Research on Maintenance Management of Flexible Pavement Based on C-LTPP

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Abstract. Based on the Canadian Long-Term Pavement Performance (C-LTPP) data, this paper chooses the road performance related data as variable factors. According to the Dipstick detection results, the characteristic values such as rut depth, wheel track width and cross section area are extracted to describe the rutting. This paper established the relationship between the pavement rutting and the cumulative service time, determined the rutting evaluation index, and proposed the pavement maintenance time threshold. Comparing the flexible layer overlay repair schemes used in various test points, it provides a reference for the pavement performance management decision-making and the road repair scheme design after repair.

Keywords: Flexible pavement, rutting, overlay repair, big data, C-LTPP.

1. Introduction
Plenty of roads have been in service for a long time and have accumulated serious damage but still need to bear heavy traffic. These pavements urgently need to be repaired for reuse. At present, the scheme of using the flexible overlay has been widely used in the rehabilitation of old pavements, and the research on its performance should also be gradually promoted [1, 2]. Rutting is one of the typical damages on pavement, and it is of great significance to study the rutting of the service performance management of repaired pavement.

The research of pavement reconstruction and repair is mainly focused on the design of repair scheme and the formulation of repair process [3]. The common method is to select milling treatment measures to deal with the original structural layer after the damage investigation of the original pavement, and then design the overlay thickness and material mix proportion according to the original pavement damage characteristics, combined with road traffic demand and other service environment information.

The study on restoration of old roads and road performance after restoration has been carried out earlier abroad, and more in-depth exploration has been made for the design of repair scheme and the evaluation of pavement service performance [4, 5]. The research on pavement restoration in our country has been carried out late. At present, most of them focus on the management and maintenance of the first built road and the pavement reconstruction and repair methods. However, little attention has been paid to the service performance of the repaired Road, and the damage development law of the
repaired pavement structure has not yet been established [6]. Nowadays, the research on the service performance change law of the repaired road sections is relatively shallow. At present, the road structure damage development law of these road sections can only be described temporarily with reference to the service performance change law after the road is first built [7]. However, the compactness of the base course and the brand-new degree of the materials in each structural layer of the reconstructed pavement structure are quite different from those of the new road section [8]. The cumulative damage of the old road before the overlay repair plays a great impact on the performance of the repaired pavement. With more and more renovated road sections put into use, more attention should be paid to the research on service performance of repaired roads. On the other hand, due to the imperfect information construction of road infrastructure, the monitoring and detection of actual road sections are not in place, resulting in insufficient collection of pavement performance related data [9, 10]. The lack of pavement performance observation results makes the research on road performance development law limited.

Among the various researches carried out for pavement repair, the Canadian Long-Term Pavement Performance (C-LTPP) is a representative test project focusing on pavement repair with flexible layers. The C-LTPP database covers various information such as materials, structure, traffic, climate and damage detection before and after the pavement resurfacing and repairing. With large data scale, long observation time and many variables involved, it provides complete and reliable data resources for various studies on service performance of flexible pavement overlay repair.

2. Data
The data comes from the C-LTPP database, and the relevant data can be obtained in LTPP InfoPave_NON-LTPP_CLTPP Data. The development trend of the rut depth on the left and right sides of each test section and the total filling area of the rut cross section over time are plotted as a graph, and the rut development trend is consistent with the cross section area. By drawing the development trend of rutting depth and total filling area of rut cross-section over time, the author finds the development trend of rut is consistent with that of cross section area.

3. Rutting Evaluation and Road Maintenance

3.1. Establishment of Pavement Rutting Evaluation Index
According to the development trend of rutting, the change of rut depth on the left and right sides of the road is selected as the rutting evaluation index. In order to facilitate the road management personnel to determine the maintenance cycle of the road surface, the cumulative service time of the repaired rear road surface is selected as the time reference to establish the change curve of rutting with the cumulative service time. The extraction method of rutting evaluation index is shown in figure 1.

![Figure 1. Extraction of rutting evaluation index.](image)

Point a represents the maintenance time threshold determined based on the cumulative rutting depth, while point b represents the maintenance time threshold based on the characteristic nodes of the
change trend of rut volume. Take the minimum value of A and B as the actual maintenance time. Firstly, it is also necessary to specify the expected service life of the pavement, that is, the upper limit of the service time. If the rutting depth does not exceed the proposed upper limit value during this period, and there is no accelerated damage characteristics of mixture, then the pavement is considered to have good rutting performance, and the pavement does not need to be maintained within the specified service life.

3.2. Pavement Maintenance Time Decision Based on Rutting

The rutting evaluation is carried out on each test section after treatment with different repair schemes, and the pavement maintenance time threshold was determined.

The rutting depth is used as the characteristic index to evaluate road rutting performance. Firstly, the upper limit of rutting depth and the expected service life are specified. It is stipulated here that the upper limit of rut depth tolerance based on A is 15 mm (i.e. RDmax=15 mm), and the service life of the designated section is 20 years.

If the characteristics mentioned in A or B is not found during the service period of 20 years, the service performance of the test section is considered to be good. Since the characteristic indexes related to the rutting depth extracted from the actual road section include the left and right rutting depth, the evaluation indexes of the left and right rutting depth are extracted firstly. Then the minimum value of the two indexes is taken. The accumulated service years that require maintenance are rounded down uniformly, as shown in figure 2.

![Figure 2. Schematic diagram of pavement maintenance time threshold extraction based on Rutting.](image)

According to the above methods, the pavement maintenance time threshold decision based on rutting is extracted for each test section, and relevant information such as overlay repair method, maintenance year time threshold and corresponding cumulative road axle load times and rutting depth are recorded.

4. Comparison and Selection of Repair Schemes for Flexible Layer Overlay

4.1. Rutting Development under Different Repair Schemes

The long-term performance observation test involves a total of 65 test road sections. Each test road section adopts different repair and overlay schemes, which are divided according to the thickness of the structure layer (T) and the asphalt mixture type of the flexible surface course, as shown in table 1.

According to the development trend of rutting, comparing the rutting performance of the road surface under different repair schemes of each test point, it is obtained that the development trend of rutting depth is basically consistent with that of the total cross-sectional filling area. The total filling area of the cross-section of each test section is taken as the rutting feature description index, and the rutting development trend comparison chart is drawn for 24 test points, as shown in figure 3.
Table 1. Repair scheme description of each test section.

| Test point | Repair solution description | Test section 1 | Test section 2 | Test section 3 | Test section 4 |
|------------|----------------------------|----------------|----------------|----------------|----------------|
|            | Overlay thickness /mm Material | Overlay thickness /mm Material | Overlay thickness /mm Material | Overlay thickness /mm Material |
| 810404     | 61 HMAC                      | 103 HMAC        | 94 RAP         | 55 RAP         |
| 820205     | 42 HMAC                      | 83 HMAC         | —              | —              |
| 820502     | 104 RAP+HMAC                 | 118 RAP+HMAC    | —              | —              |
| 820605     | 50 HMAC                      | 73 HMAC         | —              | —              |
| 830403     | 100 HMAC                     | 113 HMAC        | 148 HMAC       | —              |
| 830801     | 185 RAP+HMAC                 | 103 RAP+HMAC    | 126 HMAC       | 170 HMAC       |
| 840101     | 174 RAP+HMAC                 | 179 HMAC        | 87 HMAC        | —              |
| 840204     | 114 HMAC                     | 88 HMAC         | —              | —              |
| 840604     | 107 RAP+HMAC                 | 90 HMAC         | 30 HMAC        | 35 HMAC        |
| 850201     | 117 HMAC                     | 73 HMAC         | —              | —              |
| 850206     | 106 HMAC                     | 63 HMAC         | —              | —              |
| 850601     | 122 HMAC                     | 74 HMAC         | —              | —              |
| 860501     | 55 HMAC                      | 85 HMAC         | 41 HMAC        | —              |
| 860603     | 86 HMAC                      | 80 HMAC         | 34 HMAC        | —              |
| 870102     | 95 HMAC                      | 46 HMAC         | —              | —              |
| 870504     | 31 HMAC                      | 61 HMAC         | —              | —              |
| 870505     | 75 HMAC                      | 73 HMAC         | 105 HMAC       | 106 RAP+HMAC   |
| 870701     | 43 HMAC                      | 106 HMAC        | —              | —              |
| 880203     | 51 HMAC                      | 109 HMAC        | 51 HMAC        | 99 HMAC        |
| 890503     | 40 HMAC                      | 51 HMAC         | 106 HMAC       | 83 HMAC        |
| 890702     | 44 HMAC                      | 85 HMAC         | —              | —              |
| 900402     | 86 HMAC                      | 126 HMAC        | —              | —              |
| 900802     | 55 HMAC                      | 67 HMAC         | 104 HMAC       | —              |
| 900803     | 158 HMAC                     | 108 HMAC        | —              | —              |

Observing the trend of the total filling area of the road cross section of each test section with the cumulative service time, it is possible to intuitively compare the road rutting under different repair schemes to evaluate the rutting performance of pavement structure under each repair scheme.

(1) The paper studies the influence of pavement repair scheme on the development of rutting after repair, and finds that the development trend of rutting shows great difference in some test points while the development trend of rutting is closer in other test points, as shown in figures 3(c), 3(w) and figures 3(f), 3(g). The results show that the influence of different repair schemes on the rutting development is different.

(2) Comparing the relationship between the type of asphalt mixture and the rutting, it is found that the rutting development of the test section is less smooth when the asphalt mixture is fully recovered or partially recovered. Compared with the test section with new hot mix asphalt mixture, the accelerated growth trend of rutting appears more obvious in the later service period (as shown in figure 3(g) and figure 3(f)), but there is no significant difference in the early service period. In addition, some test sections with new hot-mix asphalt mixture developed serious rutting in the early stage of service due to material compaction, while the early compaction of test sections with recycled asphalt mixture is not significant (figure 3(q)). The influence of different paving materials on rutting development is mainly concentrated in the stage of long accumulative service time. If considering its
economic benefits, two kinds of materials can be mixed according to a certain proportion.

3) Comparing the relationship between the structural thicknesses of overlay and rutting, generally speaking, the rutting of test section with thicker overlay is generally lighter. However, when the pavement thickness is too large, the increase of pavement thickness has no obvious effect on reducing pavement rutting, and even higher rutting may be accumulated in the early compaction stage. It shows that the repair method of thick paving is not necessarily the best choice to reduce the pavement rutting. In the actual design of the repair scheme, all factors should be considered comprehensively to determine the thickness of pavement structure layer.

Figure 3. Rutting comparison of each test section.

In addition, whether to mill the pavement before paving depends mainly on the cumulative damage degree of the original pavement. For the test road section with heavier accumulated damage on the original road surface, milling treatment before paving can provide a smoother underlying structure for the paving surface. The rutting of the test section with poor surface treatment is more serious after repair.

4.2. Comparison and Selection of Pavement Repair Schemes Based on Rutting
The repair scheme has a great influence on the service performance of the repaired pavement. Based
on the rutting evaluation of each test section, the service performance of the repaired pavement under the combination scheme of different overlay thickness, overlay material type and original pavement milling thickness is judged. Above all, the comparison and selection of flexible layer overlay repair schemes for different test sections is carried out.

According to the pavement rutting severity and rutting development trend, the flexible layer overlay repair scheme was selected for 24 test points. When selecting the pavement repair scheme, the priority should be given to the duration of the pavement reaching the maintenance time threshold, and then the indexes such as accumulated rut amount, type of overlay material and thickness of overlay are considered. Since the specified upper limit of the service life of the pavement is 20 years, for the test section with good service performance evaluation, the cumulative service time to be maintained shall be recorded as 20 years. The selection of flexible layer overlay repair scheme based on rutting is shown in table 2.

| CSHRP_ID | Milling thickness /mm | Overlay Thickness /mm | Paving materials | Pavement service time /year |
|----------|-----------------------|-----------------------|------------------|----------------------------|
| 820205   | 0                     | 42                    | HMAC             | 15                         |
| 820605   | 0                     | 50                    | HMAC             | 15                         |
| 830403   | 0                     | 113                   | HMAC             | 20                         |
| 840101   | 0                     | 87                    | HMAC             | 11                         |
| 840204   | 0                     | 114                   | HMAC             | 13                         |
| 850201   | 0                     | 117                   | HMAC             | 17                         |
| 850206   | 0                     | 106                   | HMAC             | 14                         |
| 850601   | 0                     | 74                    | HMAC             | 7                          |
| 860501   | 0                     | 85                    | HMAC             | 16                         |
| 860603   | 0                     | 86                    | HMAC             | 9                          |
| 850201   | 0                     | 117                   | HMAC             | 17                         |
| 850206   | 0                     | 106                   | HMAC             | 14                         |
| 850601   | 0                     | 74                    | HMAC             | 7                          |
| 860501   | 0                     | 85                    | HMAC             | 16                         |
| 860603   | 0                     | 86                    | HMAC             | 9                          |
| 870504   | 0                     | 61                    | HMAC             | 20                         |
| 870701   | 0                     | 43                    | HMAC             | 20                         |
| 880203   | 0                     | 51                    | HMAC             | 9                          |
| 890503   | 0                     | 106                   | HMAC             | 12                         |
| 890702   | 0                     | 85                    | HMAC             | 10                         |
| 870505   | 0                     | 106                   | RAP+HMAC         | 16                         |
| 810404   | 50                    | 61                    | HMAC             | 20                         |
| 830801   | 40                    | 170                   | HMAC             | 20                         |
| 840604   | 52                    | 90                    | HMAC             | 10                         |
| 870102   | 35                    | 46                    | HMAC             | 16                         |
| 900402   | 40                    | 86                    | HMAC             | 15                         |
| 900802   | 60                    | 104                   | HMAC             | 16                         |
| 900803   | 60                    | 108                   | HMAC             | 16                         |
| 820502   | 50                    | 104                   | RAP+HMAC         | 15                         |

5. Conclusions
Based on the relationship between road rutting and road cumulative service time, this paper formulates rut evaluation indicators and proposes a pavement maintenance time threshold to provide a basis for road maintenance decision-making.
Firstly, based on the rutting development law of each test section and the mechanical properties of asphalt mixture, the pavement rutting evaluation index is formulated. Then, the relationship between the development trend of rutting depth and the cumulative service time of pavement after repair is established, and the rutting maintenance time threshold of each test section after flexible layer overlay repair is proposed. This paper analyzes the influence of different overlay repair schemes on the rutting development of the repaired pavement, evaluates the rutting performance of the pavement under different flexible layer overlay restoration schemes, which provides reference for the design of the flexible layer overlay repair scheme.

The law of pavement rutting development is complex, and the pavement rutting development after the flexible layer overlay repair is affected by more factors. The rutting development trend and service performance of the repaired pavement are different from that of the new pavement. The service history of the original pavement and the performance degradation of the old structural layer materials are all reflected in the repaired pavement. Therefore, more attention should be paid to the accelerated growth of pavement rutting caused by the accelerated damage of materials when evaluating the rutting of the repaired pavement. On the other hand, the milling treatment of the original surface course, the selection of overlay materials and the overlay thickness will affect the rutting development of the repaired pavement. Therefore, it is of great significance to select a reasonable repair scheme to maintain the service performance of the pavement after the repair of the flexible layer and extend the service life of the road.

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