Characteristics of Surface Texture on Gap-Graded Asphalt Pavement and its Influence to the Skid Resistance

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Abstract

The area of gap-graded asphalt pavement is increased to improve safety of expressways. The surface texture has been measured by volumetric method like sand patching and generally such method does not give us the detail of characteristics of texture and its influence to the skid resistance exactly.

Therefore, stationary model of laser profilometer was used to measure the profile of gap-graded asphalt pavement and new method was applied to analyze the characteristics of texture.

As the findings of this study, first, the amount of tire penetration into the surface texture is the decisive factor of skid resistance on gap-graded asphalt pavement. The amount of tire penetration reaches at certain level even if PDI get bigger, and it makes skid resistance to have same tendency. Therefore, proper profile depth is found to satisfy both enough skid resistance and durability of pavement. Second, microtexture also plays important role to decide the magnitude of skid resistance depending on the nature. Analyzing skid resistance, BPN, Profile Depth Index (PDI), we can evaluate the influence of microtexture volumetrically.

1. Introduction

Total length of expressways in operation reaches 6000km and about 3.5 million vehicles use them everyday. The second Tomei and Meishin Expressways which are designed by higher design standard are about to be constructed. Security of safety and efficient management method of road surface have high priority and we have studied surface texture to find characteristics of texture and its relation to the skid resistance.

Recently, the area of gap-graded asphalt pavement is increased to improve safety and to evaluate the surface texture, traditional volumetric method like sand patching is often used. We also have two laser profilometers called MTM (Mini Texture Meter) developed by TRL in U.K. Such methods are easier to measure the surface texture; however, they does not necessarily give us the detailed information of texture and its relation to the skid resistance exactly.

In this study, stationary model of laser profilometer was used to measure the profile of gap-graded asphalt mixture and dense-graded asphalt mixtures. New method to evaluate the surface texture was also used to find the characteristics of texture on gap-graded asphalt pavement and its relation to the skid resistance.
2. General Information of Asphalt Mixture and Surface Texture on Expressways

The content of Table 1 shows summary of asphalt mix design of expressways at where surface texture was measured. Dense-graded asphalt mixture (A) is used for countermeasure to the flow rutting, dense-graded asphalt mixture (C) is used for countermeasure to the abrasion and dense-graded asphalt mixture (B) is used for both purpose. Recently, drainage asphalt pavement is also applied for both safety and noise reduction and total area of the pavement reaches about 3.5 million at the end of 1996.

<table>
<thead>
<tr>
<th>Type of Asphalt Mixture</th>
<th>Number of Const. Site</th>
<th>Gradation (%)</th>
<th>Asphal</th>
<th>Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2.36mm Sieve Pass (Average)</td>
<td>75.0mm Sieve Pass</td>
<td></td>
</tr>
<tr>
<td>Dense-Graded (A)</td>
<td>8</td>
<td>39-43 (41)</td>
<td>5.5</td>
<td>5.9</td>
</tr>
<tr>
<td>Dense-Graded (B)</td>
<td>10</td>
<td>42-48 (44)</td>
<td>6.0</td>
<td>6.1</td>
</tr>
<tr>
<td>Dense-Graded (C)</td>
<td>3</td>
<td>48-49 (49)</td>
<td>8.7</td>
<td>6.4</td>
</tr>
<tr>
<td>Gap-Graded (G)</td>
<td>15</td>
<td>30-38 (36)</td>
<td>7.4</td>
<td>5.3</td>
</tr>
<tr>
<td>Drainage</td>
<td>8</td>
<td>13-16 (15)</td>
<td>4.3</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Figure 1 shows the relation between type of asphalt mixture and macrotexture. The macrotexture was measured by MTM and 10m calculation of standard deviation is primary output which is called SMTD (Sensor Measured Texture Depth). The SMTD in Figure 1 is average of 1 km.

Compared to the dense-graded asphalt pavement, gap-graded asphalt pavement has larger macrotexture depending on the gradation of aggregate. The SMTD has high correlation to 2.36mm sieve pass and macrotexture of pavement can be arranged to some extent in the mix design level. The drainage asphalt pavement has extremely large macrotexture and it seems to be caused by air void of surface.
Figure 2 shows the influence of microtexture to skid resistance at different measuring speed. The microtexture was evaluated by BPN measured by British Pendulum on the gap-graded asphalt pavement with comparatively narrow range of macrotexture which was evaluated by SMTD. The influence of microtexture is clearly shown on the skid resistance at measuring speed of 40 to 60 km/h and the influence is diluted at measuring speed of 80 km/h. This means that macrotexture plays important role to the skid resistance at high speed range on expressways and asphalt pavement with large macrotexture like gap-graded asphalt pavement is very useful on expressway. However, we can not find high correlation between SMTD and skid resistance at 80 km/h in this study.

3. Measurement of Profile

To catch the nature of texture precisely, stationary model of laser profilometer was used. The whole system to measure and analyze profile is shown in Figure 3 and the specification of laser sensor is shown in Table 2. Whole length of profilometer is about 700mm and profilometer consists of guide-rail, laser sensor, and motor. The laser sensor moves along with guide-rail and can measure the length of 500mm of profile. It can measure the minimum distance of 100 μm and minimum amplitude of 10 μm; therefore, 5000 X.Y displacement data can be recorded at. The laser profilometer is longitudinally set at 75cm distance from lane-mark where is almost center of rutting.
The profiles were measured at expressways and ordinary toll road which are operated for about half to four years. Tree profiles were measured to compare with skid resistance at the same section (about 1 km). Locked wheel Tester was used to measure the skid resistance coefficient at 80 km/h.

4. Analysis of Measured Data

After profiles are measured in the outfield, recorded 5000 X, Y displacement data are transacted by computer program called Micro-Researcher to reproduce shape of profile on the screen. Spectral analysis and other analysis method are used to find relation to the skid resistance; however, none of them does not give us clear answer to it yet.

New analysis method which uses histogram was developed. After the profile was reproduced, linear regression analysis is made and linear regression line is moved to the highest point of profile in parallel to be standard line. Based on the standard line, frequency distribution in each 0.5 mm depth is calculated and a histogram of gap-graded asphalt pavement is shown in Figure 4 as an example.

<table>
<thead>
<tr>
<th>Specification of Laser Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring range</td>
</tr>
<tr>
<td>Working distance</td>
</tr>
<tr>
<td>Laser beam diameter</td>
</tr>
<tr>
<td>Linearity</td>
</tr>
<tr>
<td>Response frequency</td>
</tr>
</tbody>
</table>

![Histogram of Gap-Graded Asphalt Pavement](image)

Figure 4 An Example of Profile and Histogram of Gap-Graded Asphalt Pavement
Average frequency distribution of gap-graded asphalt pavement and dense-graded asphalt pavement is shown in Figure 5. Gap-graded asphalt pavement still has frequency at deeper place compared to the dense-graded asphalt pavement. 2.36 mm sieve pass of gap-graded I is 30~34% and that of gap-graded II is 38%. Difference of gradation of aggregate affects their frequency distribution also.

![Figure 5 Difference of Average frequency distribution by Asphalt Mixture Type](image)

Using the histogram method, an index was developed to predict skid resistance. The index is based on the mechanism which skid resistance is total amount of friction generated by tire penetration and tire-pavement contact number. It is considered that the amount of tire penetration is related to the hysteresis loss and tire-pavement contact number is related to the adhesion. The index is a sort of profile depth index (PDI) in this study.

\[
PDI = \frac{(a_1 \times h_1 + a_2 \times h_2 + \cdots + a_n \times h_n)}{(a_1 + a_2 + \cdots + a_n)}
\]

(1)  

PDI: Profile depth index  
an: Frequency in nth depth from standard line (%)  
hn: Depth (0.5 \times n) (mm)

![Figure 6 Relation Between PDI and Skid Resistance](image)
Figure 6 shows the relation between average PDI and average skid resistance coefficient at 80 km/h. They have very high correlation and PDI can be one of pavement management index.

\[ \mu_{80} = -0.75(PDI)^2 + 1.91PDI - 0.63 \]  

\( \mu_{80} \): Skid resistance coefficient at 80 km/h  

PDI: Profile depth index

Figure 7 shows the relation between PDI and frequency in 0 ~ 0.5 mm depth and 1.0 ~ 1.5 mm depth. PDI = 1.0 is the turning point and the tendency of frequency in 0 ~ 0.5 mm depth and frequency in 1.0 ~ 1.5 mm depth changes at the point clearly. PDI of dense-graded asphalt pavement is less than 1.0 in many case and frequency in 0 ~ 0.5 mm gets higher and frequency in 1.0 ~ 1.5 mm gets lower. In such case, tire penetration depth is assumed to be within 1.0 mm and the role of surface microtexture gets bigger to decide magnitude of skid resistance. On the other hand, PDI of gap-graded asphalt pavement is more than 1.0 and frequency in 0 ~ 0.5 mm gets lower and frequency in 1.0 ~ 1.5 mm gets higher to certain level. Therefore, for pavement with large macrotexture like gap-graded asphalt pavement, tire penetration depth reaches at almost 1.5 mm and the penetration depth plays important role to decide magnitude of skid resistance. Frequency in 1.0 ~ 1.5 mm approaches to certain level and it leads to almost same tendency of skid resistance. Therefore, PDI = 1.1 is enough profile depth of gap-graded asphalt pavement for its proper skid resistance level and unnecessarily large amount of coarse aggregates should be avoided in mix design to achieve higher durability.

![Figure 7 Relation between PDI and Frequency in Surface and Deep Location](image)

So far, the role of microtexture on skid resistance is accounted as the issue of tire-pavement contact number; however, Figure 8 shows that comparatively large difference of BPN on gap-graded asphalt pavement leads to difference of skid resistance even in same PDI. This means almost same tire-pavement contact number creates different magnitude of skid resistance. Using formula (2), skid resistance is calculated based on given PDI and the calculated skid resistance is adjusted by difference of BPN, \( 0.1 \times (68 - \text{BPN}) \). The adjusted value of skid resistance becomes almost same as the measured value of skid resistance. For this reason, the nature of microtexture except tire-pavement contact number should be considered to predict skid resistance. The reason which extremely low BPN causes lower skid resistance even in same PDI is not clear now and the method which allows to catch more detailed information about the nature of microtexture has been studied. Analyzing skid resistance, BPN values, and PDI, we will be able to have more precise adjustment value like \( 0.1 \times (68 - \text{BPN}) \).
4. Conclusion

Stationary model of laser profilometer was used to measure the profile of gap-graded asphalt pavement and new analysis method called histogram method, PDI was used to evaluate characteristics of texture and its influence to the skid resistance. Followings become clear in this study,

(1) In case of asphalt pavement with large macrotexture like gap-graded asphalt pavement, the amount of tire penetration plays important role to decide the magnitude of skid resistance. The profile 'depth reaches at certain level even if PDI get bigger. We found proper profile depth to satisfy both enough skid resistance and durability of pavement.

(2) Even if profile depth plays important role to decide the magnitude of skid resistance, extremely low BPN causes lower skid resistance even in same PDI and it should be consider to predict skid resistance. Analyzing skid resistance, BPN, and PDI, we can evaluate the influence of microtexture volumetrically.

Reference
