Experimental study on detection of void in concrete pavement slab by FWD

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Abstract. In grouting process, first of all, detection technology should be used to detect the engineering disease area, so as to determine the location of the disease more accurately, which is not only conducive to achieving the desired reinforcement effect, but also can save unnecessary economic expenses. In this paper, the normal pavement slab and the pavement slab with different void states are constructed by self-made test device. Then the deflection values of the normal pavement slab and the pavement slab with different void states are tested by deflectometer FWD. Based on the test, the deflection laws of the normal pavement slab and the pavement slab with different void states are compared and analyzed. The test results show that FWD can accurately identify the condition of pavement void; the deflection of the void position and the area near the void position is obviously larger than that of the normal panel, and the deflection of the void position is proportional to the area of the void area.

1. Introduction

With the rapid development of China's national economy, China's highway construction is also springing up. By the end of 2018, China's highway mileage has reached 4.8465 million kilometers, ranking first in the world. However, China's highway started late, with limited technical level and maintenance experience, and most of the subgrade and pavement defects. Cavity beneath slab is a common disease of the concrete pavement (as shown in Fig. 1), which will cause the concrete pavement slab to break and stagger, seriously endangering the service quality and life of the pavement [1-2]. The traditional detection technology destroys the pavement surface and has great randomness, which can not meet the needs of pavement detection at this stage [3]. Under this background, the pavement nondestructive testing technology represented by ground penetrating radar, falling weight deflectometer (FWD), spectrum analysis and detection technology, ultrasonic detection technology, image detection technology and laser detection technology is developing rapidly, among which FWD has become a widely used pavement detection technology with its advantages of fast detection speed and high accuracy [4-7]. A large number of scholars have studied FWD. Wang Tao et al. [8] have studied the method of using FWD measured deflection value to invert the elastic modulus of pavement structure layer foundation. Pan Mingwei et al. [9] calculated the deflection distribution of cement pavement under FWD load; Liu Qiang et al. [10] proposed the "contact compensation" theory, and studied the quantitative identification method of concrete cavity. Zang Guoshuai et al. compared and
analyzed the inversion effect of sink matching model and regular method model based on the inversion of base modulus by FWD, and established a non-destructive evaluation model of base cracking [11]. Yang E et al. established a similitude model of Sigmoid function curve based on the characteristics of FWD pavement surface deflection basin, and compared the accuracy of deflection values under different pavement conditions, in order to further improve the test accuracy of the falling weight deflectometer [12]. Song Xiaojin et al. established a modified deflection model based on the structural thickness and temperature parameters by modifying the dynamic deflection values of different asphalt pavement structural thickness, considering more comprehensive factors, making the test results closer to the engineering practice [13]. Although at present, the method of cavity detection based on the falling weight deflectometer is relatively perfect, but the accuracy of the detection of the disease by the falling weight deflector needs to be further improved. It is necessary to obtain a convenient and accurate cavity recognition method to enrich the cavity recognition technology based on the deflection.

Therefore, this paper constructs the normal pavement slab and the pavement slab with different cavity states through the self-made test device, and then uses the deflectometer FWD to test the deflection values of the normal pavement slab and the pavement slab with different cavity states. Based on the test, the deflection laws of the normal pavement slab and the pavement slab with different cavity states are compared and analyzed to verify the accuracy of FWD detection and the influence of cavity state on pavement deflection, so as to provide a reference for grouting detection technology.

Figure 1. Disease map of cavity beneath slab.

2. Test scheme design

2.1. Preparation of test plate
The test pavement consists of base course and surface course. According to the provisions of code for design of highway cement concrete pavement, the test dimensions of base course and surface course are selected. The base size is $6m \times 4m \times 0.20m$, and the surface size is $4m \times 2.5m \times 0.24m$. The base course material is cement stabilized macadam, and the surface course is concrete. The surface course is made by pouring concrete on site, and the curing period is 28 days. In order to move the slab during the test, the lifting rings are embedded at four corners of the slab. In order to study the test effect of FWD on slabs with different cavity states, three groups of working conditions were set up in this test, including group 1 as normal slab, group 2 and group 3 as cavity slab. There is one cavity in group 2, which is located in the center of the test pavement slab through setting the cavity of the circular plastic formwork embedded in the test pavement slab. The cavity radius is 0.6m and the cavity depth is 0.1m. There are two cavities in group 3, which are 0.32m apart and symmetrical about the central axis of the slab. The cavity radius is 0.42m and the cavity depth is 0.1m. The layout of test base course and surface course is shown in Fig. 2.
2.2. Test device

The deflection data acquisition device of this test is FWD, model is Dynatest8000, which is one of the most advanced pavement nondestructive testing equipment at present. The deflectometer belongs to dynamic deflectometer, which has 9 deflection sensors and 1 load sensor. Among them, the deflection sensor can measure the deflection of the pavement surface with an accuracy of 2%±2μm. FWD is free fall from the set height by a certain weight of drop hammer, which produces the specified impact force and makes the pavement structure produce dynamic deflection. Therefore, the deflection $W_C$ can be calculated according to the pavement structure model. In order to improve the accuracy of FWD, the system will automatically compare the measured deflection $W_m$ and $W_C$. When their error vector is less than $e$, FWD will output the deflection data. When the error vector is greater than $e$, FWD will adjust the deflection according to the parameter adjustment algorithm. Based on the measured deflection value of FWD, the dynamic modulus of each layer of pavement structure can be back-calculated, and then the actual dynamic performance of the pavement can be reflected, and the actual situation of the pavement can be calculated. The principle of FWD system identification is shown in Fig. 3.

![Figure 3. The principle of system identification](https://example.com/figure3.png)
2.3. Test scheme
Place the test slab in the specified position according to the requirements, set a measuring point at the center of each slab, define it as measuring point 2, set a measuring point with a left offset of 50cm based on the center position, define it as measuring point 1, set a measuring point with a left offset of 50cm based on the center position, define it as measuring point 3, and see Fig. 4 for the distribution of measuring points. Each measuring point is numbered according to the group number of each slab, which are group 1-1, group 1-2, group 1-3, group 2-1, group 2-2, group 2-3, group 3-1, group 3-2 and group 3-3.

FWD is equipped with drop hammers of different weights. Refer to code for field test of highway subgrade and pavement, this test uses drop hammers of 1t, 3t, 5t, 7t, 9t and 15t respectively to load each measuring point and record the deflection value of each measuring point.

3. Analysis of test results
Under the same temperature condition of each slab (the pavement surface temperature is 25℃), the deflection test of concrete pavement slab under different cavity state under FWD impact load is carried out. Carry out 10 times of repeatability test for each measuring point, remove the maximum and minimum values, and analyze the remaining eight times of data taking the average value. The deflection data of each measuring point under FWD impact load under different cavity conditions is shown in Figure 5.
It can be seen from Fig. 5 (a) that the measured deflection of group 3-1 is significantly greater than that of group 2-1, and the measured deflection of group 1-1 is the smallest. This is because the test slabs of group 2 and group 3 have cavities, the test points of group 2-1 are located near the cavity area, and the test points of group 3-1 are just above the cavity area.

It can be seen from Fig. 5 (b) that the measured deflection of group 2-2 is far greater than that of group 3-2, which is due to the fact that the measurement points of group 2-2 are above the cavity area and group 3-2 are near the cavity area. Comparing Fig. 5 (a) and Fig. 5 (b), it can be seen that the measured deflection of group 2-2 is significantly larger than that of group 3-1, which shows that the deflection at the cavity position is directly proportional to the area of the cavity area.

From Fig. 5 (c), it can be seen that the measured deflection of group 3-3 is greater than that of group 2-3, which is the same reason as Fig. 5 (a). Comparing Fig. 5 (a) and Fig. 5 (c), it can be seen that the measured deflection of group 1-1 is basically the same as that of group 1-3, group 2-1 and group 2-3, group 3-1 and group 3-3. This is because the pavement conditions of these measuring points are basically the same, so the measured deflection data are basically the same, which also shows that FWD has high precision and good stability.

In conclusion, FWD can better detect the real situation of the pavement surface, accurately identify the pavement cavity, and has high accuracy and good stability.
4. Conclusions
The use of sections to divide the text of the paper is optional and left as a decision for the author. Where the author wishes to divide the paper into sections the formatting shown in table 2 should be used.

1. FWD measured data can better reflect the real situation of the pavement, and has high precision and good stability;
2. The cavity will increase the deflection at the cavity position and the area near the cavity;
3. The deflection at the cavity position is proportional to the area of cavity area.

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