The Post Evaluation of Hot in Place Recycling Technology Based on the AHP

Ling Yu¹,*, Siyu Jia², Longsheng Bao³

¹School of Transportation Engineering, Shenyang Jianzhu University, Shenyang, China, 110168; 1045529953@qq.com

Abstract: The hot in place recycling technology has the advantages of economy, environmental protection, high efficiency, so it becomes more and more popular. But the post evaluation of hot in place recycling technology lacks scientific system. By analyzing the pavement performance post evaluation index of hot in place recycling technology, the independent post evaluation system of hot in place recycling technology is established. Based on the characteristics of heat recovery, this paper studies the performance evaluation of hot in place recycling technology at home and abroad, and further studies the post-evaluation index of HIR pavement performance and establishes a relatively complete HIR road surface performance evaluation system.

Keywords: Hot in place recycling technology, Pavement performance, Post evaluation analytic hierarchy process

1 Pavement Performance Post Evaluation Index Of The Hot In Place Recycling Technology

According to Highway Technology Status Assessment Criteria (JTG-H0-2007), we can know that the pavement quality index (PQI) is used as an evaluation index. The pavement performance index is calculated by four indicators: pavement breakage condition index (PCI), road driving quality index (RQI), rutting depth index (RDI), and skid resistance performance index of pavement surface (SRI). So PQI can be obtained by analytic hierarchy process. As formula (1):

\[ PQI = w_{PCI} PCI + w_{RQI} RQI + w_{RDI} RDI + w_{SRI} SRI \]  

The weight of each index in the formula is determined by analytic hierarchy process.

2 Analysis of Pavement Performance Evaluation Index

2.1 Post evaluation of pavement damage condition index (PCI)

According to "Highway Technology Assessment Criteria" (JTGH20-2007) [3], the calculation formula of PCI is as follows:

\[ PCI = 100 - 15DR^{0.412} \]  

Wherein: \( DR = 100 \times \frac{\sum_{i=1}^{n} \omega_i A_i}{A} \)

\( DR \) — The pavement surface total damage rate, which is equal to the sum
of damage area of the type of asphalt pavement divided by the
total area of the test section(%):

\[ A_i = \text{The sum of the area of the damaged form } i \]

\[ A = \text{The total area of the pavement being counted (statistical length } \times \]
\[ \text{effective pavement width, } m^2 \); \]

\[ w_i = \text{The weight value of the damaged form } i. \]

Table 1 is the statistics of the asphalt pavement damage area after the test
section was treated by the hot in place recycling technology:

<table>
<thead>
<tr>
<th>Detection of road segments</th>
<th>Equivalent broken area ((m^2))</th>
<th>The total area of road sections ((m^2))</th>
<th>Comprehensive damage rate ((%)</th>
<th>Pavement Condition Index ((PCI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.95</td>
<td>1500</td>
<td>0.33</td>
<td>90.5</td>
</tr>
<tr>
<td>B</td>
<td>15.30</td>
<td>4500</td>
<td>0.34</td>
<td>90.4</td>
</tr>
<tr>
<td>C</td>
<td>5.81</td>
<td>1875</td>
<td>0.31</td>
<td>90.7</td>
</tr>
<tr>
<td>Average value</td>
<td>8.69</td>
<td>2625</td>
<td>0.33</td>
<td>90.5</td>
</tr>
</tbody>
</table>

2.2 Road driving quality

The comfort of the vehicle can be directly reflected by pavement surface
roughness. At present, pavement surface roughness is usually evaluated by the
pavement quality index (RQI). The calculation formula is as follows:

\[ RQI = 11.5 - 0.75 \times IRI \]  \hspace{1cm} (3)

\[ IRI = 0.3803BI - 0.4537 \]  \hspace{1cm} (4)

Wherein:  \( IRI \)—International flatness index \((m/km)\);

\( BI \)—The results which is collected by using the flatness equipment;

IRI is a non-dimensional index, which is detected by vehicle-mounted
rapid detection equipment, when the investigation area is small, it can be
detected by artificial methods, usually m/km as a unit. The three-meter ruler
method is suitable for short test sections and has a certain representative, so this
method is used as test method. Every 100 meters as a test group, a form of
measurement data of the 10 groups and the whole measured in this way from
randomly selected 30 meters to end to end. Then the pumping test result of the
test section is sorted. According to the formula to calculate the pavement
driving quality as shown in Table 2.
### Table 2. Statistics of pavement riding quality.

<table>
<thead>
<tr>
<th>Detection of pavement segments</th>
<th>Three meters straightness flatness (mm)</th>
<th>International flatness (IRI)</th>
<th>Driving quality index (RQI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.48</td>
<td>0.87</td>
<td>100</td>
</tr>
<tr>
<td>B</td>
<td>3.29</td>
<td>0.80</td>
<td>100</td>
</tr>
<tr>
<td>C</td>
<td>3.55</td>
<td>0.90</td>
<td>100</td>
</tr>
<tr>
<td>Average value</td>
<td>3.44</td>
<td>0.86</td>
<td>100</td>
</tr>
</tbody>
</table>

#### 2.3 Rutting depth of pavement

According to "Highway Technical Condition Evaluation Standard" (JTG H20-2007). In this paper, different functions are used to calculate for rutting of different depths, and the maximum rutting depth is limited. The model is as follows:

\[
RDI = \begin{cases} 
100 - RD & (RD \geq 20\text{mm}) \\
60 - 4RD - 2 & (20\text{mm} < RD \leq 35\text{mm}) \\
0 & (RD > 35\text{mm}) 
\end{cases}
\]

Wherein: \( RD \)—Rutting depth (\( \text{mm} \))

The rutting depth of the test pavement is measured, and the rutting depth after hot in place recycling is as follows:

<table>
<thead>
<tr>
<th>Detection of road segments</th>
<th>Rutting depth (( \text{mm} ))</th>
<th>Rutting depth index (( RDI ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.2</td>
<td>93.6</td>
</tr>
<tr>
<td>B</td>
<td>3.6</td>
<td>92.8</td>
</tr>
<tr>
<td>C</td>
<td>3.8</td>
<td>92.4</td>
</tr>
<tr>
<td>Average value</td>
<td>3.5</td>
<td>92.9</td>
</tr>
</tbody>
</table>

#### 2.4 Sliding performance of pavement

When pavement anti-skid performance is evaluated, calculating the pavement surface lateral force coefficient (SFC) is regarded as the evaluation index in China. Its model is as follows:

\[
SRI = \frac{65}{1 + 28.6e^{-0.105SFC} + 35}
\]

Wherein: \( SFC \)—Transverse force factor

The data (lateral force coefficient) is usually stored in units of 20m long.
The depth of tectonics (TD) index was measured in this test section. After the hot in place recycling technology, the pavement anti-skid performance indicators of the test pavement is shown in Table 4:

<table>
<thead>
<tr>
<th>Detection of road segments</th>
<th>Construction depth (TD)</th>
<th>Transverse force factor (SFC)</th>
<th>Anti - skid performance index (SRI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.76</td>
<td>124.12</td>
<td>100</td>
</tr>
<tr>
<td>B</td>
<td>0.81</td>
<td>126.18</td>
<td>100</td>
</tr>
<tr>
<td>C</td>
<td>0.93</td>
<td>127.61</td>
<td>100</td>
</tr>
<tr>
<td>Average value</td>
<td>0.83</td>
<td>125.97</td>
<td>100</td>
</tr>
</tbody>
</table>

3 Using Analytic Hierarchy Process To Determine The Weight Of Pavement Performance Index

According to the need for pavement performance post evaluation of the hot in place recycling project, there are two levels. The first level serves as the target level for evaluation, denoted as A. The second level is the four sub-indicators: Pavement distress rate B₁, International smoothness B₂, Rutting depth B₃ and Transverse force factor B₄. According to the post evaluation index system of the hot in place recycling project constructed in this paper, the judgment matrix is constructed, and the weight of each index of pavement performance is determined by calculating the judgment matrix.

3.1 Construct index judge matrix

First, when the two factors of each level are compared, 30 experts who are good at highway take part in the questionnaire and the results are summarized. Thus the relative importance of the two influencing factors is determined. By this way, the error is reduced as much as possible, so that the evaluation results are more comprehensive and accurate and the evaluation results can be verified by consistency at one time. Second, according to the statistical results to construct the judgment matrix. Finally, according to the steps of this analysis method, the weight of each element to the target level is determined. Analytic Hierarchy Process (AHP) usually uses the 1:9 scale to determine the importance.
of the two indicators. The scale and the meaning of the assignment are as follows:

| Table 5. the proportional scale value meaning of hierarchical model. |
| --- | --- |
| Scaling $a_{ij}$ | Meaning |
| 1 | When the two elements are compared with each other, they have the same importance |
| 3 | When the two elements are compared with each other, the former is a little more important than the latter. |
| 5 | When the two elements are compared with each other, the former is more important than the latter. |
| 7 | When the two elements are compared with each other, the former is much more important than the latter. |
| 9 | When the two elements are compared with each other, the former is most important than the latter. |
| 2, 4, 6, 8 | The two elements are compared, in the middle of the above judgments |

When the analytic hierarchy process is constructed, the assignment in row i and column j represents the importance of the factor in the row i relative to the factor in column j. If the weight of the factor in row i relative to the factor in column j is n, the relative weight of the factor in the row j relative to the factor in column i is $1/n$ and if any element is as important as itself, the value on the diagonal is "1".

The two elements are compared, in the middle of the above judgments

$$
\begin{bmatrix}
1 & 1/2 & 4 & 2 \\
1/2 & 1 & 5 & 3 \\
1 & 1 & 1 & 1/3 \\
4/5 & 1/3 & 3 & 1 \\
2 & 1/3 & 3 & 1 \\
\end{bmatrix}
$$

So the judgment matrix $A =$

3.2 The weight of each index is calculated

(1) Calculating the product of the elements of the judgment matrix $P_i$, $P_i = \prod_j a_{ij}, i=1,2\ldots, n$, In this paper $n=4$.

From the above equation, the following formula is obtained: $P_1=4$, $P_2=7.5$, $P_3=0.02$, $P_4=2$.

(2) Calculating the nth root of $P_i$, $\bar{P}_i = \sqrt[n]{P_i}$

From the above equation, the following formula is obtained: $\bar{P}_1 = 1.41$, $\bar{P}_2 = 1.65$, $\bar{P}_3 = 0.38$, $\bar{P}_4 = 1.19$. 
(3) \[ \bar{P} = (\overline{p_1}, \overline{p_2}, \ldots, \overline{p_n})^T \] is normalized, \[ p_i = \frac{\overline{p_i}}{\sum_{j=1}^{n} \overline{p_j}} \], so

\[ P = (p_1, p_2, \ldots, p_n)^T \] is the characteristic vector of the judgment matrix.

That is the weight of each index of B layer.

From the above equation, the following formula is obtained:

\[ P = (0.30, 0.36, 0.08, 0.26)^T \]. The weight of pavement damage rate \( w_1 = 0.30 \); the weight of international roughness \( w_2 = 0.36 \); the weight of rutting depth \( w_3 = 0.08 \); the weight of lateral force coefficient \( w_4 = 0.26 \).

From formula (1), the following formula is obtained. Before the hot in place recycling, the performance index of the test section \( \langle PQI \rangle \) is:

\[ PQI = 0.3 \times 90.5 + 0.36 \times 100 + 0.08 \times 92.9 + 0.26 \times 100 = 96.6 \]

<table>
<thead>
<tr>
<th>Efficiency</th>
<th>Excellent</th>
<th>Good</th>
<th>Medium</th>
<th>Bad</th>
<th>Very bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Performance ( \langle PQI \rangle )</td>
<td>( \geq 90 )</td>
<td>( 80 \leq PQI &lt; 90 )</td>
<td>( 70 \leq PQI &lt; 80 )</td>
<td>( 60 \leq PQI &lt; 70 )</td>
<td>( &lt; 60 )</td>
</tr>
</tbody>
</table>

As can be seen from Table 1, after hot in place recycling, pavement performance index \( \langle PQI \rangle \) of the test section greater than 90, so the use of the pavement performance is excellent.

4 Conclusion

Based on the analytic hierarchy process, this paper calculates the weight of each index in pavement performance of the hot in place recycling project. The weights of PCI, RQI, RDI and SRI calculated by the above are 0.3, 0.36, 0.08 and 0.26 respectively. The pavement performance index \( \langle PQI \rangle \) calculated from Eq. (1) is 96.6 and the evaluation grade is excellent. It can be concluded that the performance of asphalt pavement after hot in place recycling has been greatly improved. Pavement surface damage rate greatly reduced. Driving quality improved. The rutting depth reduced. Anti-slip ability slightly increased. From the perspective of the feasibility of the hot in place recycling technology, the performance of the pavement is greatly improved after hot in place recycling. In addition, according to the objective evaluation of the experimental section, the experimental results can reach the requirements that repair pavement surface and improve pavement performance. It is well known that post evaluation of asphalt pavement performance is the most important component of post evaluation of the hot in place recycling project. The objective and systematic post evaluation can lay a good foundation for promoting the further development of the hot in place recycling technology and forming a more systematic post evaluation guideline in the future.
Acknowledgments

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