Evaluation and Applicability of Skid Resistant Runway Surfaces

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General Aviation (GA) Airports servicing aircraft with approach speeds above 120 knots (category C, D, and E aircraft) may want to consider installing skid resistant (grooved) surfaces. Runways with grooved surfaces greatly improve traction for aircraft during landings, take offs and taxiing during wet conditions. The intent of this article is to provide Airport Authorities with helpful information on the economic and operational advantages and disadvantages of grooved pavement surfaces.

What is Grooved Pavement?

Grooved pavements are constructed by saw-cutting 1/4" deep by 1/4" wide grooves into the surface of a flexible or rigid pavement spaced horizontally 1-1/2 inches from the center of one groove to the next[1].

Grooves applied to pavement surfaces at airports must be installed perpendicular to the movement of aircraft as shown in Figure 1.
Advantages of Grooved Pavements

Studies conducted by the Federal Aviation Administration (FAA) over the past 50 years indicate that applying transverse runway grooves to hot mix asphalt (HMA) runways decreases the risk of hydroplaning and improves friction on runways that serve aircraft with high approach speeds. Hydroplaning occurs when a layer of water prevents direct contact between the pavement surface and the tires of an aircraft, resulting in the loss of steering and braking control. While all aircraft are at risk of hydroplaning on wet or flooded pavement, jet aircraft are at an increased risk due to their high approach and departure speeds. Transverse grooves provide a pathway to channel water away from the contact area when aircraft tires roll across the pavement. This rapid movement of water into the grooves and away from the contact surfaces enables tires to maintain the maximum amount of direct contact to the pavement surface, increasing friction, directional control (turning movements), and breaking performance. A study conducted at NASA’s Wallops Station Research Facility showed that the landing distance of a 36,000 lb Douglas F-4D Skyray was reduced by more than 1,000 feet during wet condition landings on a grooved pavement surface. Table 1 shows the results of this study.
An additional benefit of grooved runway pavement was discovered during a study at Washington National Airport \cite{19}. Pilots participating in this study reported a considerable reduction of surface solar glare on the wet pavement, and indicated that the grooved pavement appeared dull grey when wet. This allowed for better judgement of distances, surface condition, and peripheral vision from the cockpit. Figure 2 shows the contrast between grooved and un-grooved pavements just after a rainstorm.

### Table 1. — Landing Field Lengths for F-4D \cite{19}

<table>
<thead>
<tr>
<th>Condition</th>
<th>Distance (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry</strong></td>
<td>4,900</td>
</tr>
<tr>
<td><strong>Wet Concrete</strong> A</td>
<td>10,940</td>
</tr>
<tr>
<td><strong>Wet Concrete</strong> B</td>
<td>9,840</td>
</tr>
<tr>
<td><strong>Wet Concrete</strong> C</td>
<td>7,250</td>
</tr>
<tr>
<td><strong>Wet Asphalt</strong> F</td>
<td>6,620</td>
</tr>
<tr>
<td><strong>Wet Asphalt</strong> G</td>
<td>5,700</td>
</tr>
<tr>
<td><strong>Wet Asphalt</strong> H</td>
<td>4,850</td>
</tr>
<tr>
<td><strong>0.1&quot; to 0.3&quot; Flooded</strong> A</td>
<td>11,560</td>
</tr>
<tr>
<td><strong>0.1&quot; to 0.3&quot; Flooded</strong> B</td>
<td>8,700</td>
</tr>
</tbody>
</table>

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**Figure 2** — Wet Pavement Comparison Between Grooved and Ungrooved
Disadvantages of Transverse Grooves

As with any destructive process applied to HMA Pavement, the application of grooves to a runway can cause several problems that should be considered before implementation. Reported negative effects of grooved pavement include:

- **Increased “road noise” or the sound of the tires rolling along the pavement surface** - The noise is more prominent on roadways than on runways, since engine noise from turbines drowns out sounds from the grooves.

- **Increased vibrations in aircraft** - This is a logical result of adding grooves to the pavement surface. While not excessive, the vibrations can be felt during departures, landings, and while taxiing over grooved surfaces.

- **Deterioration of pavement and groove failure** - Differential wearing is the erosion of some areas of pavement more rapidly than others. For grooved runways, the pavement can be broken down into four areas: threshold, touchdown, braking and turning areas. Grooves in the touchdown and braking areas wear faster than the other two. This may result in a need to perform pavement repair more often than normal. Repairs may include sweeping, crack repair, and/or milling, overlaying, and regrooving.

Other grooved pavement concerns include:

- **Wearing**: The depth of the grooves becomes shallower over time. This is attributed to the asphalt binder and aggregates in the pavement. Wearing occurs most commonly in high traffic sections of pavement. Over time, the repeated travel over these areas causes the settling, wearing, and movement of the pavement surface. Wearing is common in the first two years after placement. As the asphalt ages and hardens, wearing of pavement, particularly in colder climates, diminishes.

- **Groove Closure**: Groove closure occurs when pavements are subject to repeated, heavy loading. The cause of groove closure is the same as rutting in un-grooved pavement: repeated loading of some areas (such as wheel
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paths) results in the movement of those areas relative to the surrounding, less traveled areas. It is less likely to occur in colder climates where asphalt binder is more stiff (brittle).

- Rubber Deposits: As aircraft land, the tires contact the pavement surface and begin to “spin up” to the speed of the aircraft. This spin up action causes a skidding effect. Grooved pavement provides a more textured surface that results in a more aggressive spin up and more densely deposited rubber into the grooves. On runways that see heavy traffic, periodic rubber removal will be necessary to maintain the skid resistant surface. Figure 5 shows rubber deposits on a grooved pavement section.

- Cracking: Cracking occurs when the HMA expands and contracts during seasonal freeze/thaw cycles. Although this happens with all paved surfaces subject to these conditions, it is more acute on grooved surfaces.

- Migration: Flowing of HMA can result in wavy groove patterns. The cause for this type of failure is the same as groove closure. Over time, areas which receive more use than the areas immediately adjacent to them (such as wheel paths) begin to migrate relative to the less travelled areas. The reason for this migration can be attributed to the liquid nature of asphalt. This type of deterioration occurs primarily in warm climates where asphalt binder is more fluid.

- Rounding: Rounding is the wearing away of sharp groove edges. This type of routine wear would not occur on un-grooved pavement.

Figure 4 – Spalling Pavement

Figure 5 – Heavy Rubber Deposits
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- Spalling: Spalling, or disintegration, of the HMA surface is typically caused by sharp turning movements of heavy aircraft or heavy snow removal and maintenance equipment.

- Chipping: Chipping occurs when the aggregate and/or filler material in the sharp edges of the grooves break away. This type of failure is common in HMA sections subject to colder temperatures. The fracture resistance of the asphalt binder decreases (becomes more brittle) when subjected to colder temperatures. This type of failure may be minimized with the application of surface sealants.

- Erosion: Erosion occurs when the fine filler or binder material washes away, leaving exposed aggregate.

Studies have identified several key factors that attribute to groove failure in HMA pavements. Grooves are more likely to be destroyed by 180° turning movements of heavier aircraft. Figure 4 shows spalling due to a Convair 990 turning on an HMA pavement with grooves (2) (6). Another conclusion drawn from the same study was that larger aggregate HMA sections, such as the 1/2” and 3/4” aggregates, are more likely to break loose and pose a Foreign Object Debris (FOD) risk. This study recommended that grooving only be performed in HMA Sections with aggregates less than 3/8”.

Increased Maintenance

The frequency of periodic runway maintenance may increase with a grooved runway. The time between maintenance work will depend on the day-to-day traffic at each airport. Over time, rubber deposits from landings will build up and cause a reduction in surface friction. The most common maintenance work is rubber removal.
Sprayed surface maintenance treatments for HMA pavements with grooved surfaces may also pose a problem. At the March 2014 Airfield Engineering and Maintenance Summit in Furama, Singapore, a presentation discussed the application of surface rejuvenator products to grooved runways. Since these sprayed treatments are liquid when applied, excess material flows into the grooves and reduces groove depths, thereby reducing the effectiveness of the grooves. Several application methods have been tested with varying results. A single application, applied in the transverse direction followed by immediate sweeping in the transverse direction to remove excess material in the grooves, was tested at the RAAF Base Darwin in 2002 with good results. However, 100% coverage was not obtained on the vertical faces of the groove walls. Another application method involves multiple light passes in alternating directions, resulting in full coverage of the surfaces and vertical groove walls. While this method did not significantly decrease the overall depth of the grooves, it did have a negative effect on surface friction. Applying these types of surface treatments is difficult to perform on large areas because the material must be scraped out of the grooves concurrently, making the entire process slow, labor intensive, and expensive.

**Installation of Grooves**

The FAA recommends that all runway serving or expected to serve turbojet aircraft due to their higher approach speeds have grooved surfaces. Grooves may be cut or formed in existing or new pavements. New Portland Cement Concrete (PCC) pavements may have grooves installed by forming them while the concrete is still workable in the time immediately following placement or by saw-cutting after it has cured. Whether new or existing, hot mix asphalt pavements must have grooves sawcut. Existing pavements may have surfaces that are not suitable without first being overlaid or reconstructed. It may be helpful to consider other information such as the history of aircraft accidents related to hydroplaning at the airport in question, annual rainfall rates and intensity, transverse and longitudinal grades, flat areas, depressions, mounds, or any other surface conditions that impede water runoff, surface texture quality, adequacy and length of existing runways, strength and condition of existing runway pavements.

**Conclusions**

Each airport must carefully consider the application of grooved surfaces. Before deciding to install pavement grooves, the airport authority should evaluate whether the frequency of turbojet aircraft operations necessitates runway grooves. While the benefits of grooved runways are indisputable, especially during wet conditions, decreased longevity and increased maintenance of the pavement may outweigh the benefits at airports with fewer than 10,000 annual jet aircraft operations, or at airports that do not have full-time maintenance staff.
References


7. Greg White and Bruce Rodway “Distress and Maintenance of Grooved Runway Surfaces”