary to research the faulting forecast of concrete pavement considering erosion and void, the faulting model is established to predict the variation development of different factors, it has an important guiding significance for the structure design of cement concrete pavement and formulating the pavement maintenance measures.

2. Data Acquisition and Analysis

2.1 Faulting Acquisition and Processing

The pavement roughness increases with the increase of faulting, and the corresponding erosion and void beneath slab is more serious[5]. In this paper, two kinds of lime-flyash stabilized macadam base and cement stabilized macadam base are selected for the faulting investigation in Guangxi. The testing instrument is a digital treadmill, the point is shown in Figure 1. If the vehicle into the direction of the slab is higher than out of the direction of the slab, the faulting is positive, otherwise,

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it is negative. The evaluation index of test faulting is the average faulting, the formula is $F = \frac{\sum_{1}^{n} x}{N}$, F is the average faulting value(mm); x is the faulting value(mm); N is the joint number.

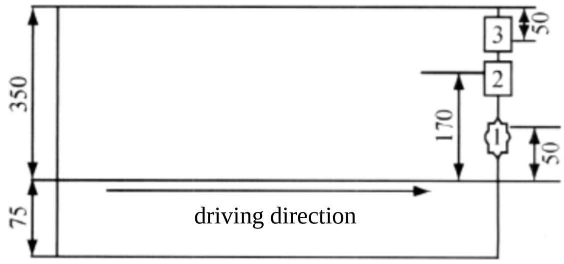


Fig.1 Test Positions for Faulting Values(Units:Cm)

2.2 Data Collection and Processing of Void Height

The deflection of board corner and edge is detected by the JN-150 standard car and Beckman beam for different base types. The car rear axle is located in the edge of transverse joints, the outermost edge of the wheel is 10cm, which is from the edge of the longitudinal joint. The bracket is placed on the shoulder, which is testing the deflection of slab corner, the probe is on the corner. The probe is in the middle of the left side of the two wheels, which is testing the deflection of slab edge, each 50m pavement panels are measured once. According to deflection results, combined with the Reference[1,2] and the overlay experiences of asphalt concrete, if a single point of deflection value is more than 0.14 mm, the slab will be void. The void height is the difference between the height of the top base and the bottom void by changing the slab or drilling core sampling.

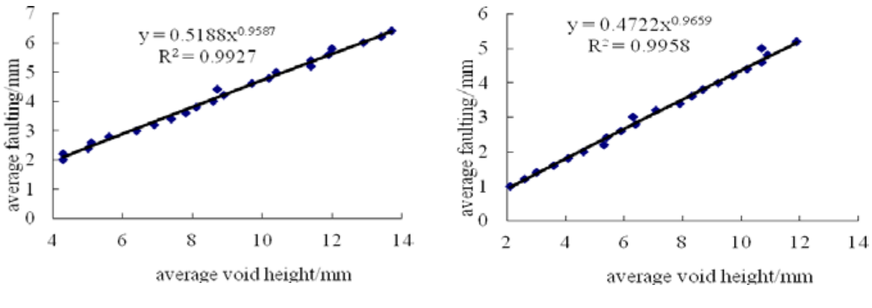
The evaluation index of test void is the average void height, the formula is $H_v = \frac{\sum_{1}^{n} y}{M}$, H_v is the average void height(mm); y is the void height(mm); M is the number of voids.

2.3 Analysis of Faulting and Void Height

In the investigation in Guangxi, it has found that there is a good correlation between the faulting and void height of the lime-flyash stabilized macadam base and the cement stabilized.

2.3.1 Without Dowel Bars

When both the lime-flyash stabilized macadam base and the cement stabilized macadam base are not setting dowel bars, the investigation is shown in Figure 2. The results have shown that if the void height is at the same level, the faulting is higher 10%~20% than that of the cement stabilized macadam base, the anti-erosion performance of the cement stabilized macadam base is better than that of the lime-flyash stabilized macadam basement. The average faulting is exponentially increased with the increase of the void height, and the regression formulas of lime-flyash stabilized macadam base is $F = 0.5188 H_v^{0.9587}$,the cement stabilized macadam base is $F = 0.4722 H_v^{0.9659}$.



a) lime-flyash stabilized macadam base   b) cement stabilized macadam base

Fig.2 Relationship between Average Void Height and Faulting without Dowel Bars

2.3.2 With Dowel Bars

In the research process, we can not find the cement concrete pavement with dowel bars on the lime-flyash stabilized macadam base, so we only analyze the average void height and faulting with dowel bars on the cement stabilized macadam base, their relationship is shown in Figure 3. Figure 3 has shown that although the cement stabilized macadam base with dowel bars will still be void and faulting, but the extent of which is greatly reduced. The maximum void height of setting dowel bars is only 4.3mm, the maximum faulting is 3.0mm, while the maximum void height without dowel bars is 11.9mm, the maximum faulting is 5.2mm. The regression formula is $F = 0.5115H_v^{1.2188}$.

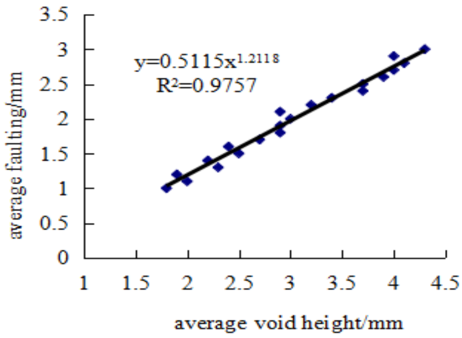


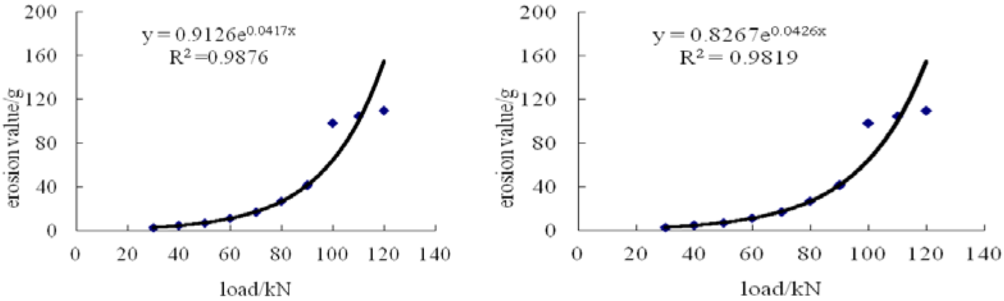
Fig.3 Relationship between Average Void Height and Faulting with Dowel Bars(Cement Stabilized Macadam Base)

3. Development of Faulting

3.1 Establish the Forecast Model of Erosion Void under Axial Load

3.1.1 Analyze the Relationship between Axle Load and Erosion

In order to study the relationship between the load and erosion with the void pavement structure, the indoor test was done. The test pavement structure of two base course was constructed. The geometric dimension of the slab was 80cm×70cm×9cm, and the base was 100cm×90cm×20cm. The void position was set in the middle of the base, and the size of which was 15cm×15cm×5cm. The load was 4kg tires from 0.5m vertical drop to the void slab, and the hydrodynamic pressure was measured by the CYB100 high-precision pressure sensor, which is buried in the void place. While the corresponding water samples and the separation of solid particles were collected, it was weighed with an analytical balance of 0.0001g. The corresponding relationship between the load and erosion value is shown in Figure 4, and the erosion value is the weight loss of materials.



a) lime-flyash stabilized macadam base   b) cement stabilized macadam base

Fig.4 Relationship between Load and Erosion Value

Figure 4 have shown that whether it is lime-flyash stabilized macadam base or cement stabilized macadam base, the erosion value is increased with the increase of the axial load, and then the base erosion becomes more serious. Further analysis shows that the lime-flyash stabilized macadam base is more 10%~12% than the cement stabilized macadam base under the same load level, which is consistent with the results of the previous research. The regression equations of lime-flyash stabilized macadam base is $V_c = 0.9126e^{0.0417P}$, and the cement stabilized macadam base is $V_c = 0.8267e^{0.0426P}$, V_c is the amount of erosion (g); P is the axial load (kN).

3.1.2 Establish the Erosion Model under Axial Load

According to the principle of the equal erosion value, it can be deduced that the relationship between the number of times required for any axle load and the number of standard axle loads was obtained under the condition of equal erosion volume.

$$V_c N = V_e N_e \quad (1)$$

Where: V_c is the erosion value of axle load(g); N is the number of erosion for axis load; V_e is the erosion value of standard load(g); N_e is the number of erosion for standard load.

Because $V_e = 100$,we can get the following formulas.

lime-flyash stabilized macadam base: $N_e = 0.9126 \times 10^{-2} e^{0.0417P} N \quad (2)$

cement stabilized macadam base: $N_e = 0.8267 \times 10^{-2} e^{0.0426P} N \quad (3)$

The erosion prediction model under the different loading can be obtained by substituting the above equation into the model of erosion in the reference [5]. They are given below.

lime-flyash stabilized macadam base:

$$l_0 = \frac{3}{10000} k_c \cdot k_d \cdot 0.9126 \times 10^{-2} e^{0.0417P} N \cdot \frac{1}{\lambda} \quad (4)$$

$$l = l_0 \cdot \sqrt[3]{1 + \frac{3}{10000} k_c \cdot k_d \cdot 0.9126 \times 10^{-2} e^{0.0417P} N \cdot \frac{1}{\lambda \cdot l_0}} \quad (5)$$

cement stabilized macadam base:

$$l_0 = \frac{3}{10000} k_c \cdot k_d \cdot 0.8267 \times 10^{-2} e^{0.0426P} N \cdot \frac{1}{\lambda} \quad (6)$$

$$l = l_0 \cdot \sqrt[3]{1 + \frac{3}{10000} k_c \cdot k_d \cdot 0.8267 \times 10^{-2} e^{0.0426P} N \cdot \frac{1}{\lambda \cdot l_0}} \quad (7)$$

Where: l_0 is the void radius after the first load(m); l is the void radius after the load(m); λ is the ratio of void height to void radius; N is the erosion numbers for axle load(times); P is the axial load (kN); k_d is the precipitation correction factor; k_c is the anti-erosion coefficient of base material(m^3/m^2.million).

3.2 Establish the Faulting Model of Concrete Pavement Considering Erosion and Void

Because of $H_V = 1000\lambda \cdot l$, and the faulting model is obtained with dowel bars or not, they can be seen in Table 1.

Table 1 Forecast Faulting Models of Pavement Considering Erosion and Void

category	base type	model
without dowel bars	lime-flyash stabilized macadam base	$F = 0.5188 H_v^{0.9587} = 0.5188(1000\lambda l)^{0.9587} = 390.03(\lambda l)^{0.9587}$
	cement stabilized macadam base	$F = 0.4722 H_v^{0.9659} = 0.4722(1000\lambda l)^{0.9659} = 373.10(\lambda l)^{0.9659}$
with dowel bars	cement stabilized macadam base	$F = 0.5115 H_v^{1.2188} = 0.5155(1000\lambda l)^{1.2188} = 2.337 \times 10^3 (\lambda l)^{1.2188}$

3.3 Verify the Faulting Model

Taking the Liu-Nan Expressway as an example, the concrete pavement structure is 26cm cement concrete surface layer+20cm lime-flyash stabilized macadam base+18cm graded crushed stone base +foundation, the design base period is 30 years. It is opened to traffic in 2000. According to the survey, the annual average precipitation in the region is 1900mm, and the precipitation is concentrated in May and June, the annual average precipitation days are conservatively estimated to 80 days. The initial traffic volume is 1.60×10^{-4}. The ratio of void height to void radius is 1: 100. The initial standard of the traffic lane is designed to 2100. The number of faulting is 2.7mm after 5 years. The applicability of the formula is verified by calculating the amount of faulting after 5 years.

(1) According to the standard, the cumulative standard axis in the first five years is 2704531 times, about 2.7 million times;

(2) Calculate the void radius after the 10000 times, $l_0 = 0.0068$ (m);

(3) Calculate the void radius after the 20000 times, $l_1 = 0.0086$ (m);

(4) And so on, calculate the void radius after 2.7 million times, $l_{270} = 0.6118$ (m);

(5) And then calculate the faulting after five years in Liu-Nan Expressway, $F = 2.90$ (mm), which is consistent with the previous research data, it verifies the accuracy of the prediction formula.

4. Conclusions

(1) Through the investigation and analysis of faulting and void height of cement concrete pavement in Guangxi, it was found that no matter what type of the base, the average faulting was increased exponentially with the increase of the void height. The faulting of cement stabilized macadam base with dowel bars was reduced by 20%~45%, the set of dowel bars can effectively control the erosion void and faulting.

(2) The concrete pavement structure of void base is built in the indoor, the relationship between the load and the erosion is analyzed. The results show that the relationship between erosion and axle load is exponential. The erosion amount of lime-flyash stabilized macadam base is more 10%~12%, and then the erosion model under axial load is established.

(3) The prediction faulting model of cement concrete pavement with different basement types is set up. Combined with the analysis of the example of Liu-Nan expressway in Guangxi, it is shown that the deviation between the theoretical calculation and the actual faulting is less than 1mm, the accuracy of the model is high.

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