AFCESA-RSC-441

RUNWAY FRICTION CHARACTERISTICS EVALUATION

KEESLER AIR FORCE BASE

MISSISSIPPI

JULY 2002

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

139 BARNES DR, SUITE 1

TYNDALL AIR FORCE BASE, FLORIDA 32403-5319

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13. ABSTRACT *(Maximum 200 words)*

A pavements surface effects team from HQ Air Force Civil Engineer Support Agency (AFCESA), at the request ofHQ AETC, conducted a runway friction characteristics evaluation at Keesler AFB, MS on 04 June19, 2002. The purpose of the evaluation was to determine the skidding and hydroplaning potential of the runway. Surface transverse/longitudinal slopes; texture depth; self-wetting coefficient of friction; and flood testing were accomplished for Runway 03/21. Based on the test results, the following recommendations are made:

1. Runway 03/21:

14. SUBJECT TERMS

Pavement Surface Slopes	Grip Tester
Pavement Surface Texture	Hydroplaning
Pavement Surface Friction	Skid Resistance

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I. INTRODUCTION

A. Scope:

1. A pavements surface effects team from HQ Air Force Civil Engineer Support Agency (AFCESA) conducted a runway friction characteristics evaluation at Keesler AFB, Mississippi on 19 June 2002. The overall purpose of this type of evaluation is to determine the runway surface's potential to contribute to a skidding or hydroplaning incident. The primary objectives of this evaluation were to:

a. Determine certain runway surface characteristics, such as slope and texture.

b. Conduct measurements of the runway surface coefficient of friction.

c. Assess the capability of the runway to drain excess water and recover its friction properties.

2. This report summarizes the methods used to collect data, presents the findings of the evaluation, and makes conclusions and recommendations based on analysis of the data. The results of this report can be used to:

a. Alert aircrews to the potential for skidding or hydroplaning problems through Flight Information Publication (FLIP) notices or other means.

b. Identify and program runway maintenance and repair requirements such as rubber removal and pavement texturing projects.

c. Support programming documents that justify major pavement restoration projects.

3. Data results are presented in four appendices to this report as described below.

Appendix	Description
A	Slope Measurements: Tabulates the slopes measured on the runway(s). The transverse and longitudinal slopes are measured every 500 feet along the length of the runway.
B	Texture Measurements: Presents the texture depth for various runway features and rainfall intensities required to flood these features.
C	Self-Wetting Grip Tester Friction Data Plots: Contains friction plots for the entire length of the runway(s) and describes the guidelines for determining acceptable friction characteristics.
D	Flood Recovery Test Data: Presents flood recovery curves for 1000-ft test sections.
E	Estimation of Rubber Deposits: Presents the inspection method for visual estimation of rubber deposits accumulated on runway.

II. BACKGROUND DATA

A. General Description of Airfield: The airfield at Keesler AFB consists of one operational runway. Runway 03/21 measures an overall length of 5030 feet and is constructed of Asphalt Concrete (AC) and Portland Cement Concrete (PCC). Runway 03/21 is not grooved to the Air Force standard of 1 ½ inch on center by ¼ inch wide and ¼ inch deep.

Runway	Length	Width	Surface	Touchdowns
03/21	5030 ft	150 ft	PCC 1000' from 21 end AC 1000' to 5030'	PCC 21 end AC 03 end

B. Previous Evaluation: A runway friction characteristics evaluation was previously accomplished at Keesler AFB in 1991. Based on test results, the recommendation was made to remove rubber and improve the surface texture of the PCC on Runway 03/21.

C. Maintenance History:

03/21	Rubber Removal	2000

III. TEST PROCEDURES

A. Slope Measurements:

1. The slope measuring equipment consists of an 8-ft aluminum level fitted with an electronic module to measure slopes to the nearest 0.1 percent.

2. Pavement surface transverse and longitudinal slopes were measured every 500 ft along the entire length of the runway. Transverse slopes were measured at 5 ft and 15 ft from the centerline, on both sides of the centerline. A single longitudinal slope was measured at the runway centerline. Good slopes promote drainage and reduce the hydroplaning potential. UFC 3-260-01 requires transverse slopes between 1 and 1.5% to promote good drainage.

B. Surface Texture Measurements:

1. A grease smear test was used to measure the texture depth of the pavement surface. The test equipment consists of 0.915 cubic inches (15 cc) of grease and a 4 in (10.16 cm) wide template in which the grease is evenly spread on the pavement surface. The volume of grease is then divided by the area of the smear to calculate the texture depth. The sum of the individual tests divided by the total number of tests yields the average texture depth (ATD) [Federal Aviation Administration Advisory Circular(FAA AC) 150/5320-12C].

2. Texture depth measurements were made at several locations to obtain a representative sampling of the pavement macrotexture. Macrotexture provides channels for bulk water drainage and is an important component in the overall friction properties of a pavement surface. Research has shown a strong potential for hydroplaning exists when the ATD is less than 0.016 in (0.4 mm). Additional testing is required to determine the hydroplaning potential of surfaces with average texture depths between 0.016 and 0.036 inches. ATDs greater than 0.036 inches generally have a low potential for hydroplaning (Williams, 1975). A complete analysis of surface texture would ideally include an assessment of the surface microtexture, the fine asperities which pierce the remaining thin film of water and grip the aircraft tire. However, there is no accurate method to measure this characteristic.

C. Friction Measurements:

1. The Grip Tester was used to measure the runway surface friction. It's a three-wheel trailer, which measures friction by the braked-wheel, fixed-slip principle. A single measuring wheel, fitted with a special smooth tread tire, is mounted on an axle instrumented to measure both horizontal drag and vertical load forces. From these measurements, dynamic friction is calculated and transmitted to the data collection computer in the towing vehicle. An onboard self-wetting system regulates water flow from a 150-gallon tank to a nozzle that distributes a 0.04 in (1 mm) film of water beneath the measuring wheel at testing speeds of 40 or 60 mph. The majority of the Grip Tester's weight is distributed over two drive wheels, which are fitted with patterned tread tires and mounted on a solid, stainless steel drive axle. This drive axle carries a sprocket of 27 teeth and the stub axle on which the measuring wheel is mounted carries a sprocket of 32 teeth. A transmission chain links the two axles and this transmission system continuously brakes the measuring wheel, forcing it to slip. This slipping wheel and the weight of the Grip Tester cause minute bending movements in the stub axle, which are measured, by two pairs of strain gauges mounted on its vertical

and horizontal faces. The signals from these strain gauges are processed by the signal-processing unit mounted on the top of the Grip Tester and are then transmitted to the data collection computer. The computer also calculates and stores the survey speed from a proximity sensor mounted on the drive axle.

2. Testing Modes:

a. Self-Wetting: Friction measurements were made along the entire runway length employing the Grip Tester self-wetting system. Test runs were conducted 5 ft from both sides of the centerline at 40 and 60 mph. A separate 40 mph test was conducted on the less trafficked pavement along the right edge of the runway and a 60 mph test was conducted on the less trafficked pavement along the left edge. These measurements help to identify those areas of the runway pavement that are smooth due to poor texture, excessive traffic wear, aggregate polishing, and/or surface contaminants such as rubber deposits and oil/fuel spills. The measured friction values are compared to Federal Aviation Administration (FAA) guidelines to determine if corrective action is required. These standards are adopted from FAA AC 150/5320-12C, "Measurement, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces." The guidelines apply only to wet runway surfaces. They do not apply to ice or snow covered surfaces. See Appendix C for additional test result interpretation guidelines.

Friction Level Classification	Grip Tester 40 mph	Grip Tester 60 mph
Minimum	0.43	0.24
Maintenance Planning	0.53	0.36

b. Runway Flooding: Runways may have different feature characteristics on the pavement, such as depressed areas or texture changes, which may pond or hold excess water during periods of moderate to heavy rainfall. Because of this, water may exceed the depth used by the self-wetting system and the actual traction capacity of the pavement in these areas may be less than that determined by the self-wetting system. Whereas the self-wetting test uses only enough water to evaluate the requirement for maintenance of the surface texture, the flooding test oversaturates the texture to evaluate the runway's ability to drain excess water. Therefore, several 1,000 ft test sections on the runway were selected for further study of the drainage properties using the following procedures:

i. A dry Grip Tester run was conducted to establish the maximum friction available for aircraft braking performance.

ii. A water truck fitted with a spray bar discharged enough water to create a 0.1-inch depth (approximately) on the test section in each of two passes.

iii. Continuous Grip Tester runs were initiated immediately following the second pass of the water truck and continued until the friction values exceeded the maintenance planning level or the time exceeded 30 minutes. The test section runs were conducted at a speed of 40 mph in one direction and at 60 mph in the opposite direction.

iv. An average friction value for the 1,000 ft section was determined for each test run and plotted versus time. This plot forms a friction-recovery curve and clearly illustrates the flood recovery characteristics of the runway surface.

c. Ground Vehicle Friction Correlation: The following chart provides a correlation between the Grip Tester and various friction testing equipment.

GROUND VEHICLE FRICTION CORRELATION CHART

Nominal Test Speed, 65 km/h (40 mph) [9]

BRAKING ACTION LEVEL	GROUND VEHICLE READINGS									ICAO INDEX [8]
	RCR [1]	DECEL METERS [2]	JAMES BRAKE INDEX [3]	MU-METER	SURFACE FRICTION TESTER [4]	RUNWAY FRICTION TESTER [5]	BV-11 SKIDDO-METER [4]	GRIP-TESTER [6]	LOCKED WHEEL DEVICES [7]	
GOOD	>17	>0.53	>0.58	>0.50	>0.54	>0.51	>0.59	>0.49	>0.51	5
FAIR	12–17	0.37–0.53	0.40–0.58	0.35–0.50	0.38–0.54	0.35–0.51	0.42–0.59	0.34–0.49	0.37–0.51	3–4
POOR	6–11	0.17–0.36	0.20–0.39	0.15–0.34	0.18–0.37	0.18–0.34	0.21–0.41	0.16–0.33	0.18–0.36	2–3
NIL	≤5	≤0.16	≤0.17	≤0.14	≤0.16	≤0.15	≤0.19	≤0.14	≤0.15	1

NOTES:

1. RCR=Runway Condition Reading=Decelerometer reading x 32
2. Decelerometers include Tapley, Bowmonk, and electronic recording decelerometer
3. JBI=James Brake Index
4. Measurements obtained with grooved aero tire inflated to 690 kPa (100 psi)
5. Measurements obtained with smooth ASTM 4 x 8.0 tire inflated to 210 kPa (30 psi)
6. Measurements obtained with smooth ASTM tire inflated to 140 kPa (20 psi)
7. ASTM E-274 skid trailer and E-503 diagonal-braked vehicle equiped with ASTM E-524 smooth test tires inflated to 170 kPa (24 psi)
8. ICAO=International Civil Aviation Organization
9. A wet runway produces a drop in friction with an increase in speed. If the runway has good texture, allowing the water to escape beneath the tire, then the friction value will be less affected by speed. Conversely, a poorly textured surface will produce a larger drop in friction with increase in speed. Friction characteristics can be further reduced by poor drainage because of inadequate slopes or depressions in the runway surface.

IV. TEST RESULTS

A. Slope Measurements:

1. Slope measurement results are illustrated in Appendix A. A positive transverse slope indicates that water will drain away from the runway centerline. A positive longitudinal slope indicates that water will drain away from the primary runway approach end.

Runway 03/21 is 150 ft wide. The runway is crowned at the centerline with transverse slopes of 0.4 to 2.0% and 32% of the transverse slopes are less than the 1% recommended minimum. The longitudinal slopes range from –0.7 to 0.4%.

B. Texture Depth: The average texture depth (ATD) measurements and rainfall flooding rates for the runway surfaces are shown in Appendix B.

1. Texture depths were measured at several locations on the pavement surface, usually near the centerline in the heavily trafficked areas, and also along the edge to make a comparison with uncontaminated pavement.

2. The measured texture depths for the runways are shown in Appendix B.

Runway 03/21: Page B-1 shows the measured texture depths. ATD ranged from 0.0158 to 0.0482 inches with an overall average of 0.0315 inches. Greatest rubber accumulation was at 500 to 1500 ft from the 21 end with rubber buildup as 'Medium to Heavy'.

3. A mathematical model was used to determine the rainfall intensity necessary to cause flooding on the runways. Keep in mind that the model does not consider weather effects like temperature, wind, and evaporation rates, which can significantly change drainage characteristics.

Runway 03/21: Page B-2 lists the predicted rainfall rates required to flood the runway macrotexture. This model indicates that rainfall rates between 0.2 to 1.6 inches per hour could flood the runway.

C. Grip Tester Friction Data:

1. Appendix C contains the measured friction values. Page C-1 outlines the parameters set by FAA AC 150/5320-12C for minimum friction levels and maintenance planning friction levels.

a. Runway 03/21: The measured friction values for the runway are shown on page C-2. The PCC portion of the runway exhibited friction characteristics just below or equal to the MPL. The AC portion of the runway exhibited good friction characteristics except for the areas with significant rubber accumulation.

3. The friction recovery curves for the flooded test sections are shown in Appendix D.

b. Runway 03/21: Two tests were accomplished on the runway. The average Mu value for the section was plotted versus time to produce the curves. Test Section A was located 500-1500 ft from the 21 end of the runway and recovered to above the MPL in approximately 18 minutes. Test Section B was located 3600-4600 ft from the 21 end of the runway and recovered to above the MPL in less than one minute. The runway also shows evidence of ponding within 35 feet of the centerline, which would create a high potential for hydroplaning. At the time of testing, the ambient temperature was 85-90°F with cloudy skies.

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions:

1. Runway 03/21 showed fair friction characteristics over the PCC section of the runway creating a moderate to high potential for hydroplaning. The AC section of the runway showed good friction characteristics except for the areas with significant rubber accumulation. The runway also shows evidence of ponding within thirty-five feet of the centerline, which would create a high potential for hydroplaning. In addition, texture testing showed the PCC pavement has fair to poor macrotexture and the AC pavement has adequate to good macrotexture. Flood testing illustrated the runway did recover to above the maintenance planning level (MPL) in approximately 18 minutes. The runway slopes have 32% of the transverse slopes less than the Air Force 1% minimum. During flood testing it became obvious that water was ponding near the paving lane construction joints. Greatest rubber buildup was 'Medium to Heavy'.

B. Recommendations:

1. Runway 03/21: **Advise pilots to use caution while landing on the runway when the pavement is saturated by rainfall.** Pilots should expect reduced braking performance in areas where water is ponded and the surface appears glassy smooth. Consider a project to improve the texture of the PCC pavement. Texture could be improved by shotblasting, grinding, or grooving to the Air Force standard of 1 ½ inch on center by ¼ inch wide by ¼ inch deep. Remove rubber accumulations on both ends of the runway.

2. These tests measure the runway's potential for contributing to a skid resistance/hydroplaning problem. They were conducted using simulated rainfall conditions. A careful evaluation of all the factors such as tire tread depth, tire pressure, ground speed, rainfall rates, crosswind, etc., should be considered prior to wet weather operations.

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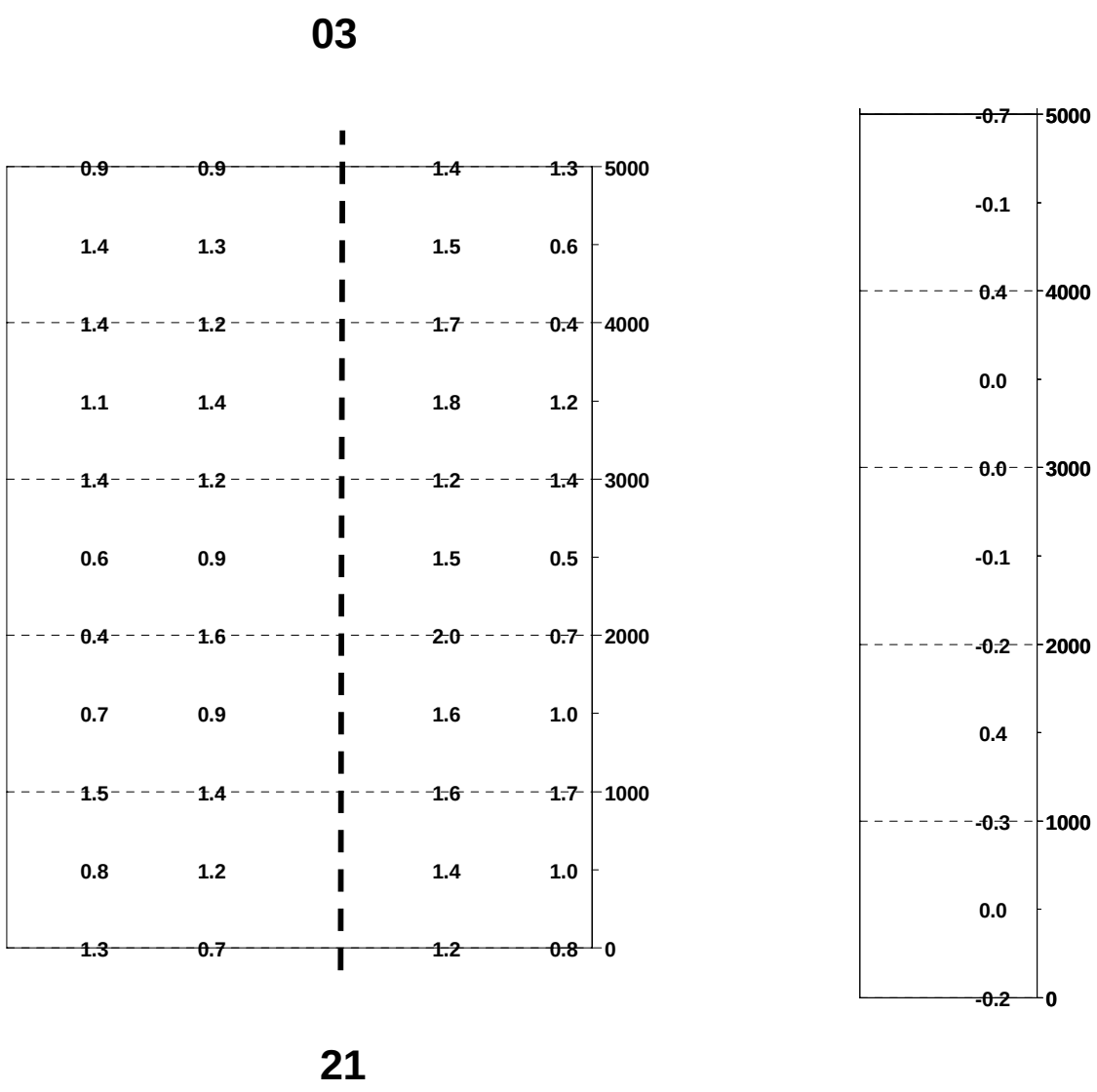
Keesler Air Force Base, MS

SLOPE MEASUREMENTS



TRANSVERSE SLOPE

1. ALL TRANSVERSE SLOPE MEASUREMENTS WERE TAKEN WITHIN 20 ' (6.1M) 0F THE CENTERLINE.
2. POSITIVE SLOPE VALUES INDICATE DRAINAGE AWAY FROM CENTERLINE.
3. NEGATIVE SLOPE VALUES INDICATE DRAINAGE TOWARD CENTERLINE.

LONGITUDINAL SLOPE

1. ALL LONGITUDINAL SLOPE MEASUREMENTS WERE TAKEN AT CENTERLINE.
2. POSITIVE SLOPE VALUES INDICATE DRAINAGE TOWARD SECONDARY END OF RUNWAY **03**.
3. NEGATIVE SLOPE VALUES INDICATE DRAINAGE TOWARD PRIMARY END OF RUNWAY **21**.

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SURFACE TEXTURE MEASUREMENTS

LOCATION		PAVEMENT TYPE	SURFACE RUBBER	LENGTH OF 4" WIDE TEST STRIP		AVERAGE TEXTURE DEPTH (ATD)	
FT FROM PRIMARY END	FT FROM CENTER LINE			INCHES	MM	INCHES	MM
900'	10' R	PCC	MEDIUM	14.50	368.3	0.0158	0.4008
900'	20' R	PCC	NONE	14.50	368.3	0.0158	0.4008
1100'	10' L	AC	MEDIUM to HEAVY	7.50	190.5	0.0305	0.7750
1100'	20' L	AC	NONE	6.00	152.4	0.0381	0.9687
2500'	10' R	AC	NONE	4.75	120.7	0.0482	1.2236
2500'	20' R	AC	NONE	8.25	209.6	0.0277	0.7045
3500'	10' L	AC	LIGHT	6.00	152.4	0.0381	0.9687
3500'	20' L	AC	NONE	6.00	152.4	0.0381	0.9687

NOTE:

AN ATD < 0.016 INCHES HAS STRONG HYDROPLANING POTENTIAL

AN ATD > 0.016 INCHES BUT < 0.036 INCHES REQUIRES FURTHER TESTING FOR HYDROPLANING POTENTIAL

AN ATD > 0.036 INCHES HAS LOW HYDROPLANING POTENTIAL

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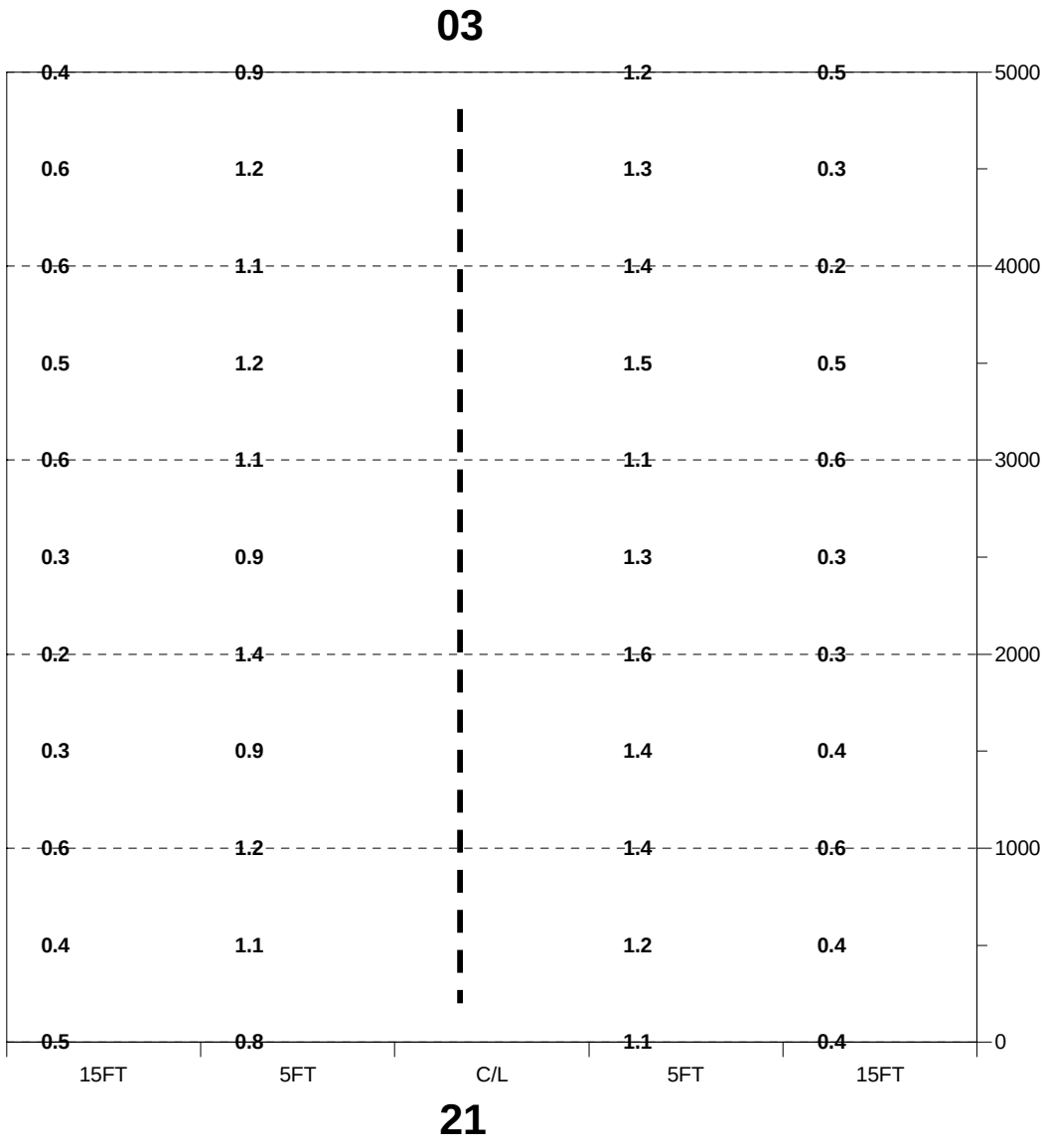
RAINFALL (INCHES/HOUR) TO FLOOD THE AVERAGE PAVEMENT TEXTURE DEPTH



NOTE: THIS IS THE AMOUNT OF RAIN IN INCHES PER HOUR REQUIRED TO CREATE A HIGH POTENTIAL FOR DYNAMIC HYDROPLANING.

GRIP TESTER SELF-WETTING
FRICTION MEASUREMENT PARAMETERS

A. Friction Deterioration Below the Maintenance Planning Level for 500 Feet.
When the average Friction value is:
> .43 and < .53 at 40 mph AND > .24 and < .36 at 60 mph
for a distance of 500 ft, AND adjacent 500 ft segments are:
> .53 at 40 mph AND > .36 at 60 mph
no corrective action is required.

These readings indicate that the pavement friction is deteriorating but the situation is not within an unacceptable overall condition.
The area in question should be monitored closely by conducting friction surveys to establish the rate and the extent of friction deterioration**.**

B. Friction Deterioration Below the Maintenance Planning Friction Level for 1000 Feet.
When the average Friction value is:
< .53 at 40 mph AND <.36 at 60 mph
For a distance of 1000 feet or more, conduct an extensive evaluation into the cause(s) and extent of the friction deterioration and **take appropriate corrective action**.

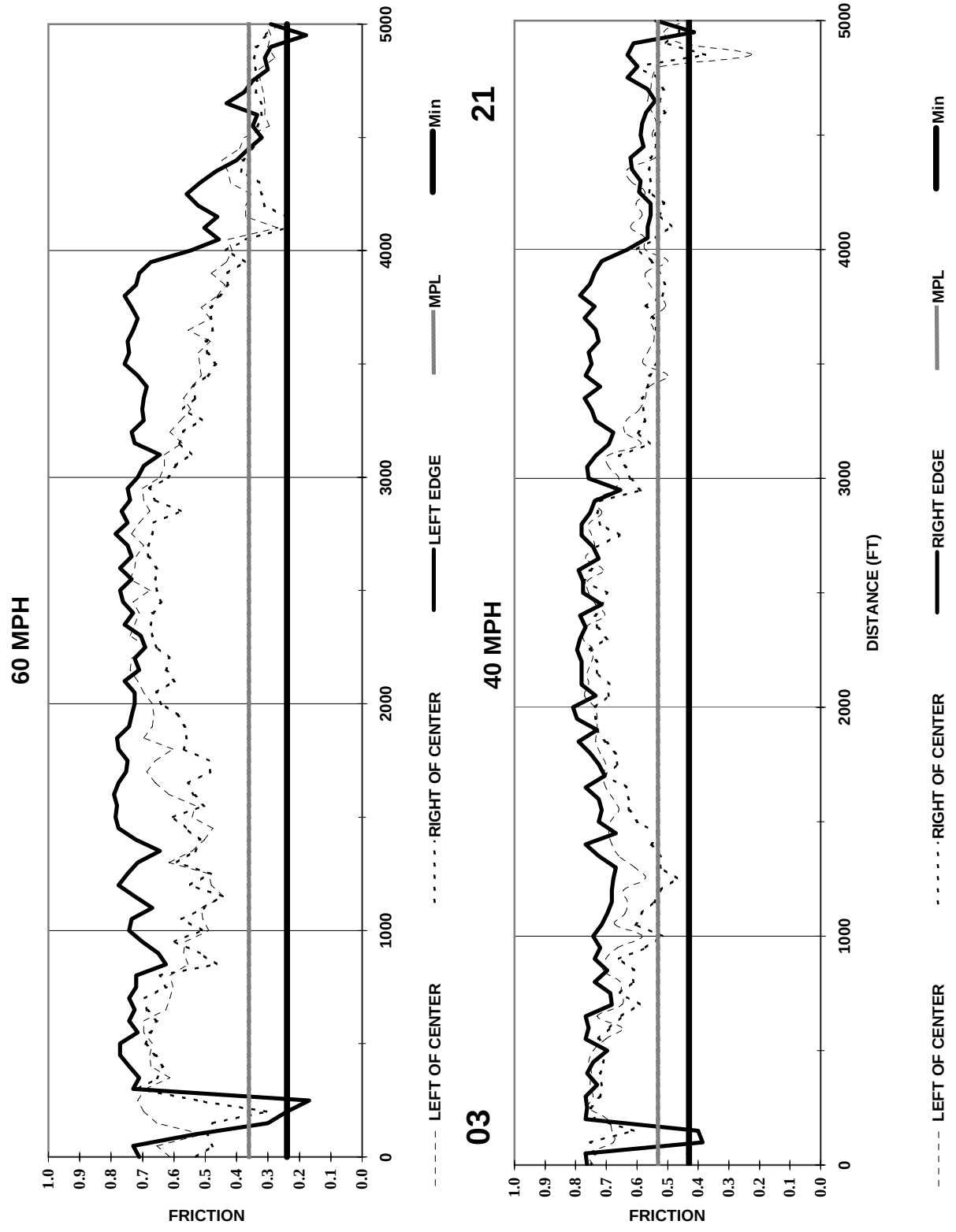
C. Friction Deterioration Below Minimum Friction Level.
When the average Friction value is:
< .43 at 40 mph AND < .24 at 60 mph
for a distance of 500 feet, AND the adjacent 500 ft segments are:
< .53 at 40 mph AND < .36 at 60 mph
Corrective action should be taken immediately after determining the cause(s) of the friction deterioration.
The overall condition of the entire runway pavement surface should be evaluated with respect to the deficient area before undertaking corrective measures.

D. New Design/Construction Friction Level.
For newly constructed runway surfaces that are either saw-cut grooved or have a porous friction course overlay, the average Friction value of the wet runway pavement surface for each 500 ft segment should be:
> .74 at 40 mph AND > .64 at 60 mph

NOTE: ALL MEASUREMENTS ARE ON WET PAVEMENT SURFACE CONDITIONS AS PER FAA AC 150/5320-12C.

Keesler Air Force Base, MS

SELF-WETTING GRIP TESTER FRICTION PLOTS



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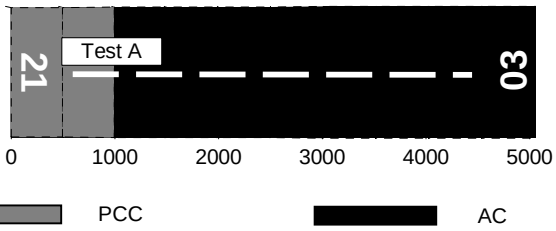
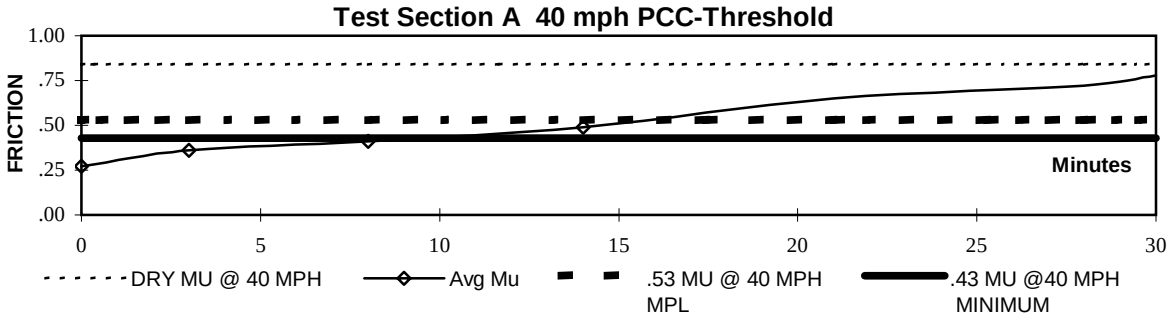
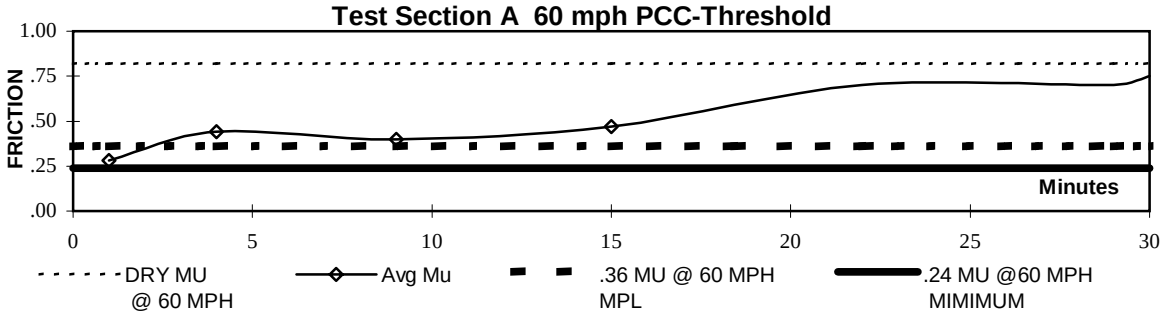
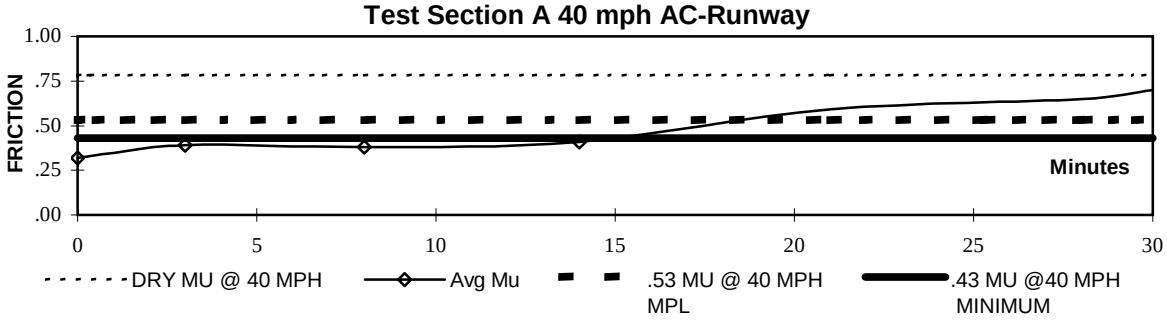
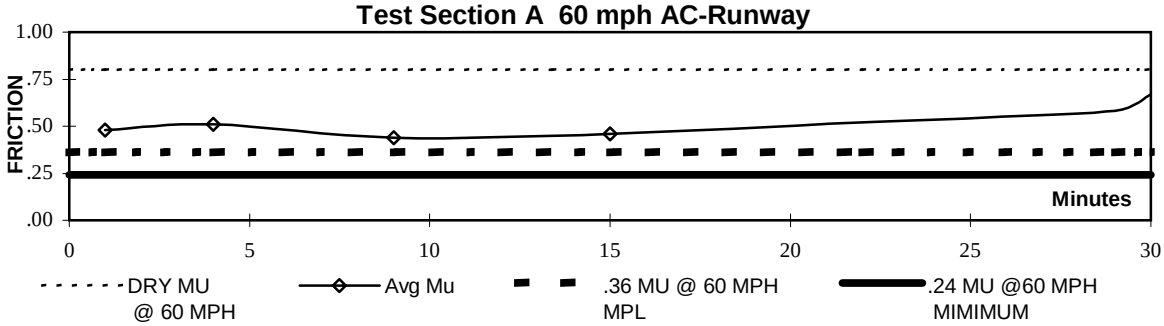
FLOOD RECOVERY TEST SECTION A











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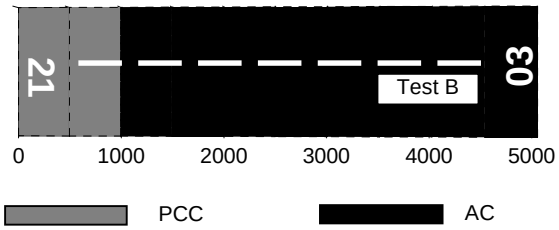
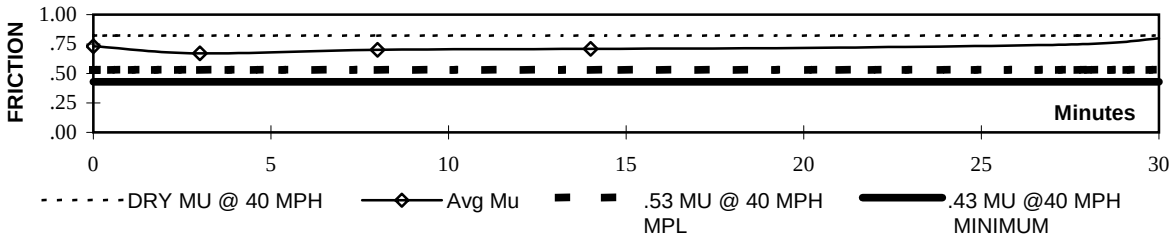
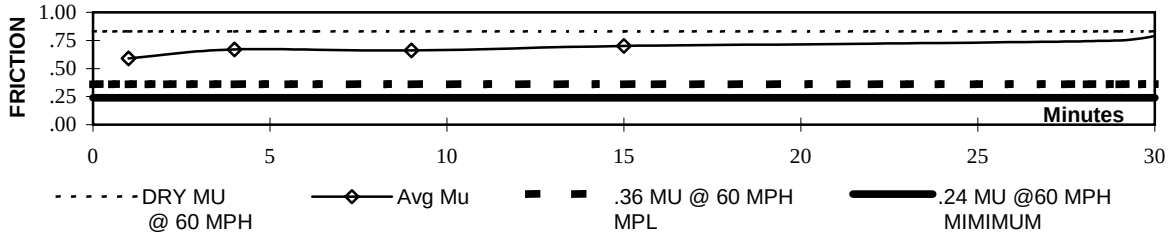
FLOOD RECOVERY TEST SECTION B



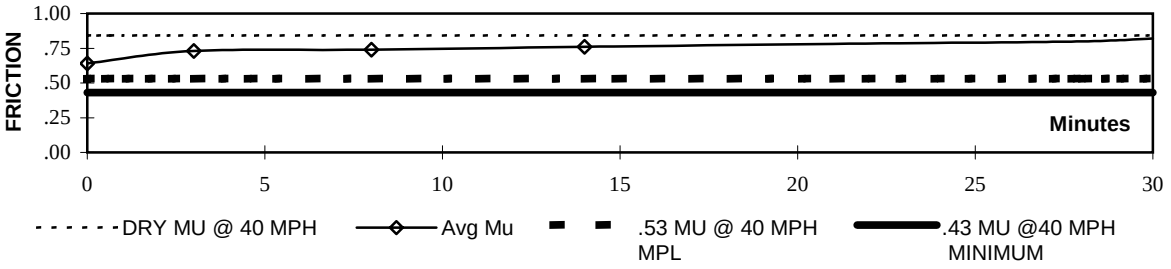
Test Section B 40 mph AC-Runway



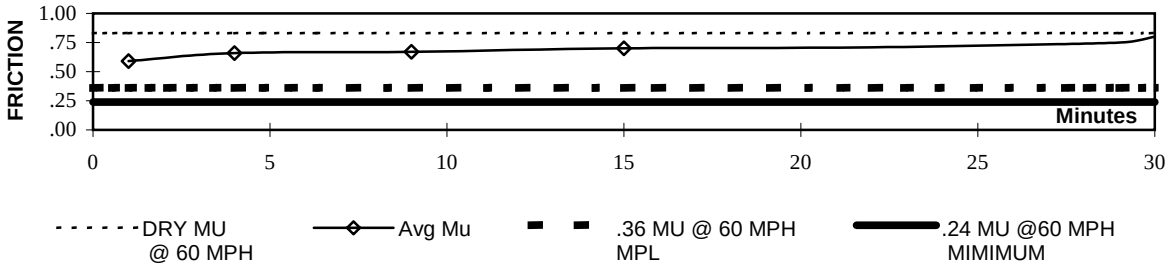
Test Section B 60 mph AC-Runway



Test Section B 40 mph AC-Threshold



Test Section B 60 mph AC-Threshold



Estimation of Rubber Deposits

Classification of rubber deposit accumulation	Estimated percentage of rubber covering pavement texture in touchdown zone of runway	Description of rubber covering pavement texture in touchdown zone of runway as observed by evaluator
Very Light	Less than 5%	Intermittent tire tracks; 95% of surface texture exposed.
Light	6 – 20%	Individual tire tracks begin to overlap; 80 – 94% surface texture exposed.
Light to Medium	21 – 40%	Central 6m traffic area covered; 60 – 79% surface texture exposed.
Medium	41 – 60%	Central 12m traffic area covered; 40 – 59% surface texture exposed.
Medium to Heavy	61 – 80%	Central 15-foot traffic area covered; 30 – 69% of rubber vulcanized and bonded to pavement surface; 20 – 39% surface texture exposed.
Heavy	81 – 95%	70 – 95% of rubber vulcanized and bonded to pavement surface; will be difficult to remove; rubber has glossy or sheen look; 5 – 19% surface texture exposed.
Very Heavy	96 – 100%	Rubber completely vulcanized and bonded to surface; will be very difficult to remove; rubber has striations and glossy or sheen look; 0 – 4% surface texture exposed.

Note.- With respect to rubber accumulation, there are other factors to be considered by the airport operator; the type and age of the pavement, annual conditions, time of year, number of wide-body aeroplanes that operate on the runways, and length of runways. Accordingly, the recommended level of action may vary according to conditions encountered at the airport. This table is modified from Airport Services Manual Part 2, Pavement Surface Conditions, Appendix 2, Doc 9137-AN/898.