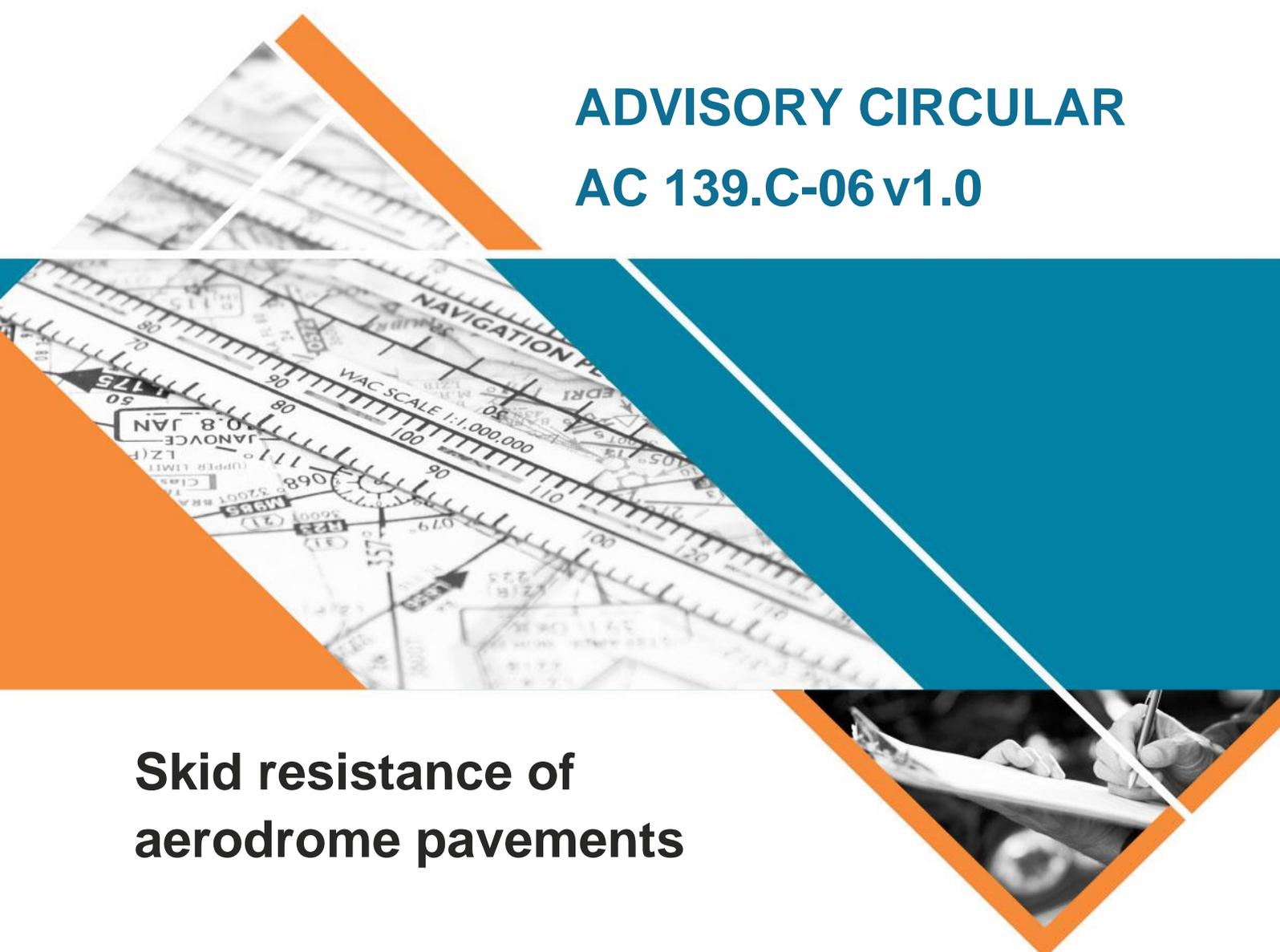




ADVISORY CIRCULAR

AC 139.C-06 v1.0



Skid resistance of aerodrome pavements

Date February 2021
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Advisory Circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.

Advisory Circulars should always be read in conjunction with the relevant regulations.

Audience

This advisory circular (AC) applies to:

- aerodrome owners/operators
- consultants engaged to act on behalf of the aerodrome owner/operator
- aircraft operators
- the Civil Aviation Safety Authority (CASA).

Purpose

This AC provides advice regarding the skid resistance requirements of aerodrome pavements, including the measurement and management of surface macrotexture and wet friction values.

For further information

For further information, contact CASA's Personnel Licensing, Aerodromes and Air Navigation Standards (telephone 131 757).

Status

This version of the AC is approved by the Branch Manager, Flight Standards.

Version	Date	Details
v1.0	February 2021	Initial release of this AC.

Unless specified otherwise, all subregulations, regulations, Divisions, Subparts and Parts referenced in this AC are references to the *Civil Aviation Safety Regulations 1998 (CASR)*.

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1 Reference material

1.1 Acronyms

The acronyms and abbreviations used in this AC are listed in the table below.

Acronym	Description
AC	advisory circular
AIP	aerodrome information publication
ATI	aerodrome technical inspection
CAR	<i>Civil Aviation Regulations 1988</i>
CASA	Civil Aviation Safety Authority
CASR	<i>Civil Aviation Safety Regulations 1998</i>
CFME	continuous friction measuring equipment
DGA	dense graded asphalt
FAA	Federal Aviation Administration (of the USA)
NOTAM	notice to airmen
OGFC	open graded friction course
ICAO	International Civil Aviation Organisation
MOS	Part 139 Manual of Standards
NASA	National Aeronautics and Space Administration (of the USA)
PSV	polished stone value
RET	rapid exit taxiway
SMA	stone mastic asphalt
USA	United States of America

1.2 Definitions

Terms that have specific meaning within this AC are defined in the table below.

Term	Definition
aquaplaning	Also referred to as hydroplaning, aquaplaning is the loss of contact between the aircraft tyre and the pavement surface, due to the presence of a film of water in between.
continuous friction measuring equipment	Internationally recognised devices specifically designed to measure pavement surface friction using a controlled slip tyre.
friction	The resistance that one surface (e.g. a tyre) encounters when moving over another (e.g. a pavement).

Term	Definition
macrotecture	The average depth of surface texture with a wavelength in the range 0.5 mm to 5 mm, generally associated with the composition of the surface materials.
microtexture	The average depth of surface texture with a wavelength below 0.5 mm, generally associated with the shape of the individual aggregate particles. In this context, this is a function of the shape of the individual aggregate particles and their surfaces.
megatecture	The depth of surface texture with a wavelength in the range 5 mm to 50 mm, meaning it is more an indication of pavement surface roughness than of skid resistance. In this context, this is a function of the overall surface material, its composition and how the aggregate particles pack together and how the resulting voids are filled with bitumen and fine material.
skid resistance	The ability of the surface to avoid skidding or aquaplaning of an aircraft during wet weather, provided by a combination of friction and surface texture.
surface texture	The micro- and macro- sized deviations in the surface that determine the physical interaction between two objects, such as a tyre and a pavement surface.
wet friction	The friction that remains available to an aircraft or vehicle tyre when the surface is wetted with a controlled (1 mm deep) film of water.

1.3 References

Regulations

Regulations are available on the Federal Register of Legislation website <https://www.legislation.gov.au/>

Document	Title
Part 139	Aerodromes
Part 139 Manual of Standards (MOS)	Part 139 (Aerodromes) Manual of Standards

International Civil Aviation Organization documents

International Civil Aviation Organization (ICAO) documents are available for purchase from <http://store1.icao.int/>

Document	Title
ICAO Doc 9157	Aerodrome Design Manual Part 1 Runways
ICAO Doc 9137	Airport Services Manual Part 2 - Pavement Surface Conditions

Advisory material

CASA's advisory circulars are available at <http://www.casa.gov.au/AC>

CASA's Civil Aviation Advisory Publications are available at <http://www.casa.gov.au/CAAP>

Document	Title
CAA 2015	Advisory Circular AC139-13, Aerodrome Maintenance - Runway Surface Friction Characteristics and Friction Testing, 30 October 2015.
FAA 2016	Advisory Circular AC 150/5320-12D, Measurement and Maintenance of Skid-Resistant Airport Pavement Surfaces, DRAFT, 24 March 2016.

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3. Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces, Advisory Circular 150/5320-12C, Federal Aviation Administration, Washington, District of Columbia, USA, 18 March 1997.
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2 Introduction

2.1 Aerodrome operator obligations

- 2.1.1 The Part 139 Manual of Standards (MOS) requires the operator of a certified aerodrome to provide and maintain paved runway surfaces in a condition:
- that meets the required surface texture or surface friction characteristics (grooved runways must meet the friction requirements)
 - free of irregularities that may adversely affect the safe take-off and landing of aircraft
 - that meets the surface gradient requirements to allow effective drainage to occur.
- 2.1.2 The surface of a paved runway must be evaluated when constructed or resurfaced to determine that the surface friction and/or surface texture characteristics achieve the minimum standards required.
- 2.1.3 In order to avoid falling below the minimum friction or texture levels required, runway surface friction or texture characteristics should be measured periodically. In the event the texture or friction is found to be below the minimum value, the aerodrome operator should:
- request the issue of a NOTAM specifying the portion of runway that is below the minimum texture or friction levels
 - initiate corrective maintenance action without delay.

2.2 The importance of skid resistance

- 2.2.1 Depending on the type of aircraft and the operating conditions, aircraft generally land at 150-250 km/hr or more [1]. Once landed, the pilot typically applies the wheel and/or thrust reversers to reduce the speed of the aircraft within the available runway length. Additionally, before reaching the runway end and to improve operational efficacy, aircraft operators may brake hard to exit at a taxiway. The ability for the wheel brakes to effectively decelerate the aircraft depends on friction between the aircraft tyres and the runway surface.
- 2.2.2 The friction provided between the aircraft tyres and the runway surface, is commonly referred to as skid resistance. Aircraft skid resistance is generally provided by the surface friction and surface texture of the runway surface.
- 2.2.3 Procedures to land aircraft in conditions of cross winds that are at the maximum permitted values also depend upon adequate skid resistance to enable pilots to readily gain control and align the aircraft when it initially touches down on the runway surface.
- 2.2.4 The runway surface must also have sufficient skid resistance to enable an aircraft to brake to a stop following an aborted take-off.

2.3 Surface friction and surface texture

2.3.1 Runway surface friction is directly relevant to the braking action that will be available to an aircraft decelerating after touching down, or after a decision to reject a take-off. In the context of pavements and aircraft tyres, the factors that affect the friction between the two include [2]:

- tyre material
- temperature of the tyre
- tyre condition
- tyre inflation pressure
- temperature of the pavement surface
- speed of travel
- pavement surface characteristics
- pavement surface contamination
- depth of water.

2.3.2 The pavement surface can become contaminated through an accumulation of pollutants which may also impact runway surface friction levels. Contaminants that may be found on the surface of a runway include [3]:

- rubber deposits from landing aircraft tyres
- mud, dust, sand and loose stone
- special pavement treatments
- excess paint marking the runway
- fuel or oil spills or other foreign materials
- rain, snow, slush and hail.

2.3.3 As these may inhibit skid resistance the aerodrome operator is responsible for the removal of contaminants to minimise their accumulation on the runway surface.

2.3.4 The friction available to an aircraft tyre is complex and is affected by the pavement surface material that is in contact with the tyre. Runway pavement surfaces are generally constructed either of:

- sprayed seal
- asphalt
- concrete.

2.3.5 For sprayed seals, the aircraft tyre is intended to run on the cover aggregate, which is usually fully crushed hard rock. However, in some locations sprayed seals are sometimes constructed with rounded natural gravel and this is likely to result in reduced skid resistance.

2.3.6 Sprayed seals can also be susceptible to flushing and stripping [4]. In flushed seals, the bitumen binder rises to a level above the cover aggregate and the aircraft tyres ride on the bituminous binder which has significantly less surface friction to offer than the cover aggregate. In stripped seals, the cover aggregate is lost, and the aircraft tyre rides on the exposed underlying bitumen film, which also reduces surface friction.

- 2.3.7 Asphalt is a mixture of coarse and fine aggregate, and bituminous binder [5]. The aircraft tyres contact an agglomerate of materials which changes significantly over the life of the pavement surface. Shortly after construction, the upper-most surface aggregate is covered by a thin film of bituminous binder resulting from the manufacturing and paving processes. Over time the binder stiffens and wears, exposing more of the aggregate particles, generally increasing the friction available.
- 2.3.8 Concrete is also an agglomerate, consisting of coarse and fine aggregate, and cement [5]. The aggregate is generally covered with cement paste, which comprises the sand and cement. Aircraft tyres generally run on the hardened mortar, which takes much longer to erode from the surface than bituminous binder takes, meaning that aircraft continue to run on the paste for many years.
- 2.3.9 There are currently no concrete runways in Australia. Although many runways have concrete pavement ends, the main portion of all Australian runways has either a sprayed seal surface or an asphalt surface. For both sprayed seals and asphalt, the surface friction available is substantially provided by the coarse aggregate particles.
- 2.3.10 The characteristics of aggregate that affect the level of friction available to aircraft are complex and include both the rock mineralogy as well as the size and shape of the aggregate particles, which affects the surface texture.
- 2.3.11 In addition to the size and shape of each aggregate particle, the overall composition of the surface also affects the surface texture.
- 2.3.12 Surface texture is complex but for the purposes of aircraft skid resistance, includes [3]:
- microtexture: wavelengths less than 0.5 mm (Figure 1)
 - macrotexture: wavelengths 0.5 mm to 5 mm (Figure 1)
 - megatexture: wavelengths 5 mm to 50 mm
 - roughness: wavelengths greater than 50 mm.

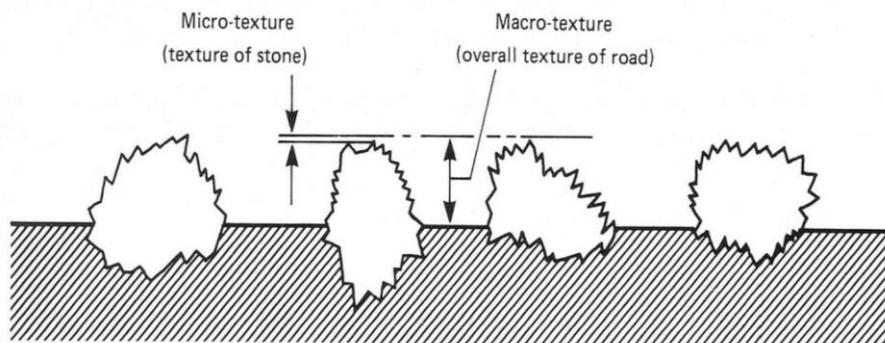


Figure 1. Microtexture and Macrotexture.

- 2.3.13 Megatexture and roughness do not directly impact aircraft skid resistance; however, microtexture and macrotexture do. The microtexture affects the physical interaction between the tyre and the surface, by providing some texture for the tyre to bend and deform around the aggregate. In contrast, the macrotexture has less influence on friction, but has a significant impact on skid resistance by providing a path for surface water to escape between the tyre and the pavement surface.

2.3.14 Microtexture is a function of the surface characteristics of the aggregate particles and any coating of the particles by the bituminous binder, cement mortar or flushed sealed bitumen. The macrotexture is primarily determined by the surface composition, rather than the individual aggregates. Both the aggregate microtexture and surface macrotexture change over the life of a pavement surface.

2.4 Wet and dry skid resistance

2.4.1 In practice, appropriately designed, constructed and maintained runways have adequate friction when they are dry. It is only in wet conditions, when the water on the surface inhibits the friction that is available to the aircraft tyre, that skid resistance becomes an issue. This is because surface water prevents the tyre contacting the pavement surface, which reduces the interaction between the tyre and the pavement surface. In the worst case this may result in the tyre riding on top of a film of water—a severe phenomenon known as aquaplaning.

2.4.2 Aquaplaning is a complex phenomenon that is affected by factors including aircraft speed, tyre inflation pressure, tyre tread, pavement surface texture and the thickness of any water film. Depending on the combination of these factors, the risk and severity of aquaplaning increases or decreases.

2.4.3 There are two types of aquaplaning, viscous and dynamic. Viscous aquaplaning can occur at low speeds where there is little pavement surface texture. It requires minimal water depth as it is dependent on the viscosity of the water which prevents it escaping from under the tyre footprint. This type of aquaplaning is most likely to occur during braking.

2.4.4 Dynamic aquaplaning will occur once the aircraft has exceeded a critical speed, at which time surface water in front of the tyre, acting as a wedge, can penetrate the tyre footprint and reduce the surface contact area. At high speeds only a small portion of the tyre footprint has dry contact. Under total dynamic aquaplaning, virtually no part of the tyre will have any contact with the surface, and even though the aircraft is travelling at great speed, the tyre can be fully locked.

2.4.5 Another phenomenon associated with aquaplaning is 'reverted rubber skidding'. Reverted rubber skidding is akin to viscous skidding in that it occurs with a thin film of water and a smooth runway surface. The locked wheels create enough heat to vaporise the underlying water film forming a cushion of steam that eliminates tyre to surface contact.

2.4.6 Aquaplaning can also result in superheating of the tyre, potentially melting the tyre rubber and leading to a tyre deflation, as well as loss of directional control and reducing effective deceleration.

2.4.7 To minimise the risk of aquaplaning, the surface water must be provided with escape paths to allow water to egress from the tyre-pavement contact footprint. These escape paths are provided by natural or artificial surface texture:

- natural surface texture is provided in the form of macrotexture in the pavement surface

- artificial texture is provided either by runway surface groove cutting, or by the tread pattern (usually circumferential grooves) in the aircraft tyre.

2.5 Runways, taxiways and aprons

- 2.5.1 Aquaplaning and the inhibition of surface friction by water is generally only a practical issue at high speeds and high rates of aircraft deceleration associated with aircraft landings and aborted take-off operations. Aircraft skid resistance is therefore generally not a practical issue for the slower movement of aircraft on taxiways and apron areas. The only exception is where rapid exit taxiways (RETs) are provided. Due to the high aircraft speeds and heavy braking expected to occur, RETs should be considered to be similar to runways at least from the perspective of aircraft skid resistance.
- 2.5.2 The Part 139 MOS also require stopways to have surface characteristics that meet or exceed the level of friction of the runway they are associated with to provide consistent and effective braking.

3 Means of compliance

3.1 General approaches to achieve compliance

- 3.1.1 The Part 139 MOS requires aerodrome operators to achieve compliance through one of two approaches:
- a. an average surface macrotexture over the full length and width of the runway:
 - i. of not less than 1.0 mm preferably
 - ii. and where this cannot be achieved, not less than 0.625 mm.
 - b. wet friction measured by an International Civil Aviation Organization (ICAO) approved continuous friction measurement equipment (CFME). The recorded friction values that apply to each type of CFME for an operational runway should be:
 - i. not less than the minimum value associated with that CFME
 - ii. preferably not less than the maintenance planning values
 - iii. preferably not less than the design objective levels for new surfaces.
- 3.1.2 Grooving significantly increases the friction provided by the runway surface to a level that exceeds the maintenance planning level. The grooves should either be perpendicular to the runway centreline, or if this is not physically possible, parallel to non-perpendicular transverse joints (e.g. in RETS).
- 3.1.3 The means of compliance are described below.

3.2 Surface macrotexture

- 3.2.1 Surface macrotexture is an indicator of the ability for surface water to escape from between the aircraft tyre and the pavement surface. It acts in a similar manner to tyre tread patterns and the higher the macrotexture the less the friction will be reduced by the presence of water, and the better the aircraft skid resistance.
- 3.2.2 Macrotexture is the primary means of Part 139 MOS skid resistance compliance for runways with sprayed seal surfaces (Figure 2), as well as types of asphalt with high natural texture (refer below). These airports are generally located in regional areas, meaning CFME is unlikely to be cost effective on regular basis.
- 3.2.3 It is important to understand that the cover aggregate that provides the texture can polish (reducing microtexture and friction) and can be crushed (reducing macrotexture). It is therefore important that aggregate for sprayed seals be selected carefully to ensure the surface texture and skid resistance are durable.



Figure 2. Typical sprayed seal runway surface.

- 3.2.4 Larger airports in Australia generally use dense graded asphalt (DGA) for runway surfacing (Figure 3). DGA is designed to maximise the packing between the aggregate particles and result in a surface macrotexture of 0.4 - 0.6 mm, regardless of the maximum aggregate particle size [5].
- 3.2.5 In contrast, open graded friction course (OGFC) and stone mastic asphalt (SMA) have naturally higher surface texture. OGFC, which is also known as popcorn mix, has a high air void content, allowing water to drain internally through the asphalt layer [6]. This provides high aircraft skid resistance, but significantly reduces the life of the surface and for this reason, is not commonly used by airports in Australia.
- 3.2.6 In contrast, the voids in SMA are filled with additional bituminous binder, making the surface impermeable, but still providing a surface macrotexture generally in the range 1.1 - 1.7 mm (Figure 4). Importantly, the larger the maximum aggregate size, the higher the macrotexture of the SMA, with 14 mm sized mixtures being demonstrated to consistently exceed 1.0 mm [6].
- 3.2.7 Sprayed seals also have naturally high surface texture, as long as 7 mm or 10 mm nominal aggregate sizes are used. Sprayed seals on runways are often treated with a sand-emulsion overspray to lock the aggregate in place and reduce the loss of stone over time. This can only reduce the surface macrotexture and is only recommended for 10 mm sized seals.
- 3.2.8 This is a sound reminder that surface texture is a balance between providing adequate skid resistance and controlling the risk of foreign object debris (FOD). Although more texture is beneficial for skid resistance, it is generally also associated with a greater potential to generate FOD in the form of loose stones.



Figure 3. Surface texture of typical ungrooved airport DGA.



Figure 4. Surface texture of typical airport SMA.

- 3.2.9 The internationally established test for surface macrotexture is known as the sand patch test. A known volume of fine sand, with a controlled particle size gradation, is poured onto the surface and smoothed into a circle until the surface texture is filled by sand (Figure 5). The diameter of the surface is measured and related to the surface macrotexture.



Figure 5. Sand patch test.

- 3.2.10 Each sand patch test provides one single surface macrotexture depth, so it is easy to interpret. However, all surfaces have variable macrotexture due to the natural variability associated with aggregates, asphalt production, and surface construction. Furthermore, joints and the start of each paving run will have different macrotexture as will any areas contaminated by asphalt mastic inadvertently stuck to the surface during works, which is usually concentrated around the transverse joints between work periods. When the measurements for selecting test locations are completed in accordance with the Part 139 MOS, the selection process should subsequently identify test sites that are visually typical of the runway surface within the vicinity of the measured test locations.
- 3.2.11 The Part 139 MOS refers to the 'average' surface texture. In this context, the term 'average' refers to the area within the sand patch test area, which is generally 200 - 400 mm in diameter. It is not appropriate to perform ten sand patch tests along a runway with clearly different areas of surface texture and average the results. That is, high textured runway edges do not 'fix' low texture results in the wheel paths by providing an average surface texture above 1.0 mm.
- 3.2.12 For example, five results in the wheel paths with a macrotexture of 0.6 mm should not be averaged with five results from near the edges of the runway with a macrotexture of 2.0 mm, to obtain an average macro-texture of 1.3 mm and conclude compliance. The five results from the wheel paths, with a macro-texture of 0.6 mm are concerning, regardless of the average of all test results exceeding 1.0 mm.
- 3.2.13 If 90% of the results from an area of visually consistent surface texture exceed 1.0 mm, then as long as the other results were not less than 0.625 mm, which is the minimum allowed by the Part 139 MOS, this would be acceptable.

3.3 Wet runway friction

- 3.3.1 Wet runway friction measured by CFME, is a more direct measure of the skid resistance available to an aircraft landing or taking-off in wet conditions. In recent years, several

types of CFME have proven to be reliable, accurate, and consistent in a variety of extensive test programmes, including a range of pavement conditions and test speeds.

- 3.3.2 Wet friction is generally used as the means of demonstrating compliance of asphalt runway surfaces. It is also commonly used as a tool for planning maintenance activities and to verify ongoing compliance.
- 3.3.3 The Part 139 MOS details three friction levels for each of the seven models of CFME. The friction levels are all based on testing friction immediately behind the application of the 1 mm deep film of water to the surface and there are different levels of friction for 65 km/hr and 95 km/hr test speeds.
- 3.3.4 The CFME models, test speeds and friction levels are all based on ICAO guidance, which in turn, is based on research performed in the USA by the National Aeronautics and Space Administration (NASA) for the recovery of returning space shuttles.
- 3.3.5 Two test speeds are intended to highlight the relative contribution of the microtexture (65 km/hr) and macrotexture (95 km/hr) to the measured level of wet friction. The three values of friction are known as:
- minimum (the minimum value below which the runway may be slippery when wet is to be made available and corrective action initiated)
 - maintenance planning (the value below which some form of intervention should be planned to ensure that the friction does not continue to fall below the minimum value)
 - design objective (indicates the likely friction level achieved by a newly constructed or resurfaced runway surface after grooving).
- 3.3.6 The testing of friction immediately after controlled wetting of the surface requires a water bladder to be carried by the test vehicle and connected to the CFME. This requires a significant volume of water that must be potable, in order to avoid foaming or clogging of the pumps.
- 3.3.7 All of the CFME models are considered to be equally valid. Whilst the Griptester (Figure 6) is most commonly used in Australia, alternate devices may also be used. It is important for ongoing friction management to use the same type of CFME, preferably the same unit and towing vehicle to minimise differences between tests, allowing trends in the friction levels to be investigated over time.



Figure 6. Example Griptester CFME in operation.

- 3.3.8 The Part 139 MOS does not explicitly state how or where to operate the CFME when undertaking a wet friction survey of a runway. The USA (FAA 2016) and New Zealand (CAA 2015) guidance both require CFME surveys to include:
- testing of the surface when otherwise dry, so that only the intended (1 mm thick film) water is present at the time of the test.
 - longitudinal runs 3 m and 6 m from the runway centreline, on both sides of the runway although this may be reduced to 3 m only, for runways servicing only narrow-bodied aircraft and may be changed to 4 m and 8 m where the dominant aircraft wheel paths are further apart.
 - both 65 km/hr and 95 km/hr test speeds.
 - in both directions along the runway, at all four offsets and both test speeds.
- 3.3.9 That requires a total of 16 runs of the CFME to complete a runway friction survey.
- 3.3.10 All CFME devices measure friction continuously and generally records the average for every 10 m length along the runway. The results contain significant scatter (Figure 7) and the results are typically averaged for each 100 m section along the runway length or using a 100 m rolling average.
- 3.3.11 Friction results are also commonly averaged over the thirds of the runway length, intended to identify differences between the touch down zones and the middle third of the runway length where aircraft are generally free rolling.

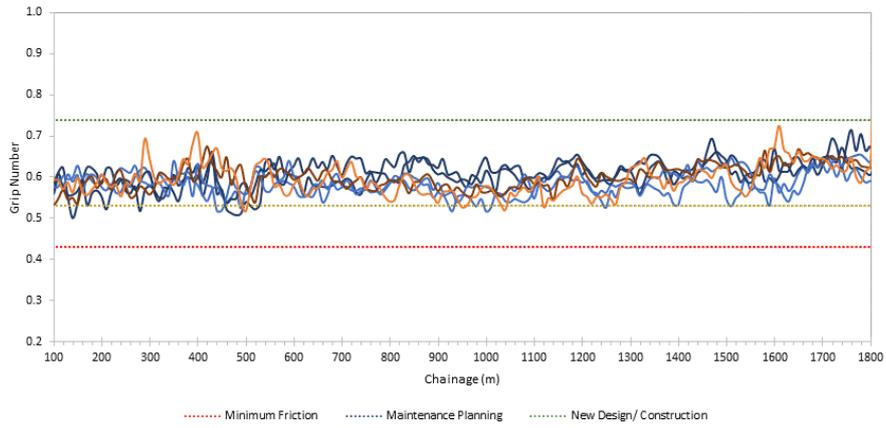


Figure 7. Example 10 m averaged CFME results along a runway.

3.3.12 The mass of data in different formats complicates the interpretation of CFME survey results. The average values for each 100 m section of the runway are generally considered to be the most informative. An example of combined results is shown in Figure 8 (for 65 km/hr) and in Figure 9 (for 95 km/hr).

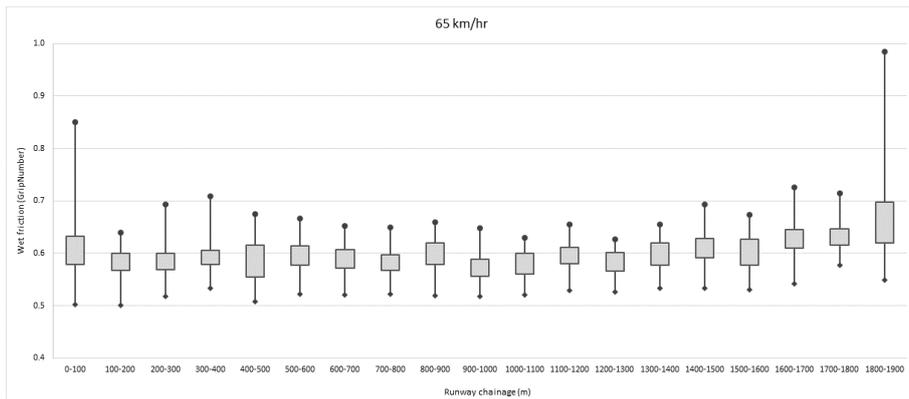


Figure 8. Example combined 100 m average CFME results at 65 km/hr.

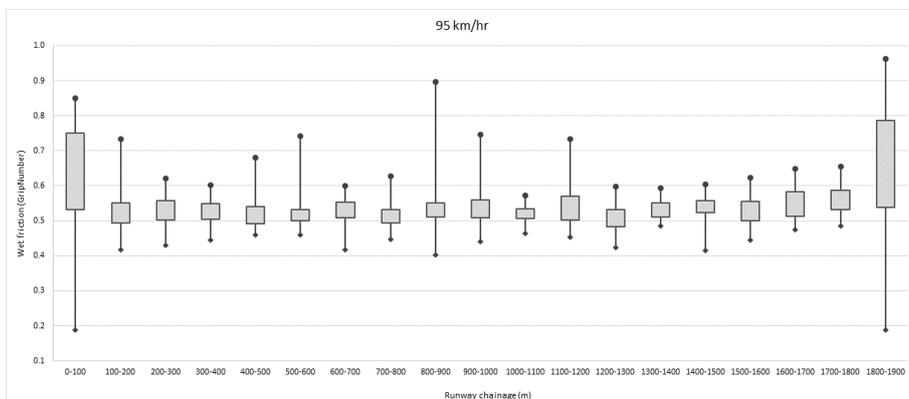


Figure 9. Example combined 100 m average CFME results at 95 km/hr.

- 3.3.13 It is clear from Figure 8 and Figure 9 that the last 100 m of the example runway had significantly higher friction than the rest of the runway. This reflects the lower (than target) speed of the CFME in those areas as the towing vehicle gets up to speed and then slows down again before running off the sealed portion of the runway pavement. Because of this complication, guidance in the USA (FAA 2016) advises the results may not be reliable in this area and should be ignored. While the test equipment and method cannot achieve usable results for the start and finish of the test runs, these sections of the runway surface must achieve the texture requirements of the Part 139 MOS and be maintained to prevent the build-up of contaminants.
- 3.3.14 Results should be recorded and maintained. Not only can the friction values measured by the CFME be used as guidelines for evaluating the pavement surface friction deterioration and current maintenance needs, by comparing historical data, the friction deterioration rate of the pavement can be forecast, and preventative maintenance can be scheduled.

3.4 Surface grooves

- 3.4.1 Surface grooves significantly increase aircraft skid resistance and wetted surface friction, they make an important contribution to safe aircraft operations.
- 3.4.2 Only concrete and DGA runway surfaces are grooved. Sprayed seal, OGFC and SMA cannot be grooved. The grooves provide 'artificial' surface texture by providing shallow channels through which surface water can escape from between the runway surface and the aircraft tyre. This additional texture depth combined with the required transverse surface slopes also provides the overall pavement surface drainage.
- 3.4.3 The Part 139 MOS requires that grooves be perpendicular to the runway centreline, and if not physically possible, parallel to transverse joints that are not perpendicular to the centreline such as RETs and runway intersections. Traditionally, grooves were all square and were 6 mm deep, 6 mm wide and spaced 38 mm from centre-to-centre (Figure 10). Given the grooves are 6 mm wide, the 38 mm spacing results in 32 mm of surface between groove edges.

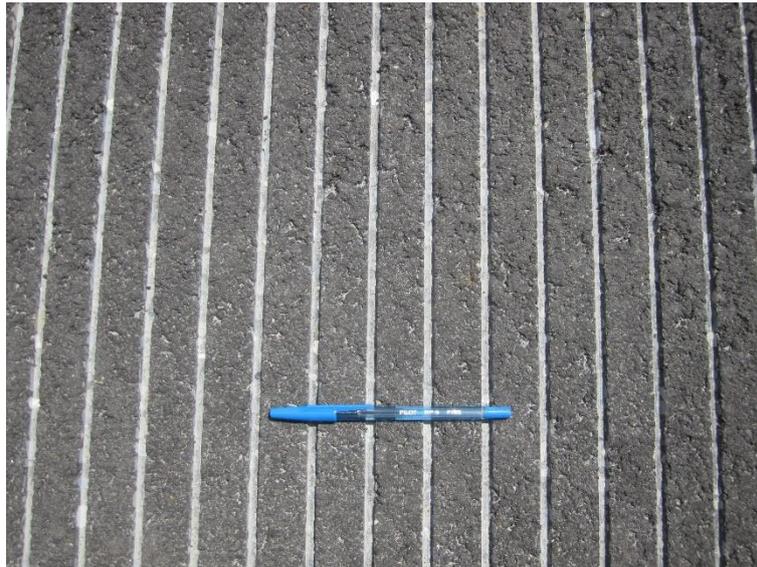


Figure 10. Typical square grooves in a DGA surface.

- 3.4.4 In recent years, trapezoidal grooves have also been developed. Trapezoidal grooves are still 6 mm deep and the flat bottom of the groove is still 6 mm wide; however, the side walls are chamfered at 45° to the vertical, meaning the top of the groove is around 12 mm wide (Figure 11).
- 3.4.5 To provide the same volumetric density of grooving and area of pavement surface in contact with an aircraft tyre, trapezoidal grooves are spaced at 57 mm, centre-to-centre, or 45 mm of surface between groove edges. The two types of grooves are compared in Figure 12, noting the use of imperial units and metric rounding.



Figure 11. Typical trapezoidal grooves in DGA surface.

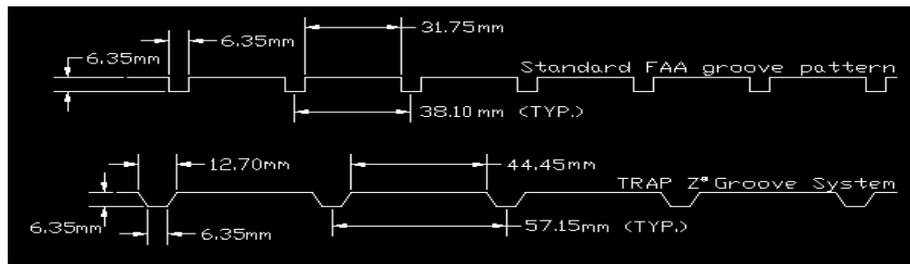


Figure 12. Square and trapezoidal groove details.

- 3.4.6 Trapezoidal grooves have been shown to provide better wet friction and surface visibility in rain. They also exhibit better resistance to groove closure and edge breakage [7].
- 3.4.7 Both trapezoidal and traditional square grooves satisfy the requirements of the Part 139 MOS and the choice is generally made based on preference and economics.
- 3.4.8 The effectiveness of grooving is simple to interpret because the surface is either grooved or it is not. However, the risk of groove closure means that grooving is delayed after surfacing, typically by 4-8 weeks. During this period, the surface is often used without grooves as it is unlikely to be lower than the minimum wet friction values.
- 3.4.9 Where the En Route Supplement Australia (ERSA) publishes that a runway has a grooved surface, and the runway has been overlaid and the process of groove cutting has not been completed, it is essential for a NOTAM to be published to advise that the surface is not grooved. This applies when any portion of a runway has been overlaid or patched and the groove cutting process has not been completed. A NOTAM is not required when the omission of grooves applies only to the portion of a runway detailed in paragraph 6.09 (4) of the Part 139 MOS and the conditions of that paragraph are met. Reinstatement of the grooved surface is recommended following all repairs to the runway surface, unless the finished texture of the repaired surface can be demonstrated to meet the required macro texture depth.
- 3.4.10 As explained above, grooves can close, particularly under slow moving and turning aircraft traffic. This commonly occurs at runway ends where no parallel taxiway is provided, meaning the aircraft back-track down the runway and turn around in a node prior to take-off. To avoid this distress, many airports choose not to groove the turning node, which means the last 60-80 m at each end of the runway length is not grooved. The Part 139 MOS makes some provision for this but requires that one of the other means of compliance must still be achieved. However, for DGA surfaces, surface texture is unlikely to be satisfied and as explained above, wet friction testing is not reliable in the last 100 m at each end of the runway. Where the standards for a runway surface have not been achieved, an approval against the Part 139 MOS must be sought from CASA. At the delegate's discretion approvals and exemptions are assessed and granted on a case by case basis.

4 Management of pavement skid resistance

4.1 General

- 4.1.1 Along with pavement cleanliness, aircraft skid resistance is one of the few physical characteristics that must be maintained throughout the life of the pavement. This requires both ongoing monitoring to detect potential issues, and intervention when required.
- 4.1.2 The management of aircraft skid resistance provided by a runway depends on the means of compliance adopted by the aerodrome owner/operator. That is, the means of compliance that was selected at the time of construction is the logical means of ongoing compliance. However, that is not necessarily always the most appropriate approach.
- 4.1.3 Aerodrome operators should make assessments for the need to conduct ongoing friction measurements based on the type of aircraft movements and frequency of operations at their aerodrome. The risk of not completing ongoing wet friction measurement of runway surfaces should be assessed using the implemented safety management processes.

4.2 Surface texture management

- 4.2.1 This section considers surface texture management for highly textured surface types. Surface texture management is most applicable to sprayed seal and highly textured asphalt surfaces, such as SMA. Once surface texture is established at the time of construction or resurfacing, and where suitable aggregate is used, it is unlikely to be significantly adversely affected over the life of the surface. Furthermore, when surface texture is compromised, it is likely to be confined to the aircraft wheel paths which is likely to be easily identified by visual inspection.
- 4.2.2 The most common deterioration expected to impact surface texture are:
- surface contamination (i.e. rubber build up)
 - wearing or polishing of aggregate
 - flushing of sprayed seals (Figure 13)
 - loss of aggregate in sprayed seals
 - loss of surface texture in SMA or OGFC
 - isolated bleeding of asphalt (Figure 14).



Figure 13. Example of wheel path flushing of a sprayed seal.



Figure 14. Example of isolated asphalt bleeding in SMA.

- 4.2.3 Visual inspection at the time of the aerodrome technical inspection (ATI) is likely to identify any potential issue for sprayed seal and highly textured asphalt surfaces, such as SMA. Subsequent testing of any potential issue is readily available and economical to perform.
- 4.2.4 The Part 139 MOS requires that surface texture verification be performed after resurfacing, after preservation treatment or otherwise not less than ten years between tests. As surface texture is the means of compliance most commonly associated with sprayed seals, and because runway sprayed seals should have an 8-10 year life expectancy, it is likely that surface texture testing will only be required as part of each periodic resurfacing, or when an issue is identified with the potential to adversely affect surface texture.

- 4.2.5 When a surface texture issue is identified, testing should be performed in the area of concern as well as in areas that are visually more consistent with expectations. For example, where the wheel paths are flushed, testing should be performed in the wheel paths and outside of them. The texture depth must not be determined by averaging the results of samples taken from the flushed and non-flushed areas.
- 4.2.6 Once an issue is confirmed by surface macrotexture testing, treatments can be determined to reinstate the surface texture, which is likely to include removal of excess bituminous binder with chemical, abrasive, or water blasting methods, or complete resurfacing.

4.3 Wet friction management

- 4.3.1 Wet friction management is the most likely means of demonstrating compliance and safe operating conditions for runways with an asphalt surface. This will commonly include grooved runways and ungrooved runways with a highly textured surface but may also include ungrooved DGA runways.
- 4.3.2 Airports with grooved runways should also use wet friction testing to demonstrate ongoing compliance and to plan rubber contamination removal. In other cases, airports with surface texture issues, such as flushed wheel paths in sprayed sealed surfaces, may use wet friction surveys to quantify the issue and to confirm it has been resolved after an intervention treatment.
- 4.3.3 When using wet friction to address specific issues, the testing should be undertaken in the area of concern, most likely the wheel paths. The visually identifiable location of the distress must be given priority over the standard 3 m and 6 m offsets from the runway centreline for testing.
- 4.3.4 One significant benefit of wet friction is the ability to track trends in the friction values over time. This is particularly powerful when the same CFME model and device is used to measure the wet friction periodically, allowing some prediction of the time and extent of the surface over which rubber removal will be required. Tracking trends in wet friction is challenging due to the influence of:
- CFME model and specific device
 - the amount of wear of the CMFE test tyre
 - the angle of connection to the tow vehicle, determined by the height of the tow hitch
 - the operating speed of the tow vehicle
 - the temperature of the CFME test tyre and the pavement surface
 - the roughness of the runway surface.
- 4.3.5 In general, asphalt surfaces increase in wet friction during the first weeks and months after surfacing, as the bituminous binder hardens and the film of binder on the surface of the uppermost coarse aggregate particles is worn off by wind, rain and aircraft tyres. However, the rate of wet friction gain is not consistent and depends upon the surface, the raw materials in the surface and the prevailing weather conditions (Figure 15). Grooving has been shown to increase wet friction values by around 5-15% (Figure 16).

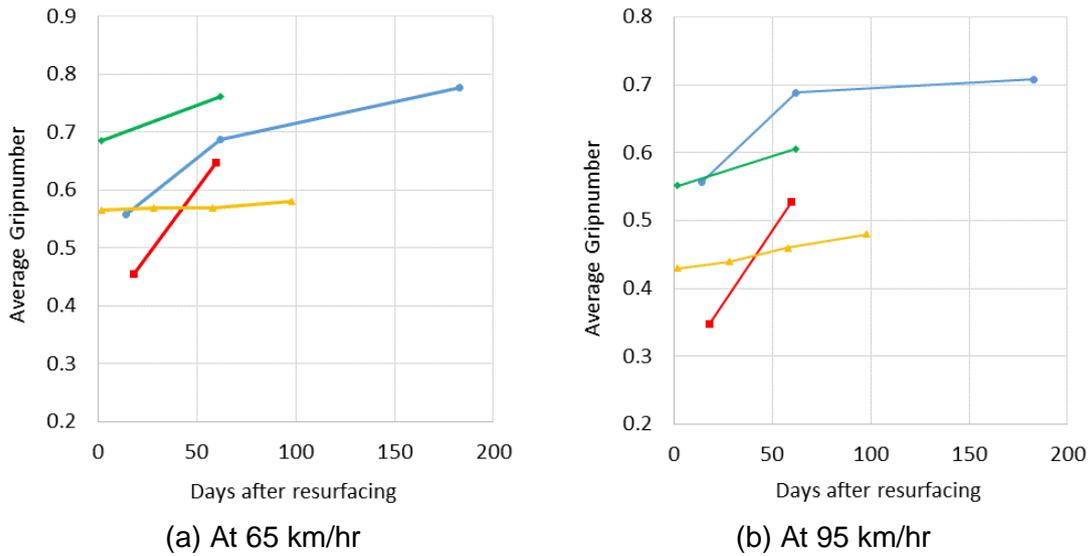


Figure 15. Examples of wet friction increase with asphalt surface age.

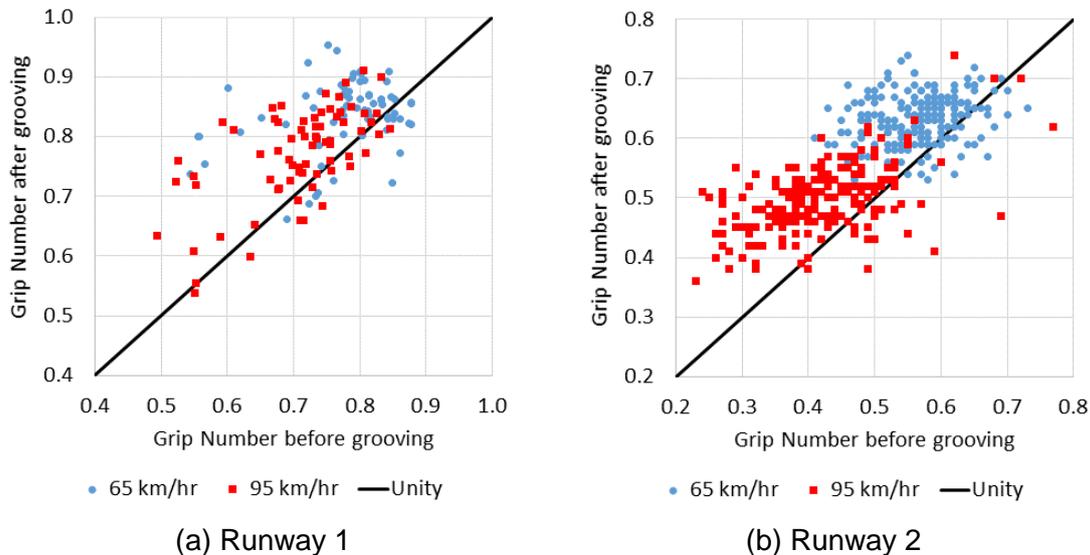


Figure 16. Examples of the effect of grooving on wet friction values.

- 4.3.6 After a new surface ages for 6-12 months, the wet friction value is expected to stabilise and the seasonal fluctuations, due to temperature, dominates the measure values.
- 4.3.7 Like surface texture testing, the Part 139 MOS requires that wet friction measurement be performed after resurfacing, after preservation treatment, when a potential issue is identified, or at least every ten years. Again, asphalt surfaces are expected to last 10-15 years, meaning testing might only be required once between surface replacement. However, issues that affect wet friction values are less readily visually identified during an ATI than surface macro-texture issues, meaning more frequent testing is appropriate. Furthermore, for international aerodromes, the Part 139 MOS requires continuous achievement of minimum wet friction values and the higher frequency of

aircraft operations increases the rate of rubber contamination build-up. Therefore, more frequent wet friction testing is appropriate.

4.3.8 The FAA guidance [3] includes recommended frequencies of wet friction surveys, depending on the number of daily jet aircraft landings per runway end. Broadening this advice to include non-jet airports, the following wet friction survey frequencies are recommended, as a minimum:

- runways that support international air transport operations, every 3-6 months
- non international, but major airport runways, every 6-12 months
- ungrooved large regional airport runways that rely on wet friction survey results as their means of ski resistance compliance, every 12-48 months
- other regional airports, every 2-5 years, where an alternate means of compliance has not otherwise been verified in that time.

4.3.9 Further investigation and/or intervention should be prompted by wet friction results below the maintenance planning values. The 100 m long section average values are most appropriate for this purpose because they filter out the noise associated with testing, but still identify the touch down zones differently to the rest of the runway length. The process of investigation and/or intervention depends on the magnitude, extent and location of the concerning results. Notification should be given to aerodrome users when the friction level is less than the minimum required by the Part 139 MOS.

4.3.10 Publishing a NOTAM advising aircraft operators that the runway is potentially slippery when wet is essential to inform aircraft operators when a significant portion of the runway is below the minimum friction value at either of the test speeds.

Note: A portion of runway in the order of 100 m long may be considered significant for maintenance or reporting action.

4.3.11 Where a runway surface has the potential to be slippery when wet, direct communication with air transport operators is also recommended to enable pilots to make informed decisions for their intended operating procedures.

4.3.12 For runways where the trends in wet friction have been monitored over time, the consistence of any given result with the overall trends and predicted time to interventions should also be considered.

4.3.13 Once the cause, location and extent of low wet friction values are determined, an intervention can be planned accordingly. This is most likely to include:

- rubber removal from the asphalt surface in the touch down zones
- removal of flushed bitumen from the wheel paths with spray sealed runway surfaces.

4.3.14 There are no mandatory provisions that address competency for personnel engaged in the operation of CFME or reporting on the outcome of completed tests. Aerodrome operators should however ensure that persons carrying out these functions have gained the appropriate competence or experience to undertake those functions.

4.4 Management of surface grooves

4.4.1 Visual inspection is generally sufficient to determine whether the effectiveness of the grooves has been compromised.

4.4.2 Grooves can be adversely affected by:

- rubber contamination (generally, only in the touch down zones. The rubber accumulates on the sides and the bottom of the grooves and will eventually completely fill the grooves if not removed periodically (Figure 17)
- closure (most common in slow moving and heavy braking areas, such as turning nodes and RETs, and the grooves are most susceptible to closure in the first year after surfacing, while the asphalt is still young (Figure 18).
- Erosion (as the asphalt surface erodes with age, the remaining depth of grooves is reduced and in severely eroded surfaces, the groove depth can be reduced significantly (Figure 19).
- Replacement (usually by an asphalt patch provided to address some other form of distress).



Figure 17. Example rubber contamination of a grooved runway.



Figure 18. Example of closed runway grooves.



Figure 19. Example of severely eroded grooved surface.

- 4.4.3 Rubber contamination is readily identified by visual inspection but the effect on aircraft skid resistance is appropriately determined by a wet friction test. Generally, a surface looks severely contaminated by rubber before the wet friction falls below the minimum values. Once it is determined that intervention is required, the rubber should be removed.
- 4.4.4 Groove closure is easily identified but it is not readily treatable because the grooves cannot be re-sawn, meaning that removal and replacement of the surface, and reinstatement of the grooves, is the only viable treatment. However, groove closure is rarely severe and extensive enough to significantly impact aircraft skid resistance, which is best determined by a wet friction survey.

- 4.4.5 Surface erosion is primarily weather, and age related, meaning that it will likely occur over the full runway surface area. However, a surface that is eroded enough to compromise the groove depth over a significant portion of the runway (40% of grooves not greater than 3 mm depth within a 457 m long section), is likely to have developed more than 1.0 mm surface texture and this is likely to provide more than adequate wet friction if the microtexture is also suitable. CFME surveys will confirm whether an alternate means of compliance has been satisfied.
- 4.4.6 When considering the effect of compromised grooves on the aircraft skid resistance provided by a runway, the extent of groove compromise is generally isolated to the wheel paths, or the touch down zone of areas of patches. Whether a significant intervention is justified depends on the severity of the compromise, as well as the extent.