Preserving the Effectiveness of Grooving in Airport Runways

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ABSTRACT: It is now common practice worldwide to cut transverse grooves into the surface of airport runways in order to increase skid resistance. These grooves lose their effectiveness, however, when they collapse under heavy aircraft loads or become filled with tire rubber deposited during landings. To prevent groove collapse, both new and overlay pavements must be cured for a certain amount of time before the grooves can be cut when constructed using straight asphalt. If adequate curing time is not available, modified asphalt should be used. Tire rubber can be effectively removed from grooves with warm water, thereby restoring skid resistance. The friction coefficient, normally measured using vehicle-type equipment, can be estimated using hand-held equipment. The friction coefficient varies with temperature and other conditions.

KEY WORDS: grooving, runway, skid resistance, groove collapse, tire rubber, construction.
1. INTRODUCTION

Freshly laid asphalt pavement usually has a very smooth surface due to the rolling process that is used to compact the asphalt. Moderate surface friction should be achieved by any of several methods, including using special surface materials such as open graded friction courses and chip seals, cutting grooves into the surface, etc. (FAA, 1997).

For airport runways, transverse grooves are cut into the surface to increase skid resistance. The grooves also decrease dynamic hydroplaning by rapidly channeling water away from the tire contact area during touchdowns (Agrawal, et al., 1981). Thus, the number of accidents in wet weather conditions has decreased.

Runway grooving is becoming a common practice worldwide. The standard configuration specified by the Federal Aviation Administration is presently used in Japan: 6 mm deep, 6 mm wide and spaced 32 mm apart center-to-center (CAB, 2001 (2)). The grooving has been installed two months or later of the pavement construction to ensure its durability according to the current specification in Japan (CAB, 2001 (1)), which was based mainly on an earlier study (Sato, et al., 1978).

However, the effectiveness of the grooving will be reduced if the grooves collapse under heavy aircraft loads or if the grooves in the touchdown zone become filled with tire rubber that is deposited during landings.

The former includes the loss of groove volume due to deformation of the asphalt concrete in hot weather, and abrasion of the asphalt concrete in cold weather. As aircraft become larger and the number of landings increases, the grooves will deteriorate at a faster rate. To investigate the durability of asphalt concrete under heavy loads, we conducted a series of laboratory tests.

The latter also reduces friction on wet runways, which can cause aircraft to skid. This is not a problem during dry weather operations since the adhesion component is markedly increased, resulting in a net increase in skid resistance. However, skid resistance is drastically reduced on wet runways. To study this and determine a standard value for skid resistance, we conducted tests both in the laboratory and on an existing airport pavement.

2. COLLAPSE OF GROOVES

2.1. Background

Fine-grade aggregates provide greater durability under heavy-duty aircraft loads. Although pavements must be at least two months old before they can be grooved, grooving is often required within two months of paving to ensure safer aircraft operation, especially in the case of overlay pavements. To determine if this is possible, the following items were investigated.

1) The aggregate gradations for the two maximum aggregate sizes are specified as the asphalt concrete for the surface course. Straight asphalt is generally adopted. Materials suitable for grooved surface courses were studied.

2) Two factors that influence resistance to groove distortion are aging and aircraft loads before installation of the grooving. Both were investigated using accelerated test methods.

2.2. Experiments

The wheel tracking test was used to evaluate the loss of groove volume at high temperatures. Table 1 lists the various asphalt concretes that were examined. Several gradations of aggregate with two maximum sizes, three penetration grades of straight asphalt, and modified asphalt were examined.
Currently, grooving is installed after a specific period, e.g., two months or more. Therefore, both the accelerated aging method and accelerated tire loading method were used in this study to simulate this situation. Table 2 lists the test conditions. If accelerated aging for twelve hours corresponds to an actual age of four weeks (Nomura et al., 1996), then the period after construction is equivalent to one to six months in this study. Assuming 60 aircraft landings per day, in four weeks 1,400 landings would be made.

The following materials were used: coarse aggregates, fine aggregates (screenings, fine sand and coarse sand), filler, straight asphalt (40/60, 60/80, and 80/100 penetration grade) and modified asphalt (type I and II (JRA, 2001)). According to the standard specifications used for airport civil engineering work (CAB, 2001 (1)), the compositions of asphalt concretes are designed using the Marshall stability test method. The properties of these mixtures, such as air voids, stability, flow and retained stability, satisfy the specified values.

To evaluate the durability of the grooves in asphalt concrete, two different curing procedures were employed: aging and wheel loading. Following the accelerated aging method described by Nomura et al. (1996), the ambient temperature of the oven was intentionally kept high (60°C) in order to accelerate the aging process of the asphalt concrete through oxidation. Aging was conducted as follows:

1) All of the air was removed from the oven using a vacuum pump.
2) Pressurized oxygen was introduced into the oven.
3) Asphalt concrete specimens were kept in the oven for six hours.
4) Steps 1 through 3 were repeated for another cycle.

Accelerated wheel loading was done by passing a weighted wheel over the specimen after each accelerated aging cycle. In other words, a tire with a contact pressure of 320 kPa moves back and forth over the specimen 700 times with a transverse shift. Asphalt concrete was compacted into a 300 mm wide, 300 mm long and 50 mm deep mold to a compaction degree of 98% or higher. After curing, grooves are cut into the asphalt concrete using a cutter with diamond-tipped heads. Seven grooves with a width and depth of 6 mm were cut 32 mm apart (center to center) in the specimen.

The wheel tracking test of which procedure follows standardized testing procedures (JRA, 1989) was then conducted on the specimen. Table 3 lists the test conditions. Equation 1 was used to calculate the loss of groove volume.

\[
LV = \left( \frac{a_0 - a_i}{a_0} \right) \times 100\% 
\]

where, 
\( LV \): loss of groove volume,
\( a_0 \): initial groove volume and
\( a_i \): final groove volume.

<table>
<thead>
<tr>
<th>Items</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>40°C</td>
</tr>
<tr>
<td>Wheel type</td>
<td>Solid tire</td>
</tr>
<tr>
<td>Wheel size</td>
<td>200 mm in diameter and 50 mm in width</td>
</tr>
<tr>
<td>Load</td>
<td>700 N</td>
</tr>
<tr>
<td>Tracking speed</td>
<td>42 times/min.</td>
</tr>
</tbody>
</table>

2.3. Test results

Described below are the results of tests on the influences of the above-mentioned factors on groove durability.

Asphalt concretes made using the same type of asphalt were compared in order to evaluate the influence of different aggregate gradations. Figure 1 shows the loss of groove volume in the case of straight asphalt 60/80. While the asphalt concrete containing larger aggregate showed a smaller loss in the early stages of the test, in the final stage, there was little difference in durability between those with various gradations. Comparing No.1 and No.2, the asphalt concrete with fine aggregate gradation showed better performance.
In the case of aggregates with a maximum size of 13 mm and the usual gradation, asphalt concretes made from five different types of asphalt were evaluated. Figure 2 shows the variations in groove volume loss by the number of trackings. Modified asphalt showed better resistance to volume loss under repeated loading, which means that the asphalt viscosity is a useful indicator.

To determine the influence of the curing method on groove durability, specimens were cured using different accelerated curing methods and then tested. The specimens consisted of conventional asphalt concretes made with straight asphalt 60/80 and standard graded aggregates with a maximum size of 13 mm.

Figure 3 shows the test results for the specimens that were not subject to loading. After 72 hours of curing, the performance of the specimens had improved. On the other hand, loading had an enormous effect on asphalt concrete’s ability to resist groove volume loss, as shown in Figure 4.
Table 4 shows the properties of the asphalt recovered from the tested asphalt concretes. The viscosity of the asphalt increases as the curing period increases, especially in the specimens that underwent loading.

2.4. Discussion

The ability of modified asphalt to maintain the groove’s shape was confirmed in this study. Both the maximum size and the gradation of the aggregate were factors in the performance of the modified asphalt.

When new asphalt pavement runways are constructed, they should be properly cured before being grooved. In this test, 72 hours of curing were required to improve the durability. This is equivalent to almost six months in real time according to Nomura, et al., (1996). Therefore, modified asphalt should be used when sufficient time for curing is not available. In the case of overlay pavements, the curing period before grooving can be shortened as loading has a great effect on the durability of the grooves.
Table 4  Properties of recovered asphalt

<table>
<thead>
<tr>
<th>Items</th>
<th>Without</th>
<th>a-1</th>
<th>a-2</th>
<th>a-3</th>
<th>a-4</th>
<th>b-1</th>
<th>b-2</th>
<th>b-3</th>
<th>b-4</th>
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<tbody>
<tr>
<td>Penetration at 25°C (1/100cm)</td>
<td>48</td>
<td>49</td>
<td>45</td>
<td>45</td>
<td>46</td>
<td>44</td>
<td>44</td>
<td>41</td>
<td>43</td>
</tr>
<tr>
<td>Softening point (°C)</td>
<td>51.5</td>
<td>52</td>
<td>52</td>
<td>52.5</td>
<td>52.5</td>
<td>52.6</td>
<td>53</td>
<td>53.5</td>
<td>53</td>
</tr>
<tr>
<td>Ductility (15°C) (cm)</td>
<td>42</td>
<td>41</td>
<td>31</td>
<td>16</td>
<td>13</td>
<td>16</td>
<td>15</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>Viscosity (60°C) (Pa·s)</td>
<td>3900</td>
<td>4000</td>
<td>4200</td>
<td>4600</td>
<td>4500</td>
<td>4700</td>
<td>5000</td>
<td>5900</td>
<td>4900</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>1.042</td>
<td>1.043</td>
<td>1.043</td>
<td>1.042</td>
<td>1.043</td>
<td>1.044</td>
<td>1.044</td>
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3. TIRE RUBBER ADHESION

3.1. Background

The friction between the tire and the pavement surface is an important safety factor for aircraft operation. Factors affecting surface friction include the tire and pavement materials, the water depth, the temperature of the surface, etc. Tire rubber that adheres to the runway surface when an aircraft touches down must also be considered.

The friction coefficients of runways at four selected airports were measured. Figure 5 summarizes the results obtained using a Surface Friction Tester (SFT). Values of 0.55 in the case of grooved runways and 0.45 in the case of ungrooved runways have been tentatively adopted as the standard for rehabilitation projects in Japan (Hachiya, et al., 1996). Comparing the data in Figure 5 to these standard values, all of the runways had generally satisfactory skid resistance. However, the touchdown zones, particularly between 300 m and 360 m of the end of the runways, had extremely small values due to the large amounts of rubber adhering to the runways as result of landings and braking actions.

3.2. Experiment

In order to determine the factors that influence skid resistance and study the effectiveness of small measuring devices, the friction coefficients were measured at in-service airports. In addition, specimens were taken from an airport runway and the surface friction coefficients were measured in the laboratory.

![Figure 5  Friction coefficient of runways](image_url)
SFT measurements were made while the surface was covered with a 1 mm-deep film of water. The SFT was driven over the full length of the runway at a speed of 95 km/h. Dynamic Friction Tests (DFT) were also performed. Specimens were taken from an in-service airport runway. The friction coefficients of the specimens were measured using DFT. The condition of the grooves was classified as clear, partially plugged, or fully plugged. The test conditions were as follows.
1) Temperature: 10 - 15ºC
2) Water film thickness: 1 - 3 mm
3) Rotating speed of DFT: 65/80 km/h

3.3. Factors that influence skid resistance
A series of laboratory tests were conducted to study the factors that influence skid resistance. First, the effect of pavement surface temperature on friction coefficients was studied. As shown in Figure 6, which describes the relationship between the DFT-measured coefficient and temperature, the coefficients gradually decrease as the temperature increases, irrespective of the amount of rubber adhering to the surface. The coefficients decrease as the grooves become increasingly plugged.
As shown in Figure 7, the influence of the water film thickness is not clear under this condition. To achieve a higher friction coefficient, it might be necessary to decrease the water film thickness to less than 1 mm.

3.4. Measures to restore skid resistance
According to these laboratory test results, removing the adhering tire rubber will restore skid resistance.
Regarding the change in the friction coefficients before and after removing the tire rubber, Figure 8 shows the results of SFT measurements at a major in-service airport. It was found that removing the rubber has a remarkable effect on skid resistance; the friction coefficient increased from 0.5 before removal to 0.7 after removal.
Figure 7 Friction coefficient and water film thickness

Figure 8 Friction coefficients before and after rubber removal

Figure 9 clearly shows the effect of removing the tire rubber. Warm water removes the rubber more effectively than cold water.

3.5. Applicability of hand-held equipment

Hand-held equipment is more convenient for measuring friction coefficients. Figure 10 shows the difference in the coefficients obtained using DFT and SFT equipment in the longitudinal direction of an in-service runway. Because the correlation coefficient is 0.82, DFT can be used instead of SFT.
4. SUMMARY AND CONCLUSIONS

Two aspects were studied in regard to preserving the effectiveness of grooving on airport runways: groove collapse and rubber deposits. Regarding groove collapse, the following results were obtained.

1) Both the gradation and the maximum size of the aggregate can affect durability to some degree.
2) Modified asphalt greatly improves durability.
3) The curing period has a small effect on performance while loading has a large effect.

Based on these results, modified asphalt will be recommended for both new and overlay pavements when sufficient time for curing is not available. Straight asphalt, however, can be used in both cases, particularly for overlay pavements, when sufficient time for curing is available before the grooves are cut.

Regarding rubber deposits, the following results were obtained.
1) The friction coefficient is smaller in the touchdown area than at the mid-point of the runway.
2) The friction coefficient decreases as the temperature increases.
3) Warm water effectively removes tire rubber to restore skid resistance.
4) The friction coefficient measured by vehicle type equipment can be estimated using hand-held equipment.

REFERENCES


