Asphalt Pavement Compaction Monitoring based on Fiber Grating Sensing Technology

Ioannis Kalpakidis
School of Civil Engineering and Hydraulic, Central State University of New York, NewYork, 12201, USA

Abstract: In order to effectively control the quality of asphalt pavement compaction, its monitoring method was studied. Strain responses in molding process were monitored by fiber Bragg grating (FBU) sensor installed in the composite rutting plates. Through analyzing the relationship between strain responses and rolling times, the compaction process was analyzed. Through loading on rutting plates molded with different rolling times using rut meter, strain response law was analyzed to estimate the compaction degree of asphalt mixture. The results show that strain response variation measured by FBU sensor begins to be gentle after nineteenth compaction in the process of plate molding. At the same time, compaction degree of asphalt mixture approaches the specification requirement, which shows that using FBU sensor to monitor compaction process is feasible. Strain responses of rutting plates with different compaction degrees in loading test at the same temperature are decreased with the increasing of compaction degree, which has the same trend with the strain variation of corresponding compaction times in molding process.

Keywords: Road engineering; Asphalt pavement; Fiber grating sensing technology; Compaction momtormg; Strain

1. Introduction

In recent years, with the widespread application of asphalt pavement in the construction of expressway, the disease of asphalt pavement appears gradually. The investigation found that the lack of compaction or overpressure is one of the important causes of asphalt pavement diseases. For example, insufficient pavement compaction can cause pavement rutting, cracks and other diseases. The overvoltage will lead to pavement bleeding phenomenon. Therefore, in the process of pavement construction, reasonable control of the number of times of rolling is the key to ensure the quality of asphalt pavement construction.

At present, some traditional asphalt pavement compactness testing methods have been widely used, such as coring method, nuclear density meter method and road surface radar technology, etc. These can effectively test the degree of compaction of the road surface. Zhou Zhigang and other [1] obtained the change law of the degree of compaction and the number of times of the thermal regeneration layer by means of the nuclear density tester. The quality evaluation of asphalt pavement compaction was studied by Wang Haitao [2] using road radar technology. Platl and other [3] have detected the compactness of the road using ground penetrating radar technology. Chen and other [4] determine the degree of compaction of the road by infrared thermometer. However, these methods have their own shortcomings. The coring method is destructive test, and the non-nuclear density meter and the road radar technology are all the detection of the exterior of the asphalt pavement, so the accuracy depends on the calibration reference. The application of FBG sensing technology in asphalt pavement has been more mature. Chen Shaoxing and other [5] studies show that FBG sensing technology is feasible for detecting the dynamic response of road surface. Tan Yiqiu and [6] designed the test method of cooperative Deformation Evaluation between sensors and asphalt mixtures. Dong Zejiao et al. [7-8] studied the effectiveness and correction method of using FBG sensors to monitor the strain information of pavement structures under complex stress conditions. The theoretical correction formula of strain measured value under tension state is established by Tian [9]. Tan Yiqiu and other [10-11] have carried out rutting prediction research on Rutting disease of asphalt pavement. These results prove the reliability of FBG sensors in the structural response monitoring of asphalt pavement. Therefore, based on FBG sensing technology, this paper studies the compaction monitoring method of asphalt road, and analyzes the feasibility of this monitoring method combined with solid engineering.

2. Specimen Forming Method and Test Scheme

2.1. Forming method

In order to simulate the real pavement structure, an improved double deck composite rutting plate is prepared. In order to ensure the survival of the sensor and make the sensor can be accurately positioned, the sensor is installed by "after installation" method. When the lower layer is formed, a cylindrical cement block of a size of 50 mm (high) X 100 mm (diameter) is embedded at the top thereof. When the lower layer is formed, the prefabricated block is taken out and a vertical optical fiber grating sensor is arranged in the reserved channel. Fill the sensor with the pre-mix AC-5 asphalt mixture, which allows the sensor to be fully encapsulated by the mixture, as shown in Figure 1.

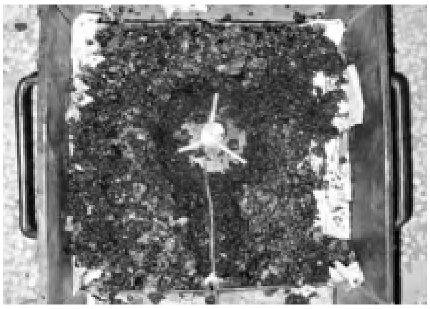

Figure 1. Composite Rutting Specimen Molding

2.2. Test scheme

2.2.1 Compaction process monitoring

The results show that the roller compaction is closer to the [12] than the field roller. Therefore, the wheel compaction process is adopted to simulate the pavement compaction process. In order to ensure the parallel test temperature of the rutting test piece, the composite rutting test specimen with good pre compression is placed in the oven for 10 min. Because of the short molding time, the temperature change of the specimen during the rolling process can be neglected. Start the wheel forming instrument, as shown in Figure 2 (a), and connect the fiber grating sensor to the demodulator, as shown in Figure 2 (b). After forming, the position of the top in the rut and sensor location mark sensor with "white chalk.

2.2.2. Compaction degree analysis

Because the strain response of pavement structure is stable under certain compaction degree, this paper tests the strain response of asphalt mixture rutting structure under the same load under different compaction degree. Load is an important factor influencing the strain response of pavement structure [7]. Before the test, the calibration of the wheel tracking instrument is carried out, and the results are shown in table 1. First, the sample is placed in a temperature controlled chamber of 40 DEG C, and the test is started when the temperature sensor is 40 degrees centigrade and remains stable when the temperature sensor is inside the wheel plate; Then, 1 block or 2 loading block is arranged on the loading system, and will be placed in advance loading wheel on the perpendicular strain sensor tag; Finally, adjust the temperature settings.

(a) Rutting forming instrument

(b) Demodulator

Figure 2. Molding of Composite Rutting Specimen and Monitoring Equipment

Table 1. Loading Calibrating Results with Rut Meter

Test item	1 piece loading block	2 piece loading block
Quality of test wheel /kg	51.485	89.643
The test wheel grounding area /cm²	0.79	0.83
Test wheel grounding pressure /MPa	0.65	1.08

3. Compaction Process Monitoring

As can be seen from Fig. 3, since the roller is just falling on the sensor, there are 1 strain troughs at the beginning of rolling. First troughs are removed, and then 22 troughs are added, and 11 times corresponding to the wheel forming machine. This shows that in the molding process, the sensor corresponds to the response of each roll, and each roll is effective. As can be seen from figure 4,5: the 2 roundtrip waveforms are similar and consistent. Through the comparative analysis of each round of changes can be found, the singular rolling response waveform or even rolling response waveforms are also consistent with each other. Thus, in the whole rolling process, the FBG strain sensor can monitor the strain change of the asphalt mixture in real time, effectively and steadily.

As can be seen from Figure 6, the strain response of fiber grating strain sensor increases gradually with the increase of rolling times before the seventh round trip. The reason is that before the seventh roller rolling, the asphalt mixture is gradually compacted, so the ability of the mixture to transfer deformation gradually increases. When the mixture is compacted after seventh times of compaction, the elastic modulus increases gradually. When rolled to nineteenth times, the strain change began to flatten.

With the increase of rolling times, the change law of the degree of compaction is shown in figure 7. As can be seen from Figure 7, with the increase of rolling times, the degree of compaction increases gradually. And after compaction fifteenth times, the increase of the degree of compaction gradually slowed down. When rolled to 18 times, the degree of compaction reached 95.6%, which basically reached the requirements of compaction in the relevant specifications. This shows that the fiber grating strain sensor has consistency in rolling late on Asphalt Mixture Compaction monitoring results and real-time change of mixture compaction trend, which further proves the feasibility of this method.

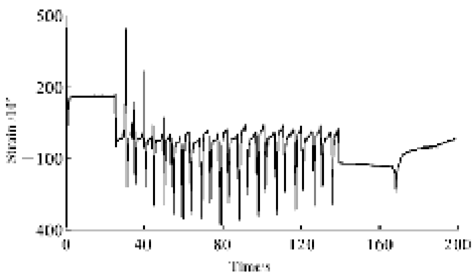

Figure 3. Variation Law of FBG Sensor Strain

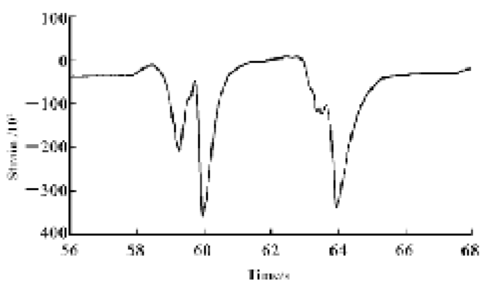

Figure 4. Forth Round-trip Variation Law of Compaction Strain

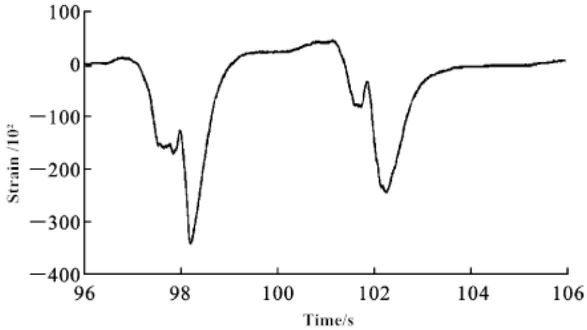

Figure 5. Eighth Round-trip Variation Law of Compaction Strain

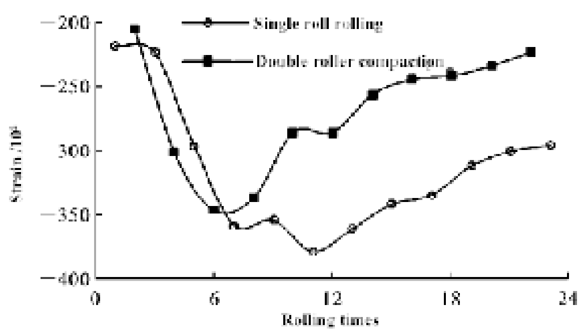

Figure 6. Variation Law of Maximum Strain vs. Rolling Times

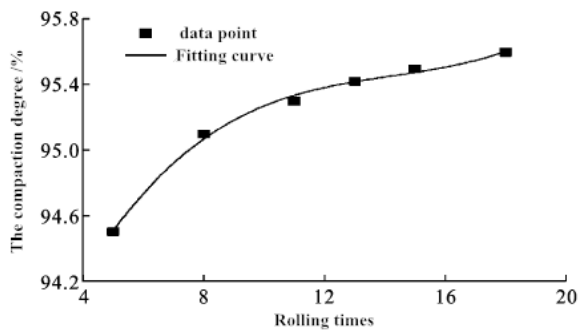

Figure 7. Degree of Compaction vs. Rolling Times

4. Compaction Degree Analysis

Under intermittent loading, the strain produced by the load is relatively stable. But under continuous load, because of the asphalt mixture in the high temperature can easily restore the residual deformation, so there is accumulation of deformation. Therefore, the discontinuous load can reflect the strain of asphalt mixture under different compaction degree. The strain response of the 3 tests at different temperatures can be obtained by means of mean value analysis. This shows that the strain in the different degree of compaction and the strain in the forming process are consistent with the increase of rolling times. The above data and analysis are based on the condition that a 1 loading block is set on the rutting loading system, and when the 2 loading block is set, the strain data will be obtained.

The strain response of FBG strain sensor also increases. The strain variation tendency of the 2 loading blocks under different temperature and different compaction degree is consistent with that of the 1 loading blocks. This shows that the different degree of compaction rutting specimens under different loads will show the same rule.

5 . Conclusions

Using fiber Bragg grating sensing technology to monitor the formation of indoor rutting plate, when the rolling to nineteenth times, the strain began to flatten. The degree of compaction basically meets the requirements of the specification, which shows that it is feasible to monitor the compaction process of asphalt pavement with fiber Bragg grating sensing technology. Using fiber grating sensor strain response analysis of compaction degree of asphalt mixing material, due to the continuous load sensor output results of strain accumulation, so the strain response peak intermittent load generated by the analysis. Under the same temperature, the load test of the rutting test specimens with different compactness decreases with the increase of the degree of compaction.

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