CENTER OF EXCELLENCE FOR AIRPORT TECHNOLOGY

TECHNICAL NOTE

TECH NOTE NO: 28
TITLE: Performance of Grooved Bituminous Runway Pavement

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1. Introduction

Grooving of flexible (and rigid) pavements is a technique performed to reduce hydroplaning and to improve friction on all runways that serve turbojet aircrafts. Despite their widespread application, grooves in hot-mix asphalt (HMA) runways are prone to several distresses that limit their longevity at the desired level of serviceability. This technical note presents a synthesis of the available literature regarding the performance of grooved HMA runway pavements. It focuses on runway grooving patterns, common groove distresses, runway critical locations of groove distresses, and groove collapse. In addition, preliminary tests on groove collapse evaluation in the laboratory are discussed. Particular attention is given to the effects of aggregate gradation, maximum aggregate size, and binder type on groove collapse.

2. Runway Groove Patterns

Pavement grooving is used on airfields to control hydroplaning and to ensure adequate friction; especially under wet pavement conditions. Common pavement groove orientations are transverse, longitudinal and angled. Transverse grooving is more common on airfields than on highways. Longitudinal grooves are usually applied to reduce noise and to improve directional control of vehicles. Various groove profiles have been used including rectangular, trapezoidal and rounded. Guidelines and standards for construction and maintenance of runway grooves are available through FAA (1). These guidelines were developed based on the results of extensive grooving studies. For HMA, the standard groove dimensions are ¼-in-deep, ¼-in-wide and 1½-in center-to-center spacing, as shown in Figures 1 and 2. The first HMA runway grooving at a commercial airport was applied at Washington National Airport. A$^{1}/_{8}$-in-deep, $^{1}/_{8}$-in-wide and 1-in center-to-center grooving pattern was used (10).

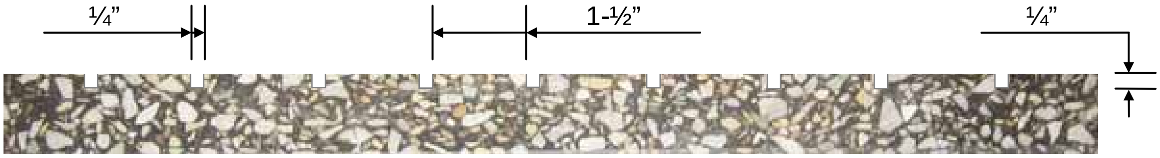

Figure 1 Schematic of standard HMA runway groove pattern.

Figure 2 Five-year old saw-cut grooves at Volk Field Air National Guard Base in Wisconsin; the HMA runway regularly supports heavy cargo planes (4)

3. Groove Distress Critical Locations

For the purpose of evaluating groove deterioration, the runway can be segmented into four areas: the threshold; touchdown; braking; and turning (11). The threshold area is where final engine runs are performed prior to takeoff. The touchdown areas are used to transition from flight to landing. Braking and turning areas include sections near taxiway exits and/or intersections. Figure 3 is a schematic of the groove distress critical locations. Grooves in touchdown and braking areas are the most seriously damaged. The distresses include wear, groove closure, and rubber deposits. Migration of grooves generally occurs in threshold areas (Figure 4). In a survey by Melone (11), it was reported that grooves in turning areas had experienced the least damage, where limited wear and closure were observed. The type/level of groove deterioration was found to be dependent upon airport location. Migration and closing were found to be more common in warm climates than in cold ones. This notion was supported by the results of the survey conducted in 1974. The migration and groove closure occurred in all the critical areas on Runway 9L/27R at Ft Lauderdale-Hollywood International airport, while none were reported on O'Hare's Runway 14L/32R. On the other hand, cracking and wear were observed on all critical areas at O'Hare, while almost none were observed at Ft Lauderdale-Hollywood. Both surveys were conducted in the same year.

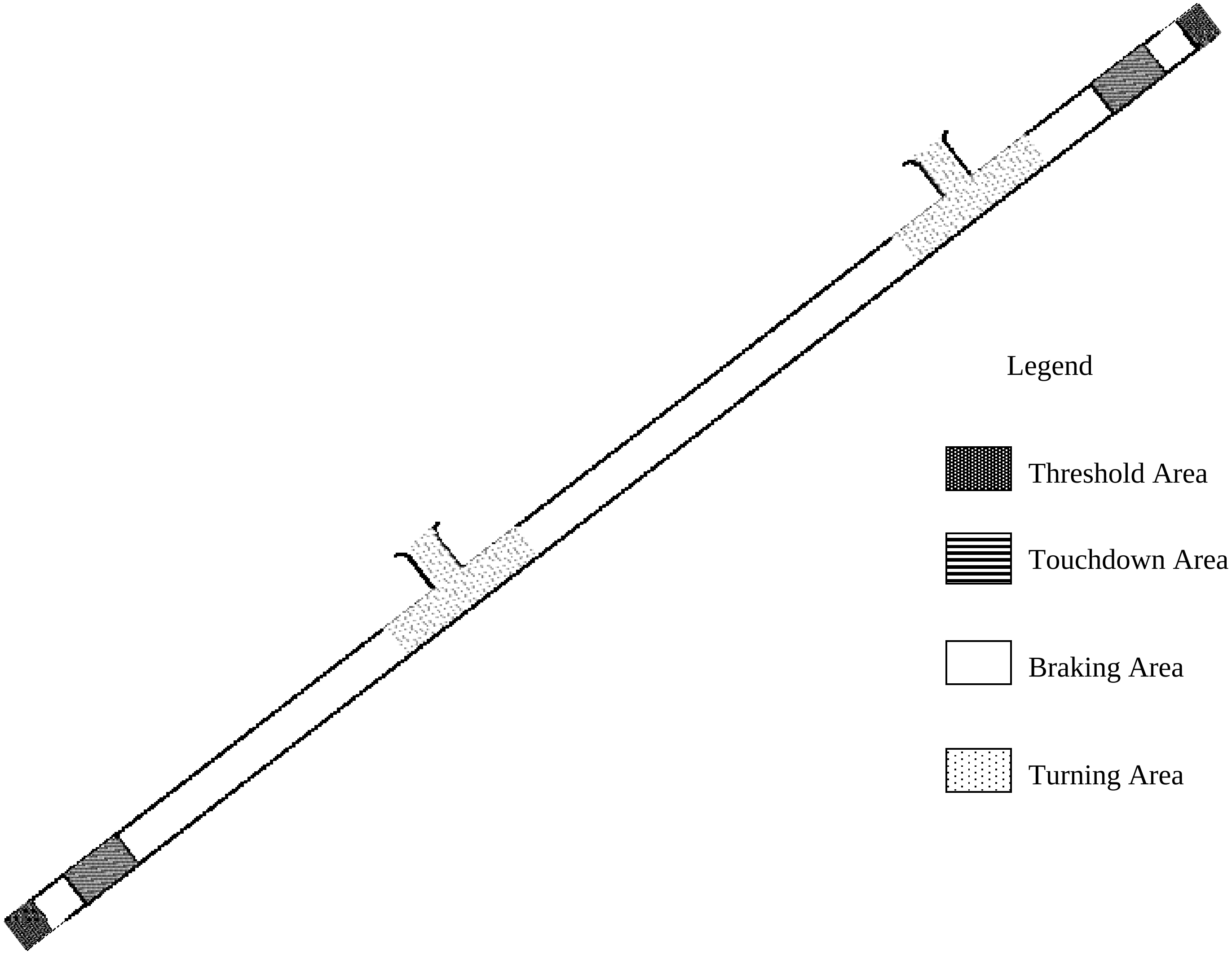

Figure 3 Runway groove distress critical locations

4. Common Groove Distresses

Some of the more common distresses that can be associated with HMA runway pavements are shown in Table 1. These distresses were identified from a runway groove survey (11). The surveyed runways were selected from airports located in both warm and cold climates and included both low and heavily trafficked runways. Some of the reported distresses, such as wearing, cracking, spalling, and erosion, are intrinsic to HMA pavements and could occur in both grooved and ungrooved surfaces. However, the most serious distresses associated with groove deterioration were wear, groove closure, and rubber deposits. Two of these three distresses, groove wear and groove closure, could be attributed directly to the influence of asphalt binder and the aggregate characteristics. Groove wear and closure, and migration all result in groove collapse and may be related to plastic flow of the HMA.

Table 1 Common distresses associated with grooved HMA runways (11)

Distress	Definition
Wear	Groove depth measuring 1/8" or less compared with standard depth of 1/4"
Groove Closure	Groove width measuring 3/16" or less compared with standard width of 1/4"
Rubber Deposits	Rubber in grooves and on runway
Cracks	Reflection cracks and cold seam cracks propagated along grooves
Migration	Flowing of HMA resulting in a wavy groove pattern (Figure 4)
Deep/Shallow Cutting	Adjacent grooves of different depths caused by defective cutting methods
Rounding	Wearing away of sharp groove edges
Spalling	Disintegration, breaking up of HMA surface
Chipping	Breaking away of aggregate and/or filler material in sharp edges of grooves
Erosion	Washing out of fine filler or binder material leaving exposed aggregate

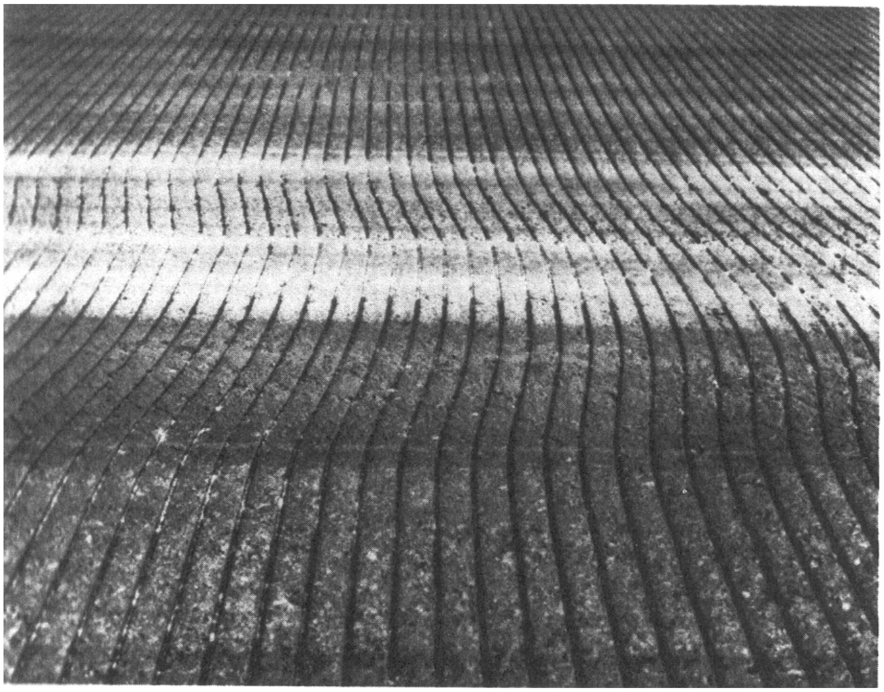

Figure 4 Wavy groove patterns caused by migration (11)

5. Groove Collapse

Wear, closure, and migration can lead to groove collapse. Allen and Quillen (3) evaluated the effects of aircraft loading and climatic conditions on the performance of grooved HMA runways. Tests were conducted on an 8750-ft-long runway at NASA's Wallops research facility. The grooves were ¼-in-deep by ¼-in-wide and spaced at 1-in centers. Two HMA mixtures identified as small aggregate HMA (3/8 in nominal maximum aggregate size); and large aggregate mixtures (3/4 in nominal maximum) were used. Repeated aircraft loadings (McDonnell Douglas F-4D and Convair 990) were applied on the grooved pavements. The study reported unsatisfactory performance of the transverse grooves; especially in areas where the Convair 990 aircraft made 180º turns. The study identified the following problems with HMA grooves: i) grooves were destroyed during 180º turns, as shown in Figure 5; and ii) in the large aggregate HMA sections, the ½ and ¾ in aggregates tended to break loose from the grooves and pose foreign object damage FOD danger. The study recommended that grooving should be performed only in HMA with aggregates less than $^3/_8$ in.

Figure 5 Damaged grooves by Convair 990 during 180 ° turns at Wallops Facility (3)

Grooved pavements were also evaluated at five airfields (Miami, Cleveland, New York JFK, Salt Lake City, and Las Vegas airports) that represent various climatic regions. Different groove patterns (width, depth, and pitch) were used (10). The grooves were monitored over four seasons. Grooved HMA sections in colder climates at New York JFK and Washington National performed better than the sections in the warmer regions. The results indicated that HMA grooved sections did not perform satisfactorily in the warmer locations (e.g. Las Vegas, Salt Lake City, and Miami). The high pavement temperature along with aircraft loading resulted in plastic flow and displacement of aggregates in the wheel tracks. The following observations were made based on the Salt Lake City, Miami, and Las Vegas test results: 1) $^1/_4$ in deep grooves were structurally inappropriate when compared to the $^1/_8$ in deep grooves; 2) grooves spaced 2 in apart, $^3/_8$ in wide, and $^1/_8$ in deep had the least deformation; and 3) under high ambient temperatures, aggregate size appears to affect the longevity of HMA grooves.

Emery investigated the collapse of HMA grooves on Australian runways (5, 6). He suggested that slow moving and heavy aircrafts were responsible for most of the groove closure. Groove collapse was commonly observed in taxiway-runway intersections. The following observations were also made: 1) groove closure typically occurs within 1-3 years of HMA placement and is eventually mitigated with asphalt age-hardening; 2) groove closure is related to asphalt binder viscosity (or stiffness), which could be the critical parameter, and; 3) groove closure is more severe in warmer weather.

The importance of asphalt binder characteristics on groove collapse was also reported by Mosher (12). This finding was based on measurements of seven sections in five climatic regions.

6. Mechanism of Groove Collapse

One mechanism of groove collapse involves plastic flow, which is similar to the mechanism of rutting in ungrooved HMA surfaces. Emery (5, 6) suggested that the mechanism of groove closure involved viscous flow. Microscopic analysis of HMA that had flowed into grooves indicated that the binder still covered the aggregates. This suggested a cohesive (or stiffness) deficiency rather than an adhesive failure. Based on this mechanism of failure, it was suggested that groove closure should be related to binder characteristics, which are function of temperature and time loading as well as age.

Another type of grove collapse involves groove edge breakage (5, 6). Groove edge breakage is thought to be caused by horizontal stresses induced by aircraft tires. It was reported that horizontal stresses up to 72 psi and up to 40 kPa could be induced in the transverse and longitudinal directions, respectively, by a B747 aircraft. Repeated application of this stress level on the unsupported groove edges could lead to edge failure. Examination of broken groove edges indicated that the aggregates were still covered with binder, suggesting a cohesive failure. Hence, groove edge breakage is dependent on asphalt binder viscosity/stiffness. However, the mechanism of groove edge breakage may be more critical under cold weather conditions than under warm weather conditions. When subject to cold temperatures, the fracture resistance of asphalt binder is decreased (mixture becomes more brittle).

In addition, other field conditions are believed to contribute to edge breakage: age-hardening, freeze-thaw cycling, moisture effects, de-icing chemicals, and snow plow damage.

Laboratory Tests for HMA Groove Collapse Evaluation

Since groove collapsing in HMA pavement is, in part, similar to rutting, laboratory test methods used to evaluate rutting development in HMA could be considered to investigate groove collapse. The standard FAA specifications for evaluating groove collapse are based on the Marshall method (15). With FAA's adoption of SuperPave^{TM}, new mechanistic-based tests methods become readily available for rutting (and possibly groove collapse) evaluation (7). Of the suggested evaluation methods the following two are the most promising: The number of gyrations to maximum shear stress during the gyratory compaction, parameter N-SR$_{max}$ (3); the rut-depth versus number of loading cycles from the Asphalt Pavement Analyzer (APA) (9, 13). In addition, full scale accelerated testing can be used to evaluate the performance of grooves (14).

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