Rapid Evaluation of Cracked Cement Pavement Repair in Expressway Service Area

Zhe Gao[1,a*], Yao Feng[2,b], Qingbing Li[3,c], Xiaoyan Yang[4,d], Chuang Chen[4,e]

[1]Baise University, Guangxi, China

[2]Financial Investment Evaluation Center of Jinzhou Development Zone, Jinzhou, Liaoning, China

[3]Ningbo Zhengxin Detection Technology Co., Ltd., Ningbo, Zhejiang, China

[4]Ningbo Institute of Technology, Zhejiang University, Ningbo, Zhejiang, China

[a]gaozhe0072001@163.com,
[b]398470841@qq.com, [c]95121469@qq.com, [d]423324723@qq.com, [e]251326109@qq.com

*Corresponding Author

Keywords: Road engineering, Pavement treatment, Fwd test, Evaluation methods, Crack

Abstract: In order to take effective repairing measures to solve cement pavement cracking distress in expressway service area which is getting more and more serious, basing on a project repairing cracked pavement in an expressway service area, this paper developed the repairing design and testing design and put forward evaluation criterion and corresponding evaluation standard for repairing. Results showed that the combination of grouting at each side of the crack under pavement and crack sealing brought significant effect for improving pavement structure. After repairing, for pavement with serious cracking, the average dynamic deflection value had a 20%~30% decrease and the load transfer efficiency was raised 3-4 times. D0 and D0/D200 were advised as evaluation criterions. Besides, structure strength in 1m range at the two sides of crack should be given enough consideration in repairing design.

1. Introduction

With the rapid development of China's transportation industry, the construction of highway is changing quickly. By the end of 2014 years, the total mileage of highways in China has reached 119000km. As an important facility of highway, the construction of service area has attracted more and more attention. According to the provisions of JTG01, a service area should be built for an average of every 50km on the highway, and one to three parking areas should be established between the two large service areas [1]. The pavement condition of the service area has become an important index to measure the service level of the regional highway [2]. At present, the pavement structure of the highway service area basically adopts the type of soil foundation or base with concrete slab. The design thickness is calculated by using the relevant formula in provision of JTGD 40. However, the driving speed of the vehicle in the service area is relatively low, generally at 5km/h, and the time that the load acts on the pavement structure once is equivalent to 6 times of the common pavement time [3], and the driving direction of the vehicle is even more unstable. The fracture of Common Cement Concrete Pavement is mostly located at the corner of the slab, but the difference of traffic load causes the pavement crack in the highway service area to often appear in the middle of the slab. The position of the crack is easy to cause cavity beneath road slab, which will further aggravate the expansion of the crack and cause the overall cracking failure of the slab. The concrete pavement is seriously cracked and damaged, the handling methods with crack is not only to crack pouring, but also to treat the cavity beneath road slab at the fracture position by grouting [4]. The grouting material is mainly by cement slurry, cement-fly ash grout or cement mortar. Through the infiltration, filling and compaction process, it can block the void area at the bottom of the slab and achieve the purpose of delaying the damage such as slab mud pumping and fracture.

  DOI: 10.25236/civeb.2020.019

Deflection experiment is the most commonly method to judge pavement cracking damage and cavity beneath slab [5]. Because of Falling Weight Deflectometer (FWD) can not only rapidly complete deflection detection, but also obtain complete deflection basin of pavement structure under dynamic load of vehicles. In this paper, the FWD measured data before and after the maintenance of highway service area pavement fracture location was analyzed and the indexes of maintenance effect by maintenance of highway service area pavement crack was put forward.

2. Experiment Method

The length and width of cement pavement slab are 6m and 4m in a certain highway service area, respectively, as shown in Figure 1. The concrete slab has continuous fracture damage, and the cracks are mostly transverse to the center of many slabs, and the slab bottom near the cracks has already appeared void. The slab bottom grouting method is adopted to treat the void, and the crack pouring treatment is carried out on the cracks.

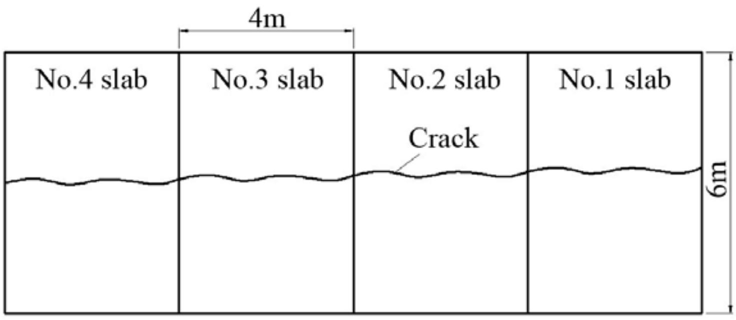


Fig.1 Relative Plane Positions between Testing Pavement Slabs in Expressway Service Area

In this section, four consecutive slabs with fracture failure in the middle of the slab are selected. Grouting holes are staggered on both sides of the crack. The interval between adjacent grouting holes on each side is 1m. The grouting material consists of cement, fly ash and admixture. The diameter of grouting holes is 5cm, the depth of holes is about 45cm, and the grouting pressure is 1.5~2.0MPa. FWD is used to test the deflection basin at the same position before and after slab repair. The radius of load plate for vehicle is 15cm. There are 7 sensors for D_0~D_{1500}, as the distances between check and load center is 0, 200, 300, 600, 900, 1200 and 1500mm, respectively. For example, Figure 2 shows the located of FWD points and load centers on each slab. FWD points are arranged on the median line parallel to the longitudinal edge of the slab, and the load centers are respectively at the positions 0.15m, 0.5m and 1m away from the crack on both sides. When testing at different points, the corresponding positional relationship between cracks and sensors are shown in Table 1. The testing at three measuring points, cracks are between sensors 1 to 2, 3 to 4 and 5 to 6, respectively. When the load center is 0.15m from the crack, the positional relationship between the crack and the sensor is shown in Figure 3.

Table 1 Relative Position between Crack and Sensors at Different Measuring Points

L(m)	Crack position
0.15	between sensors 1 to 2
0.50	between sensors 3 to 4
1.00	between sensors 5 to 6

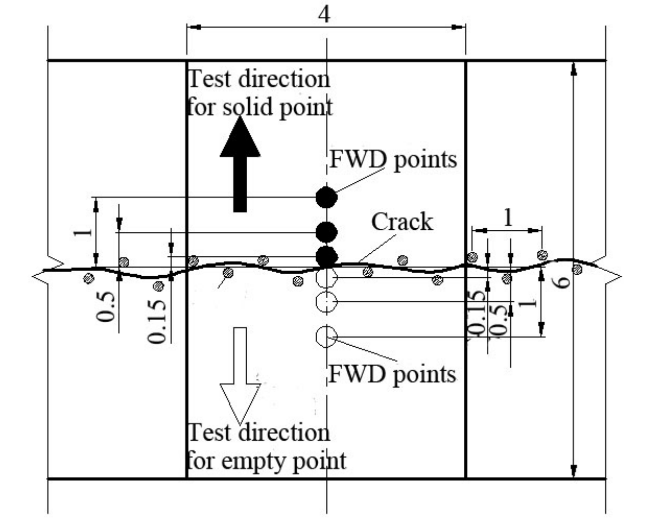
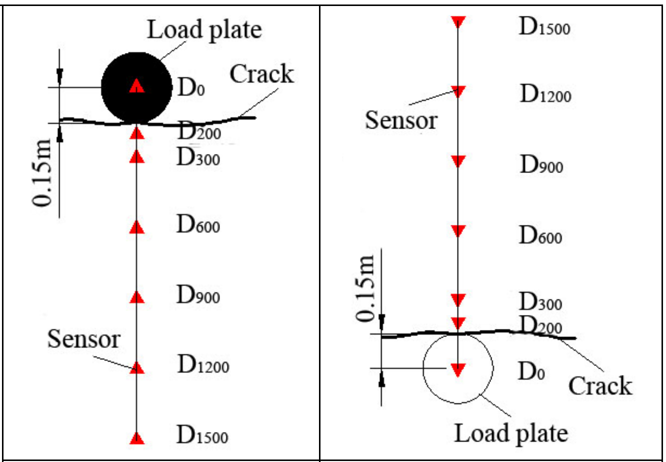


Figure 2 FWD experiment method (Unit: m)



(a) Solid point

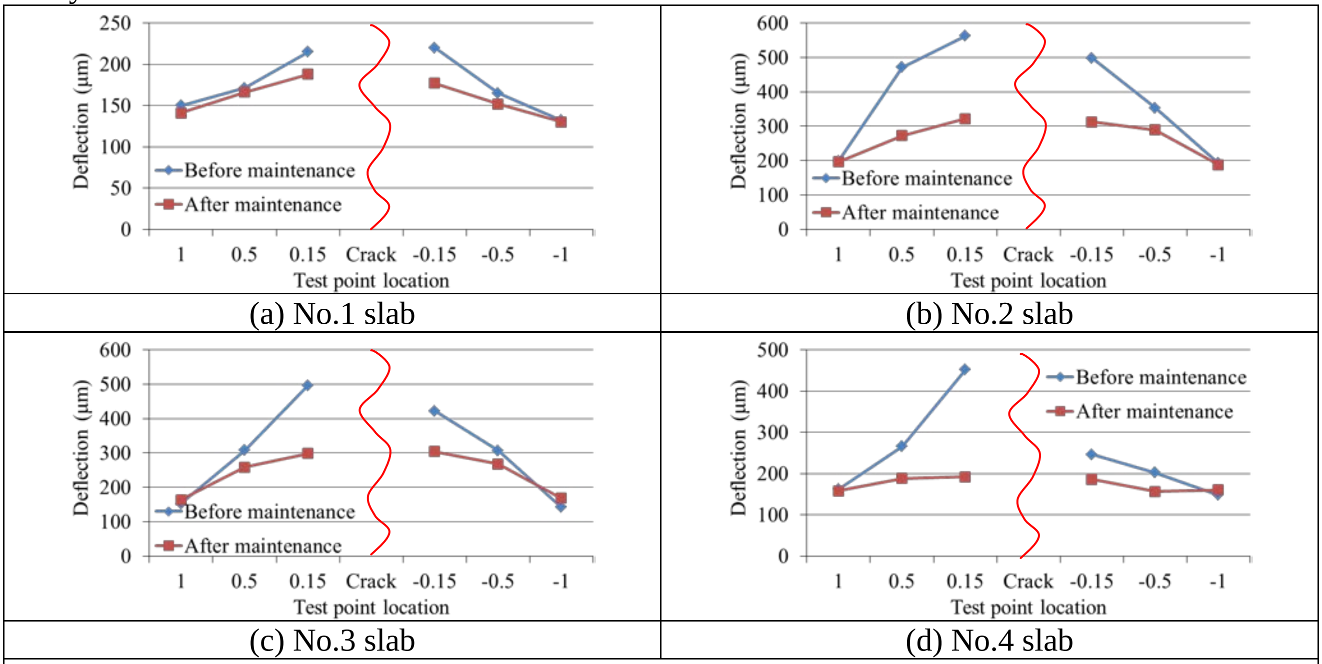
(b) Empty point

Figure 3 Relative positions (L=0.15m)

3. Experiment Results Analysis

3.1 Variation of Pavement Deflection

Deflection at the center of the bearing slab reflects the whole deflection of the pavement, which is an important parameter in evaluating the structural performance of the pavement [6]. Therefore, through the comparative analysis of deflection value of load center, the pavement structure condition near cracks before and after maintenance can btee obtained. The results of dynamic deflection for No.1 to No.4 slabs are shown in Figure 4. The average value and standard deviation of dynamic deflection of load center before and after maintenance are shown in Table 2.



(a) No.1 slab

(b) No.2 slab

(c) No.3 slab

(d) No.4 slab

Figure 4 Dynamic deflections at center of loading plate

Figure 4(a) shows that the deflection of No.1 slab at each measuring point after maintenance is reduced, but the reduction is not significant. Figure 4(b) shows that the deflection of No.2 slab near the crack has exceeded 500μm before maintenance, and the structural damage is very serious. after maintenance treatment, the deflection at the measuring point 1m away from the crack has little change, but the deflection at the positions 0.5m and 0.15m away from the crack has greatly decreased, with the maximum dynamic deflection decreased to about 300μm. Figure 4(c) shows the deflection of No.3 slab at the measuring point 1m away from the crack also has little change, while the deflection at the positions 0.5m and 0.15m away from the crack is greatly decreased, with the maximum dynamic deflection is decreased from 500μm to about 300μm. Figure 4(d) shows the deflection of No.4 slab on one side 0.15m away from the crack exceeds 450μm, while the dynamic deflection value on the other side is only about 250μm.

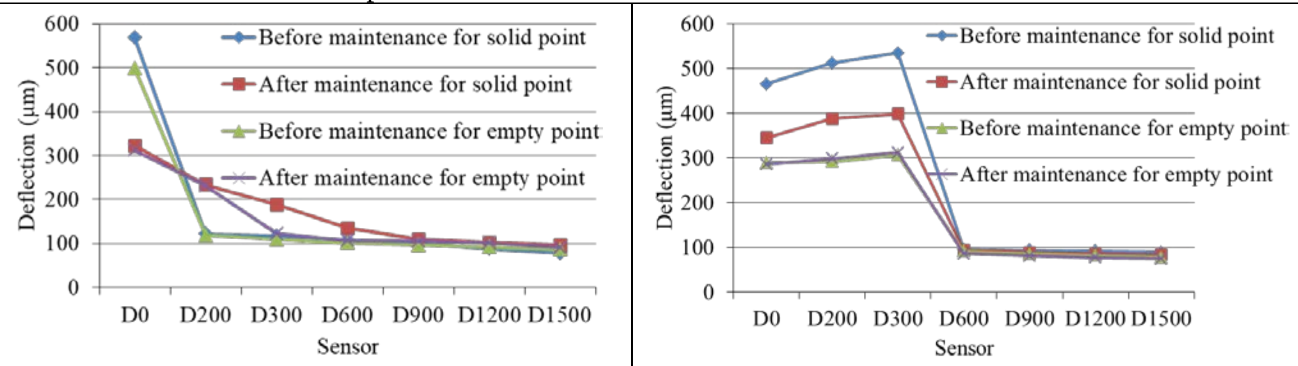
Table 2 Average Value and Standard Deviation of Dynamic Deflections

No.	Average value			Standard deviation		
	before maintenance(μm)	after maintenance(μm)	Ratio(%)	before maintenance(μm)	after maintenance(μm)	Ratio(%)
1	172	156	9.19	35.4	24.7	30.05
2	365	261	28.46	166.7	61.6	63.06
3	304	240	21.01	143.2	63.0	56.01
4	242	163	32.69	116.3	19.2	83.49

As shown in Table 2 that the deflection at the measuring point 1m away from the crack has little change, indicating that the influence range of the crack on the pavement structural strength is within 1m on both sides of the crack. Therefore, the pavement structural strength within 1m on both sides of the crack should be mainly considered when designing the maintenance method. The average value of dynamic deflection of No. 1 slab is reduced by 8~9% after maintenance, while No.2 to No. 4 slabs with serious cracks on the original pavement, the average value of dynamic deflection for each plate is reduced by 20%-30%. The reduction ratio of deflection standard deviation of each slab is above 30%, and that of slab 4 is even 83%. It indicates that the maintenance scheme combining grouting and crack pouring has significantly improved the strength of the pavement structure.

3.2 Deflection Shape

The FWD deflection index of load center mainly reflects the improvement of pavement structure strength near cracks by maintenance treatment, it not directly reflect the change of load transfer capacity of crack positions before and after maintenance. The deflection shape can evaluate the change of pavement load transfer capacity at crack location before and after maintenance. When the crack is 0.15m away from the load center, it is located between sensors 1 and 2, i.e. between D_0 and D_{200}, shown in Figure 5(a). When the crack is 0.5m away from the load center, it is located between sensors 3 and 4, i.e. between D_{300} and D_{600}, shown in Figure 5(b). D_{200} and D_{300} are even larger than D_0 at the load center due to serious crack damage and low structural strength of the pavement near the crack for No.2 slab. After maintenance, the deflection at each sensor position is reduced, but the whole deflection shape is still similar to that before maintenance.



(a) Distance between load center and crack for 15cm

(b) Distance between load center and crack for 50cm

Figure 8 Deflection shape before and after treatment for No.2 slab

In order to quantify the morphological changes of deflection basin before and after maintenance, the ratio D_{200}/D_0 (load transfer coefficient) between D_0 and D_{200} with obvious changes is selected as the morphological parameter. The grading standard for load transfer capacity at crack position is proposed based on the specified of JTG D40-2002 [5], as shown in Table 3.

Table 3 Grading Standard of Load Transfer Efficiency of Crack

Grade	Good	Medium	Second	Poor
D_{200}/D_0 (%)	>80	56~80	31~55	<31

4. Conclusions

Based on a highway service area pavement maintenance project, this paper formulates a cracked pavement maintenance scheme and a maintenance effect detection scheme. On the basis of measured FWD data, through the analysis of deflection value in load center and deflection basin shape parameters, the evaluation index and standard of highway service area pavement maintenance effect based on FWD are proposed. The following are the main conclusions:

(1) The combination of grouting treatment and crack pouring on both sides of the crack has a significant effect on the treatment of slab cracking and the improvement of pavement structural strength and structural uniformity. After repairing the damaged position, the average value of dynamic deflection is reduced by 20%-30%, and the load transfer coefficient is increased to 3-4 times of the original value.

(2) It is recommended to adopt a detection method that the outer edge of the load plate is tightly attached to the crack for No.1 and No.2 sensor are located on both sides of the crack, respectively.

(3) The influence range of cracking on the pavement structural strength is within 1m on both sides of the crack. In designing the maintenance scheme, the pavement structural strength within 1m on both sides of the crack should be mainly considered.

References

[1] T. P. Yan, X. J. Zeng. Discussion on Expressway Service Area Construction. Journal of China & Foreign Highway, Vol.27, No. 7, pp. 7-9, 2007.

[2] H. J. Cheng, Y. Zhao, Y. H. Zhang. Analysis of Bearing Capacity in Service Area of Expressway with 3D Finite Element Model. Highway, No.5, pp. 130-135, 2015.

[3] Z. C. Xue, S. C. Zhao, Q. Yang. Design Features and Sensitivity Analysis of Pavement Structure for Service Areas of Jinan-Heze Expressway. Journal of Highway and Transportation Research and Development, Vol. 27, No. 7, pp. 33-37+47, 2010.

[4] S. Zeng, J. Zhao, J. F. Zou. Inspection Index of Grouting Treatment Validity for Void beneath Cement Concrete Slab. China Journal of Highway and Transport, Vol. 23, No. 7, pp. 7-15, 2010.

[5] W. G. Su. Analysis of FWD Data from Field Test for Existing Cement Concrete Pavement. Journal of Highway and Transportation Research and Development, Vol. 21, No. 7, pp. 12-15, 2004.

[6] P. Thitikorn; K. Warat; Y. W. Sompote. Correlations between Strains in a Thin Asphalt Pavement Structure and Deflection Basins Investigation by Linear Elastic Analysis and Experiments. Journal of the Transportation Research Board, No.2473, pp. 83–90, 2015.