FAA Guidance on Use of Friction Measuring Equipment for Maintaining Highly Skid Resistant Runway Pavement Surfaces at Civil Airports

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A revision is presented to the procedures and guidelines recommended by FAA for frictional standards involving maintenance of highly skid resistant runway pavement surfaces at civil airports that have commercial turbojet aircraft operations. Revision of AC 150/5320-12B presents guidance relative to the visual inspection of runway pavement surface condition, when continuous friction measuring equipment is not available at civil airports, and the use of continuous friction measuring equipment, when available at civil airports, to monitor the deterioration of runway pavement surfaces. Periodic friction surveys will help identify those areas on the runway that are potentially hazardous conditions for aircraft braking and directional control. Once the deficient areas have been located and the cause of the deterioration identified, corrective action can be determined and expedited by the airport management. Guidance is also given on types of surface treatments that successfully mitigate aircraft hydroplaning potential and maintenance methods used to remove rubber deposits in the touchdown zones of runway pavement surfaces.

FAA conducted a tire performance evaluation and friction equipment correlation study in August 1989 at NASA Wallops Flight Facility at Wallops Island, Virginia. The study was performed in response to a request from ASTM to evaluate the performance of tires manufactured according to its specifications ASTM E524 and ASTM E670. Some 1,650 tests were conducted on five types of surfaces using three brands of tires and four types of friction measuring device. Friction tests were conducted at 40 and 60 mph (65 and 95 km/hr), using each device's self-water system on dry test surfaces. The water was applied at a depth of 0.04 in. (1 mm). The analyses conducted involved 156 reliability and performance studies and 31 correlation comparisons.

Limits of acceptability were established for the data evaluation. The McCreary tire performed best on the runway friction tester (RFT), Saab friction tester (SFT), and the skiddometer (SKD). The Dico tire performed best on the mumeter (MUM).

The tire formulation given in ASTM E524 specification for locked-wheel trailers will be put into a new ASTM standard to describe the characteristics of the McCreary tire. The current ASTM E670 specification will contain the specifications for the Dunlop and Dico tires.

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REQUEST FOR RESEARCH

On June 17, 1988, the chairman of ASTM Subcommittee E17.21 asked FAA to conduct tests to evaluate tire performance on friction measuring devices. The chairman requested that these tests be performed by the FAA Technical Center at the National Aeronautics and Space Administration (NASA) Wallops Flight Facility.

PURPOSE OF TIRE PERFORMANCE STUDY

The purpose of the tire performance study was twofold:

1. To establish the reliability, performance, and consistency of tires on all types of dry runway pavement surfaces, using continuous friction measuring devices equipped with self-water systems (T. H. Morrow, unpublished studies, Dec. 1980 and Aug. 1991).
2. To select the best-performing tires that will achieve consistent correlation between the various friction measuring devices and to develop guidelines that will be dependable and useful to airport operators in maintaining runway pavement surfaces for safe aircraft operations during wet weather conditions.

Further details can be found in works by Morrow concerning the tire performance study (*1,2*).

FACTORS THAT AFFECT SKID-RESISTANT PAVEMENTS

Over time, several factors cause the skid resistance of the runway pavement to deteriorate:

- *Mechanical wear and polishing action*: aircraft tires' rolling or braking on the pavement surface causes texture loss.
- *Accumulation of contaminants*: contaminants such as rubber, jet fuel, oil spillage, chemicals, and dust particles cause the runway to be slippery when wet.
- *Influence of seasonal variances*: ambient temperature, wind, sun, rainfall intensity, and such cause deterioration to the pavement surface.

• *Airport maintenance practices and subsequent surface treatment*: poor maintenance and repair practices cause textural loss.

• *Structural and other surface deficiencies*: rutting, raveling, cracking, joint failure, slab faulting, and depressions caused by settling, or other indicators of distressed pavement, cause frictional loss.

CONDUCTING FRICTION EVALUATIONS WITHOUT CFME

If the airport does not own or have access to continuous friction measuring equipment (CFME), the following procedures are given to evaluate the potential loss of frictional properties caused by one or more of the factors identified in the previous paragraph.

Touchdown Zone

The evaluator should investigate each 500-ft segment of the touchdown zones. In addition, the evaluator should observe the condition of the midpoint zone of the runway.

Minimum Survey Frequency

Table 1 shows the frequency for conducting friction surveys according to annual aircraft traffic activity at runway end.

Recording Pavement Condition Survey

The evaluator should complete the following information in Figure 1 on the pavement condition survey form:

• Date of Visual Survey.
• Runway Designation.
• Contaminants in Touchdown Zone on Runway—The evaluator classifies the rubber accumulation according to the levels given in Table 2, for example, very light, medium, very dense. The evaluator also includes a recommendation for scheduling rubber removal, where applicable.
• Other Contaminants Found on Runway—The evaluator lists any other contaminants found on the runway and provides recommendations for removal.
• Surface Treatment Condition—Table 3 shows two types of grooves and a rating of their conditions.
• Other Contaminants Found on Runway—The evaluator lists any other contaminants found on the runway and provides recommendations for removal.
• Surface Treatment Condition—Table 3 shows two types of grooves and a rating of their conditions.
• Pavement Surface Type Condition—Table 4 shows two pavement types and a rating system for each.
• Additional Relevant Observations—The evaluator can record any other relevant observations of conditions that may result in significant friction loss.

TABLE 1 SCHEDULE FOR CONDUCT OF FRICTION SURVEYS

NUMBER OF DAILY TURBOJET AIRCRAFT LANDINGS PER RUNWAY END	MINIMUM FRICTION SURVEY FREQUENCY
LESS THAN 15	ANNUALLY
16 TO 30	6 MO
31 TO 90	3 MO
91 TO 150	MONTHLY
151 TO 210	2 WKS
GREATER THAN 210	WEEKLY

Note: Each runway should be evaluated separately.

Pavement Textural Measurement

Pavement texture measurements should be taken in conjunction with visual inspections and the results recorded on the form provided in Figure 1. The method for measuring texture was developed by NASA and is called the NASA grease-smear test (GST). The measurements represent the average distance between the peaks and valleys of the surface texture. Over time, the measurements will indicate any textural deterioration that has taken place on the pavement surface. A minimum of three measurements should be taken in each of the touchdown, midpoint, and rollout zones of the runway. A good skid resistant pavement surface should have an average texture depth of 0.025 in. or more.

For grooved portland cement concrete pavements, measurements can be taken in traffic areas either near transverse joints or at light-fixture locations, wherever the surface has not been grooved. Likewise, on grooved asphalt concrete pavements, the measurements may be taken in nongrooved areas near light-fixture locations.

CONDUCTING FRICTION EVALUATIONS WITH CFME

Background Information on CFME

Performance Standards

Performance standards for CFME and friction measuring tires are given in ASTM ES17 for the fixed-brake slip devices and ASTM E670 for the side force device. These standards were developed through research conducted at the NASA Wallops Flight Facility.

Federal Funding

The Airport and Airway Improvement Act of 1982 includes friction measuring equipment as an eligible item for airport development; before programming or procuring equipment,

DATE OF VISUAL SURVEY	RUNWAY	CONTAMINANTS IN TOUCHDOWN ZONE ON RUNWAY			OTHER CONTAMINANTS OBSERVED ON RUNWAY			AVERAGE TEXTURE DEPTH MEASUREMENT	
		LOCATION OF RUBBER DEPOSIT ACCUMULATION AND CLASSIFICATION LEVEL		RECOMMENDED ACTION	LOCATION OF OTHER CONTAMINATES AND THEIR IDENTIFICATION		RECOMMENDED ACTION		
		STATION	CLASSIFICATION		STATION	IDENTIFICATION		STATION	DEPTH

SURFACE TREATMENT CONDITION			PAVEMENT SURFACE TYPE CONDITION		ADDITIONAL REMARKS AND OBSERVATIONS
SAW-CUT GROOVE CONDITION	PLASTIC GROOVE CONDITION	POROUS FRICTION COURSE CONDITION	ASPHALTIC CONCRETE CONDITION	PORTLAND CEMENT CONCRETE CONDITION	

FIGURE 1 Forms for visual inspection of runway pavement surface conditions.

airport operators should contact their FAA airport's field office for guidance.

Qualification

Figure 2 gives the manufacturers and CFME that meet the requirements given in the referenced ASTM standard specifications.

Training

Success in obtaining reliable data from friction measuring equipment depends heavily on the efficiency of the personnel in correctly operating and maintaining the equipment. Therefore, FAA requires the manufacturer of the equipment to provide professional training to airport personnel in operation, maintenance, and procedures for conducting friction surveys on runways. To ensure that high proficiency is maintained for those responsible for operating the equipment, FAA also recommends that the manufacturer provide a continued periodic training program.

Calibration

Before conducting friction surveys, all CFME shall be furnished with self-water systems and be calibrated according to the tolerances required by the manufacturer.

Communications Equipment

The airport operator shall ensure that all appropriate communications equipment and frequencies are provided on all vehicles used in conducting friction surveys and that all personnel that operate the equipment are properly trained and fully cognizant of current airport safety procedures.

CFME Vehicles

All vehicles used in conducting friction surveys shall be checked for adequate braking ability.

Presurvey Preparation

Before conducting friction surveys, the airport operator should conduct a thorough visual inspection of the runway pavement surface to locate, identify, and record any deficiencies encountered on the runway.

Conduct of Friction Surveys

Vehicle Speed for Friction Survey

All approved CFME can operate safely at either 40 or 60 mph. The lower speed of 40 mph is used most often and

TABLE 2 INSPECTION METHOD FOR VISUAL ESTIMATION OF RUBBER DEPOSIT ACCUMULATED ON RUNWAY

DESCRIPTION OF RUBBER COVERING PAVEMENT TEXTURE IN TOUCHDOWN ZONE OF RUNWAY AS OBSERVED BY EVALUATOR	CLASSIFICATION OF RUBBER DEPOSIT ACCUMULATION LEVELS	ESTIMATED RANGE OF MU VALUES AVERAGED 500 FOOT SEGMENTS IN TOUCHDOWN ZONE	SUGGESTED LEVEL OF ACTION TO BE TAKEN BY AIRPORT AUTHORITY
Intermittent individual tire tracks. 95 % of surface texture exposed	VERY LIGHT	0.65 or greater	None
Individual tire tracks begin to overlap. 80 % to 94 % surface texture exposed	LIGHT	0.55 to 0.64	None
Central 20 foot traffic area covered. 60 % to 79 % surface texture exposed	LIGHT TO MEDIUM	0.50 to 0.54	Monitor deterioration closely.
Central 40 foot traffic area covered. 40 % to 59 % surface texture exposed	MEDIUM	0.40 to 0.49	Schedule rubber removal within 120 days.
Central 50 foot traffic area covered. 30 % to 69 % of rubber vulcanized and bonded to pavement surface. 20 % to 39 % surface texture exposed	MEDIUM TO DENSE	0.30 to 0.39	Schedule rubber removal within 90 days.
70 % to 95 % of rubber vulcanized and bonded to pavement surface. Will be difficult to remove. Rubber has glossy or sheen look. 5 % to 19 % surface texture exposed	DENSE	0.20 to 0.29	Schedule rubber removal within 60 days.
Rubber completely vulcanized and bonded to surface. Will be very difficult to remove. Rubber has striations and glossy or sheen look. 0 % to 4 % surface texture exposed	VERY DENSE	Less than 0.19	Schedule rubber removal within 30 days or as soon as possible.

Note: The schedules given in the above table are for a runway end that has medium turbojet aircraft activity, about 31 daily operations. As aircraft activity on a runway increases above 31, especially an increase in the wide-body aircraft activity, the airport operator may have to compress the schedule. The percent of coverage should be estimated only on the central portion of the runway most heavily used at touchdown, about 20 to 30 feet on each side of the runway centerline, not edge to edge of the pavement. The MU ranges given above are from fixed-brake CFME and are representative for each classification level. Though the airport does not have a CFME, these values will indicate the projected level of deterioration in friction over time.

determines the overall macrotextural-contaminant/drainage properties of the runway pavement surface.

If the airport operator suspects that the runway is deficient in microtextural properties (pavement does not feel "sandpapery" to the touch or aircraft have reported skidding on the wet surface at the higher speeds), then friction measurements should be made at the higher speed of 60 mph to obtain a proper evaluation.

TABLE 3 ALPHANUMERIC CODING FOR GROOVE CONDITION

Pavement surface treatment	Alpha code	Numerical coding with description
Groove type	H	0-none 1-sawed grooves 2-plastic grooves (C-8 in Table 1-4)
Groove condition	G	0- ... uniform depth across pavement 1-10% ... % of grooves not effective 2-20% " 3-30% " 4-40% " 5-50% ... When this level is exceeded, 6-60% the airport operator should 7-70% take corrective action to 8-80% improve groove efficiency. 9-90% ... grooves not effective.

Location of Friction Survey on Runway

When conducting friction surveys at 40 mph, the airport operator should begin recording data at 500 ft from the threshold end of the runway to allow adequate acceleration distance for the friction vehicle. At the opposite end of the runway, the airport operator should terminate the friction survey at least 500 ft from the end of the runway to allow for adequate distance for the friction vehicle to stop safely.

When conducting friction surveys at 60 mph, the airport operator should begin recording data at 1,000 ft from the threshold end of the runway to allow adequate acceleration distance for the friction vehicle. At the opposite end of the runway, the airport operator should terminate the friction survey at least 1,000 ft from the end of the runway to allow adequate distance for the vehicle to stop safely.

Unless surface conditions are noticeably different on either side of the runway centerline, a survey on the one side in the same direction the aircraft lands should be sufficient. However, when both ends are to be evaluated, the vehicle should be programmed to record data on the return trip (both ways).

The lateral location on the runway for performing friction surveys is based on the type and mix of aircraft operating on the runway.

TABLE 4 ALPHANUMERIC CODING FOR PAVEMENT SURFACE TYPE

Pavement surface type	Alpha code	Numerical coding with description
Asphalt concrete pavement	A	0-slurry seal coat 1-new, asphalt-covered aggregate, black color 2-microtexture, 75% fine aggregate, color of aggregate 3-mixed-texture, 50-50 fine, coarse aggregate color of aggregate 4-macrotexture, 75-100% coarse aggregate 5-worn surface, coarse aggregate protrudes and/or abraided out 6-open-graded surface course, PFC 7-chip seal 8-rubberized chip seal 9-other
Portland cement concrete pavement	C	0-belt finished 1-microtextured, predominately fine aggregate 2-macrotextured, predominately coarse aggregate 3-worn surface, coarse aggregate protrudes and/or abraided out 4-burlap dragged 5-broomed or brushed 6-wire comb 7-wire tined 8-float grooved 9-other

Runways Serving Only Narrow-Body Aircraft Friction surveys should be conducted 10 ft to the right of the runway centerline.

Runways Serving Narrow- and Wide-Body Aircraft Friction surveys should be conducted 10 and 20 ft to the right of the runway centerline to determine the worst-case condition.

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AIRPORT TECHNOLOGY U.S.A. President 6 Landmark Square Suite 400 Stamford, Connecticut 06901 FAX (203) 378-0501 **(Mark 2)** (203) 359-5730 **SURFACE FRICTION TESTER**

FIGURE 2 Qualified product list for CFME.

Wet and Dry Friction Surveys

Because wet pavement always yields the lowest friction measurements, CFME should routinely by used on wet pavement to simulate the worst-case condition.

Wet Pavement Simulation CFME is equipped with a self-water system to simulate rain-wet pavement surface conditions and provide a continuous record of friction values for each foot traveled along the runway.

Dry Pavement Simulation CFME is used on dry runway to establish the maximum available friction for aircraft braking performance. In addition, it sets a baseline for comparing existing and newly constructed pavements to determine the deterioration level over time.

Rainfall Survey The self-water systems used by CFME cannot simulate actual rainfall conditions on runway pavements that have depressed areas that pond during moderate to heavy rainfall. When these conditions exist on the runway, CFME cannot accurately predict the aircraft hydroplaning potential. Therefore, FAA recommends that the airport owner conduct periodic visual inspections of the runway surface during rainfall, noting the location and extent of any ponded areas. If the water depth exceeds 0.125 in. over a longitudinal distance of 500 ft, the depressed area should be corrected to the standard transverse slope.

CFME Correlation Chart

Research tests concluded at NASA Wallops Flight Center in 1989 confirmed the qualification and correlation of the CFME.

TABLE 5 CORRELATION OF MU-VALUES FOR CFME USING SELF-WATER SYSTEM

TYPE OF FRICTION EQUIPMENT	MOUNTED WITH DICO TIRE		MOUNTED WITH McCREARY TIRE			
	MARK 4 MU METER TRAILER		M 6800 RUNWAY FRICTION TESTER		BV-11 SKIDDOMETER TRAILER	MARK 2 SAAB FRICTION TESTER
RUNWAY SURFACE	FRICTION SURVEY SPEED		FRICTION SURVEY SPEED		FRICTION SURVEY SPEED	
FRICTION LEVEL	40 MPH	60 MPH	40 MPH	60 MPH	40 MPH	60 MPH
CLASSIFICATION	FRICTION VALUES		FRICTION VALUES		FRICTION VALUES	
MINIMUM	42	26	50	41	50	34
MAINTENANCE PLANNING	52	38	60	54	60	47
NEW DESIGN/ CONSTRUCTION	72	66	82	72	82	74

Table 5 shows the correlation relationship for the four approved CFMEs.

Corrective Action Guidelines

Mu numbers measured by CFME should be used as maintenance guidelines for identifying the appropriate corrective action required to improve and maintain runway pavement surfaces for safe aircraft operations. Poor friction conditions for short distances on the runway do not pose any serious threat, but long stretches of slippery pavement are of concern to the airport operator and require appropriate corrective methods.

Friction Deterioration Below Maintenance Planning Friction Level for 500 ft (152 m) When the averaged mu value on the wet runway pavement surface is below the maintenance planning friction level but above the minimum friction level for 500 ft, and the adjacent 500-ft segments are at or above the maintenance planning friction level, no corrective action may be required. These readings indicate that the pavement friction is deteriorating but the overall condition is acceptable. The airport operator should monitor the situation closely by conducting periodic friction surveys to establish the rate and extent of the deterioration.

Friction Deterioration Below Maintenance Planning Friction Level for 1,000 ft (305 m) When the average mu value on the wet runway pavement surface is less than the maintenance planning friction level for 1,000 ft (305 m) or more, the airport operator should conduct extensive evaluation of the cause and extent of friction deterioration and take appropriate corrective action.

Friction Deterioration Below Minimum Friction Level When the average mu value on the wet pavement surface is below the minimum friction level for 500 ft (152 m), and the adjacent 500-ft (152 m) segments are below the maintenance planning friction level, corrective action should be taken immediately after determining the cause 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.

New Design and Construction Friction Level for Runways For newly constructed runway pavement surfaces that are sawcut, grooved, or have a porous friction course overlay, the average mu value on the wet runway pavement surface for each 500-ft (152 m) segment should be no less than the new design and construction friction level.

Evaluation of Paint Areas on Runway Paint on wet runway pavement surfaces causes very slippery conditions. Friction surveys should be conducted over painted surfaces at 40 mph, under dry and wet conditions, to check the magnitude of the change in friction values between the unpainted and painted surfaces. When the averaged mu value is at the minimum friction level for 100 ft (30 m) or more or the difference between the wet and dry averaged mu readings is greater than 40, corrective action should be taken. Usually this means adding a small amount of sand to the paint mix to increase the friction properties of the paint to an acceptable level.

SURFACE TREATMENTS TO PREVENT HYDROPLANING

Three surface treatments have been used successfully to alleviate hydroplaning on wet runway pavement surfaces. Portland cement concrete pavements can be constructed with sawcut or plastic grooves. Asphalt concrete pavements can have either sawcut grooves or a porous friction course overlay.

MAINTENANCE METHODS FOR RUBBER REMOVAL

Two methods are used successfully to remove rubber on runways: high-pressure water and chemical/detergent. A combination of both may also be used.

High-Pressure Water

Most equipment used today operates at pressures between 5,000 to 8,000 psi and can exceed 15,000 psi. Some contractors can operate at pressures in excess of 35,000 psi.

Chemical/Detergent Application

Chemical/detergents have been successfully used to remove rubber deposits on runways. Chemical/detergents must meet Environmental Protection Agency requirements; those that are volatile and toxic in nature are not used on runways.

High-Pressure Water and Chemical/Detergents

Some asphalt concrete pavements are more susceptible to damage by the high-pressure water technique; therefore, applying chemical/detergents before using the high-pressure water method has been demonstrated successfully. Usually, the use of the chemical/detergents lowers the overall pressure required to remove rubber.

SUMMARY

This paper shows the application of the results obtained from an FAA research program that has led to the development of national and international standards for friction measuring equipment, pavement textural and drainage design, and friction measuring tire performance. The research effort has resulted in the publication of the following standards:

1. *Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces*—Revisions included a new correlation table for friction measuring devices and closer tolerances for sawcut grooves.
2. *Emergency Standard Specification for Special Purpose, Smooth-Tread Tire*, ASTM ES17-90, 1990—A new specification that includes new performance standards for friction measuring tires developed during the research program.
3. *Standard Test Method for Side Force Friction on Paved Surfaces Using the Mu-Meter*, ASTM E670-87 (under revision)—Includes new performance standards for friction measuring tires developed in the research program.
4. *International Civil Aviation Organization: Revisions to Aerodromes, Annex 14* and *Airport Services Manual, Part 2* are in final preparation for publication.

Standards for the various friction measuring devices were provided to the International Civil Aviation Organization by FAA and are included in the revisions.

CONCLUSIONS

The importance of setting well-defined goals and developing a test plan before conducting the field test program resulted in the successful completion of the study. The program was designed to establish and improve standards for friction equipment and friction measuring tire performance. The resulting standards are published in FAA standards and are accepted worldwide by the aviation community.

REFERENCES

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